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*A fool thinks himself to be wise,
but a wise man knows himself
to be a fool.*
William Shakespeare

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Editor's Note

The International Journal of Interactive Multimedia and Artificial Intelligence provides an interdisciplinary forum in which scientists and professionals can share their research results and report new advances on Artificial Intelligence and Interactive Multimedia techniques.

The research works presented in this issue are based on various topics of interest, among which are included: bayesian networks, evolutionary algorithms, virtual reality, web advertising, 3D technologies, traffic expression, Smart Cities, computational sustainability, computer vision, image recognition, deep neural networks, graphical models, mobile devices, human/complex system interactions, multi-agent systems, Physics inspired behaviours, etc.

Fukuda et al. [1] talks about bayesian network, which are regarded as one of the essential tools to analyze causal relationship between events from data. To learn the structure of highly-reliable Bayesian networks from data as quickly as possible is one of the important problems that several studies have been tried to achieve. In recent years, probability-based evolutionary algorithms have been proposed as a new efficient approach to learn Bayesian networks. In this paper, they target on one of the probability-based evolutionary algorithms called PBIL (Probability-Based Incremental Learning), and they propose a new mutation operator. Through performance evaluation, they found that the proposed mutation operator has a good performance in learning Bayesian networksdata source for a certain activity.

Kalochristianakis et al. [2] presents a scene composition approach that allows the combinational use of standard three dimensional objects, called models, in order to create X3D scenes. The module is an integral part of a broader design aiming to construct large scale online advertising infrastructures that rely on virtual reality technologies. The architecture addresses a number of problems regarding remote rendering for low end devices and last but not least, the provision of scene composition and integration. Since viewers do not keep information regarding individual input models or scenes, composition requires the consideration of mechanisms that add state to viewing technologies. In terms of this work they extended a well-known, open source X3D authoring tool.

Silva et al. [3] writes about road traffic which is a problem which is increasing in cities with large population. Unrelated to this fact the number of portable and wearable devices has also been increasing throughout the population of most countries. With this advent, the capacity to monitor and register data about people habits and locations as well as more complex data such as intensity and strength of movements has created an opportunity to contribute to the general wealth and comfort within these environments. Ambient Intelligence and Intelligent Decision Making processes can benefit from the knowledge gathered by these devices to improve decisions on everyday tasks such as deciding navigation routes by car, bicycle or other means of transportation and avoiding route perils. The concept of computational sustainability may also be applied to this problem. Current applications in this area demonstrate the usefulness of real time system that inform the user of certain conditions in the surrounding area. On the other hand, the approach presented in this work aims to describe models and approaches to automatically identify current states of traffic inside cities and use methods from computer science to improve overall comfort and the sustainability of road traffic both with the user and the environment in mind.

Raveane W. and González Arrieta, M. A., [4] introduce a hybrid system composed of a convolutional neural network and a discrete graphical model for image recognition. This system improves upon traditional sliding window techniques for analysis of an image larger than the training data by effectively processing the full input scene through the neural network in less time. The final result is then inferred from the neural network output through energy minimization to reach a more precize localization than what traditional maximum value class comparisons yield. These results are apt for applying this process in a mobile device for real time image recognition

Lal, N., [5] write abour the mobile ad hoc network which is a wireless technology that contains high mobility of nodes and does not depend on the background administrator for central authority, because they do not contain any infrastructure. Nodes of the MANET use radio wave for communication and having limited resources and limited computational power. The Topology of this network is changing very frequently because they are distributed in nature and self-configurable. Due to its wireless nature and lack of any central authority in the background, Mobile ad hoc networks are always vulnerable to some security issues and performance issues. The security imposes a huge impact on the performance of any network. Some of the security issues are black hole attack, flooding, wormhole attack etc. In this paper, they will discuss issues regarding low performance of Watchdog protocol used in the MANET and proposed an improved Watchdog mechanism, which is called by I-Watchdog protocol that overcomes the limitations of Watchdog protocol and gives high performance in terms of throughput, delay.

Caicedo Acosta et al. [6] shows the implementation of mutual exclusion in PCBSD-FreeBSD operating systems on SMPng environments, providing solutions to problems like investment priority, priority propagation, interlock, CPU downtime, deadlocks, between other. Mutex Control concept is introduced as a solution to these problems through the integration of the scheduling algorithm of multiple queues fed back and mutexes.

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Getcher et al. [7] talks about Multi-agent systems which are now wide spread in scientific works and in industrial applications. Few applications deal with the Human/Multi-agent system interaction. Multi-agent systems are characterized by individual entities, called agents, in interaction with each other and with their environment. Multi-agent systems are generally classified into complex systems categories since the global emerging phenomenon cannot be predicted even if every component is well known. The systems developed in this paper are named reactive because they behave using simple interaction models. In the reactive approach, the issue of Human/system interaction is hard to cope with and is scarcely exposed in literature. This paper presents Sphericall, an application aimed at studying Human/Complex System interactions and based on two physics inspired multi-agent systems interacting together. The Sphericall device is composed of a tactile screen and a spherical world where agents evolve. This paper presents both the technical background of Sphericall project and a feedback taken from the demonstration performed during OFFF Festival in La Villette (Paris).

Dr. Rubén González Crespo

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A Probability-based Evolutionary Algorithm with Mutations to Learn Bayesian Networks

Sho Fukuda, Yuuma Yamanaka, and Takuya Yoshihiro

Wakayama University, Sakaedani, Wakayama, Japan

***Abstract* — Bayesian networks are regarded as one of the essential tools to analyze causal relationship between events from data. To learn the structure of highly-reliable Bayesian networks from data as quickly as possible is one of the important problems that several studies have been tried to achieve. In recent years, probability-based evolutionary algorithms have been proposed as a new efficient approach to learn Bayesian networks. In this paper, we target on one of the probability-based evolutionary algorithms called PBIL (Probability-Based Incremental Learning), and propose a new mutation operator. Through performance evaluation, we found that the proposed mutation operator has a good performance in learning Bayesian networks.**

***Keywords* — Bayesian Networks, PBIL, Evolutionary Algorithms**

I. Introduction

BAYESIAN network is a well-known probabilistic model that represents causal relationships among events, which has been applied to so many areas such as Bioinformatics, medical analyses, document classifications, information searches, decision support, etc. Recently, due to several useful tools to construct Bayesian networks, and also due to rapid growth of computer powers, Bayesian networks became regarded as one of the promising analytic tools that help detailed analyses of large data in variety of important study areas.

To learn a near-optimal Bayesian network structure from a set of target data, efficient optimization algorithm is required that searches an exponentially large solution space for near-optimal Bayesian network structure, as this problem was proved to be NP-hard [1]. To find better Bayesian network structures with less time, several efficient search algorithms have been proposed so far. Cooper et al., proposed a well-known deterministic algorithm called K2 [2] that searches for near-optimal solutions by applying a constraint of the order of events. As for the general cases without the order constraint, although several approaches have been proposed so far, many of which uses genetic algorithms (GAs), which find good Bayesian network structures within a reasonable time [3][4][5]. However, because recently we are facing on large data, more efficient algorithms to find better Bayesian network models are expected.

To meet this requirement, recently, a new category of algorithms so called EDA (Estimation of Distribution Algorithm) has been reported to provide better performance in learning Bayesian Networks. EDA is a kind of genetic algorithms that evolves statistic distributions to produce individuals over generations. There are several types of EDA such as UMDA (Uni-variate Marginal Distribution Algorithm) [12], PBIL (Population-Based Incremental Learning) [7], MIMIC (Mutual Information Maximization for Input Clustering) [13], etc. According to the result of Kim et al. [11], PBIL-based algorithm would be the most suitable for learning Bayesian networks.

The first PBIL-based algorithm for Bayesian networks was presented by Blanco et al. [9], which learns good Bayesian net- works within short time. However, because this algorithm does not include mutation, it easily falls into local minimum solution. To avoid converging at local minimum solutions, Handa et al. introduced a *bitwise mutation* into PBIL and showed that the mutation operator improved the quality of solutions in four-peaks problem, Fc4 function, and max-sat problem[10]. Although this operator was not applied to Bayesian networks, Kim et al. later proposed a new mutation operator transpose mutation specifically for Bayesian networks, and compares the performance of EDA-based Bayesian network learning with several mutation variations including bitwise mutation [11].

In this paper, we propose a new mutation operator called *probability mutation* for PBIL-based Bayesian Network learning. Through evaluation, we show that our new mutation operator is also efficient to find good Bayesian network structures.

The rest of this paper is organized as follows: In Section 2, we give the basic definitions on Bayesian networks and also describe related work in this area of study. In Section 3, we propose a new mutation operator called probability mutation to achieve better learning performance of Bayesian networks. In Section 4, we describe the evaluation results, and finally we conclude this paper in Section 5.

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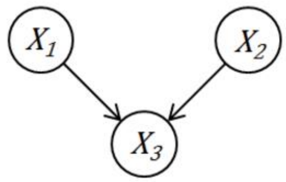
X_1	$P(X_1)$
0	0.999
1	0.001



X_2	$P(X_2)$
0	0.998
1	0.002

X_1	X_2	$P(X_3 \| X_1,X_2)$	
		0	1
0	0	0.999	0.001
0	1	0.710	0.290
1	0	0.060	0.840
1	1	0.050	0.950

Fig. 1. A Bayesian Network Model

II. Learning Bayesian Networks

A. Bayesian Network Models

A Bayesian network model visualizes the causal relationship among events through graph representation. In a Bayesian network model, events are represented by nodes while causal relationships are represented by edges. See Figure 1 for example. Nodes X_1, X_2, and X_3 represent distinct events where they take 1 if the corresponding events occur, and take 0 if the events do not occur. Edges $X_1 \to X_3$ and $X_2 \to X_3$ represent causal relationships, which mean that the probability of $X_3 = 1$ depends on events X_1 and X_2. If edge $X_1 \to X_3$ exists, we call that X_1 is a parent of X_3 and X_3 is a child of X_1. Because nodes X_1 and X_2 do not have their parents, they have own prior probabilities $P(X_1)$ and $P(X_2)$. On the other hand, because node X_3 has two parents X_1 and X_2, it has a conditional probability $P(X_3 \mid X_1, X_2)$. In this example, the probability that X_3 occurs is 0.950 under the assumption that both X_1 and X_2 occur. Note that, from this model, Bayesian inference is possible: if X_3 is known, then the posterior probability of X_1 and X_2 can be determined, which enables us to infer events that causes the child event.

The Bayesian networks can be learned from the data obtained through the observation of events. Let $O = \{o_j\}, 1 \le j \le S$ be a set of observations, where S is the number of observations. Let $o_j = (x_{j1}, x_{j2}, ..., x_{jN})$ be a j-th observation, which is a set of observed values x_{ji} on event X_i for all $i (1 \le i \le N)$, where N is the number of events. We try to learn a good Bayesian network model θ from the given set of observations. Note that the model θ should be able to explain the observation O, i.e., O should be likely to be observed under θ. As an evaluation criterion to measure the level of fitting between θ and O, we use AIC (Akaike's Information Criterion) [6], which is one of the best known criterion used in Bayesian networks. Formally, the problem of learning Bayesian networks that we consider in this paper is defined as follows:

Problem 1: From the given set of observations O, compute a Bayesian network model θ that has the lowest AIC criterion value.

B. K2 Algorithm

K2 [2] is one of the best-used traditional algorithms to learn Bayesian network models. Note that searching good Bayesian network models is generally time consuming because the problem to learn Bayesian networks is NP-hard [1]. K2 avoids the problem of running time by limiting the search space through the constraint of totally order of events. Namely, for a given order of events $X_1 < X_2 < ... < X_N$, causal relationship $X_k \to X_l$, where $k > l$ is not allowed. Note that this constraint is suitable for some cases: if events have their time of occurrence, an event X_k that occurred later than X_l cannot be a cause of X_l. Several practical scenes would be the case.

The process of K2 algorithm applied to a set of events $X_1, X_2, ..., X_N$ with the constraint $X_1, X_2, ..., X_N$ is described as follows:

(1) Select the best structure using two events X_N and X_{N-1}. Here, the two structures, i.e., $X_{N-1} \to X_N$ and the independent case, can be the candidates, and the one with better criterion value is selected.

(2) Add X_{N-2} to the structure. Namely, select the best structure from every possible cases where X_{N-2} has edges connected to X_{N-1} and X_N. Namely, from the cases (i) $X_{N-2} \to X_{N-1}$ and $X_{N-2} \to X_N$, (ii) $X_{N-2} \to X_{N-1}$ only, (iii) $X_{N-2} \to X_N$ only, and (iv) where X_{N-2} has no edge.

(3) Repeat step (2) to add events to the structure in the order $X_{N-3}, ..., X_2, X_1$.

P		Parent Node					
		X_1	X_2	...	X_i	...	X_N
Child node	X_1	0.0	0.5	...	p_{i1}	...	0.5
	X_2	0.5	0.0	...	p_{i2}	...	0.5
	⋮	⋮	⋮	⋱	⋮	...	⋮
	X_j	p_{1j}	p_{2j}	...	p_{ij}	...	p_{Nj}
	⋮	⋮	⋮	⋮	⋮	⋱	⋮
	X_N	0.5	0.5	...	p_{iN}	...	0.0

Fig. 2. A Probability Vector

(4) Output the final structure composed of all events.Although K2 requires low computational time due to the constraint

of event order, many problems do not allow the constraint. In such cases, we require to tackle the NP-hard problem using a heuristic algorithm for approximate solutions.

C. Related Work for Un-ordered Bayesian Network Models

Even for the cases where the constraint of order is not allowed, several approaches to learn Bayesian network models has been proposed. One of the most basic method is to use K2 with random order, where randomly generated orders are applied repeatedly to K2 to search for good Bayesian network models.

As more sophisticated approaches, several ideas have been proposed so far. Hsu, et al. proposed a method to use K2 algorithm to which the orders evolved by genetic algorithms are applied [3]. Barrière, et al. proposed an algorithm to evolve Bayesian network models based on a variation of genetic algorithms called co-evolving processes [4]. Tonda, et al. proposed another variation of genetic algorithms that applies a graph-based evolution process [5]. However, with these approaches, the performance seems to be limited, and a new paradigm of the algorithm that learn Bayesian networks more efficiently is strongly required.

D. Population-Based Incremental Learning

Recently, a category of the evolutionary algorithms called EDA (Estimation Distribution Algorithm) appears and reported to be efficient to learn Bayesian network models. As one of EDAs, PBIL [7] is proposed by Baluja et al. in 1994, which is based on genetic algorithm, but is designed to evolve a probability vector. Later, Blanco et al. applied PBIL to the Bayesian network learning, and showed that PBIL efficiently works in this problem [9].

In PBIL, an individual creature s is defined as a vector $s = (v_1, v_2, ..., v_L)$, where $v_i\ (1 \le s \le L)$ is the i-th element that takes a value 0 or 1, and L is the number of elements that consist of an individual. Let $P = (p_1, p_2, ..., p_L)$ be a probability vector where $p_i\ (1 \le i \le L)$ represents the probability to be $v_i = 1$. Then, the algorithm of PBIL is described as follows:

(1) As initialization, we let $p_i = 0.5$ for all $i = 1, 2, ..., L$.
(2) Generate a set S that consists of C individuals according to P. Namely, element v_i of each individual is determined according to the corresponding probability p_i.
(3) Compute the evaluation value for each individual $s \in S$.
(4) Select a set of individuals S' whose members have evaluation values within top C' in S, and update the probability vector according to the following formula:

$$p_i^{new} = ratio(i) \times \alpha + p_i \times (1.0 - \alpha) \quad (1)$$

where p_i^{new} is the updated value of the new probability vector P^{new} (P is soon replaced with P^{new}), $ratio(i)$ is

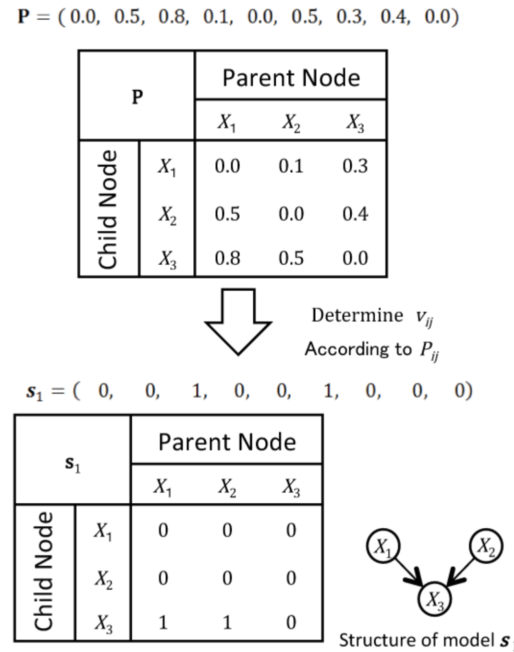


Fig. 3. Step (2): Generating Individuals

the function that represents the ratio of individuals in S' that include link i (i.e., $v_i = 1$), and α is the parameter called learning ratio.

(5) Repeat steps (2)-(4).

By merging top-C' individuals, PBIL evolves the probability vector such that the good individuals are more likely to be generated. Different from other genetic algorithms, PBIL does not include “crossover” between individuals. Instead, it evolves the probability vector as a “parent” of the generated individuals.

III. PBIL-BASED BAYESIAN NETWORK LEARNING

In this section, we present a PBIL-based algorithm to learn Bayesian network models to which we apply a new mutation operator. Since our problem (i.e., Problem 1) to learn Bayesian networks is a little different from the general description of PBIL shown in the previous section, a little adjustment is required.

In our algorithm, individual creatures correspond to each Bayesian network model. Namely, with the number of events N, an individual model is represented as $s = (v_{11}, v_{12}, ..., v_{1N}, v_{21}, v_{22}, ..., v_{N1}, v_{N2}, ..., v_{NN})$, where v_{ij} corresponds to the edge from events X_i to X_j, i.e., if $v_{ij} = 1$ the edge from X_i to X_j exists in s, and if $v_{ij} = 0$ it does not exist. Similarly, we have the probability vector P to generate individual models as $P = (p_{11}, p_{12}, ..., p_{1N}, p_{21}, p_{22}, ..., p_{N1}, p_{N2}, ..., p_{NN})$ where

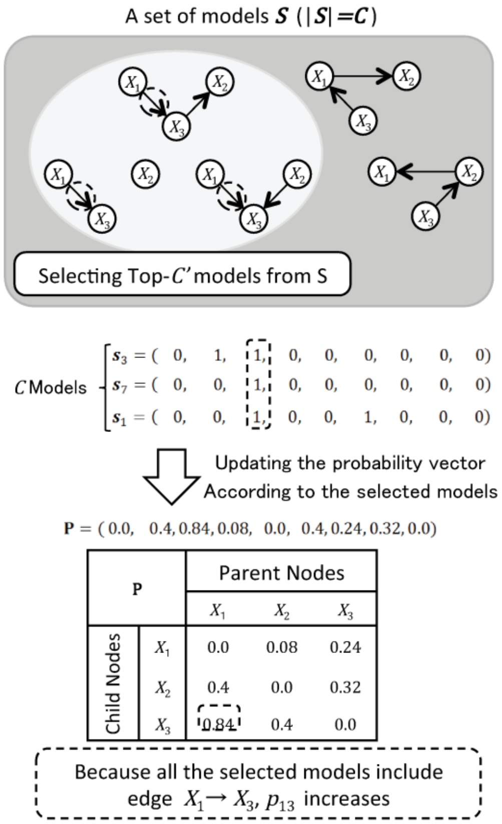


Fig. 4. Step (3)(4): Updating the Probability Vector

p_{ij} is the probability that the edge from X_i to X_j exists. A probability vector can be regarded as a table as illustrated in Fig. 2. Note that, because Bayesian networks do not allow self-edges, p_{ij} is always 0 if $i = j$.

The process of the proposed algorithm is basically obtained from the steps of PBIL. Namely, the basic steps are described as follows:

(1) Initialize the probability vector P as $p_{ij} = 0$ if $i = j$ and $p_{ij} = 0.5$ otherwise.

(2) Generate S as a set of C individual models according to P. (This step is illustrated in Fig. 3.)

(3) Compute values of the evaluation criterion for all individual models $s \in S$.

(4) Select a set of individuals S' whose members have top-C' evaluation values in S, and update the probability vector according to the formula (1). (These steps (3) and (4) are illustrated in Fig. 4.)

(5) Repeat steps (2)-(4).

Same as PBIL, the proposed algorithm evolves the probability vector to be likely to generate better individual models. However, there is a point specific to Bayesian networks, that is, a Bayesian network model is not allowed to have cycles in it. To consider this point in our algorithm, step 2 is detailed as follows:

(2a) Create a random order of pairs (i, j), where $1 \le i, j \le N$ and $i \neq j$.

(2b) Determine the values of v_{ij} according to P, with the ordercreated in step (2a); every time v_{ij} is determined, if v_{ij} is determined as 1, we check whether this edge from X_i to X_j creates a cycle with all the edges determined to exist so far. If it creates a cycle, let v_{ij} be 0.

(2c) Repeat steps (2a) and (2b) until all pairs (i, j) in the order are processed.These steps enable us to treat the problem of learning good Bayesian network models within the framework of PBIL. Note that checking the cycle creation in step (2b) can be done efficiently using a simple table that manages the taboo edges that create cycles when they are added to the model.

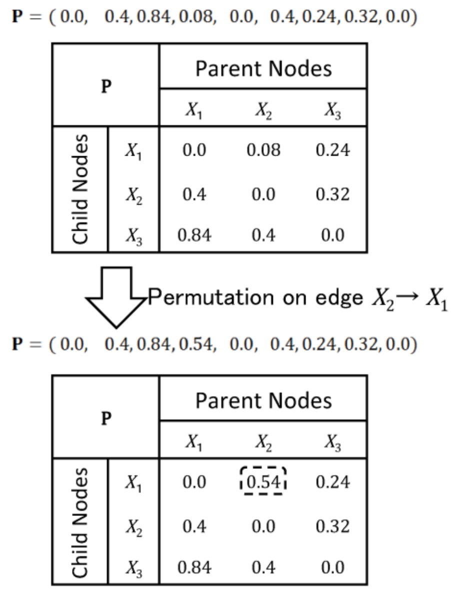


Fig. 5. Probability Mutation (PM)

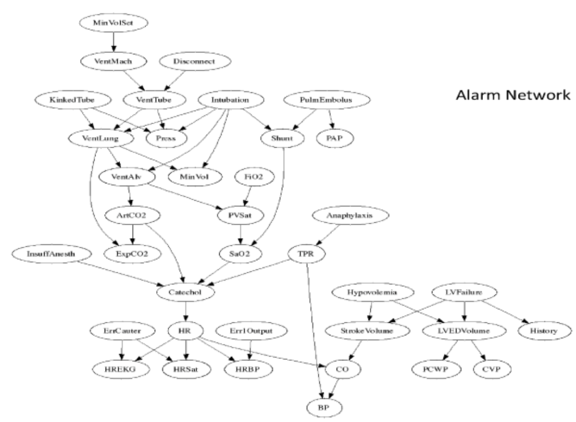


Fig. 6. The Alarm Network

A. Mutation Operators

Note that the algorithm introduced in the previous section does not include mutation operator. Thus, naturally, it is easy to converge to a local minimum solution. Actually, PBIL-based algorithm to learn Bayesian networks proposed by

Blanco et al. [9] stops when the solution converges to a minimal solution, i.e., when score does not improve for recent k generations. However, local minimum solutions prevent us to search for better solutions, thus it should be avoided.

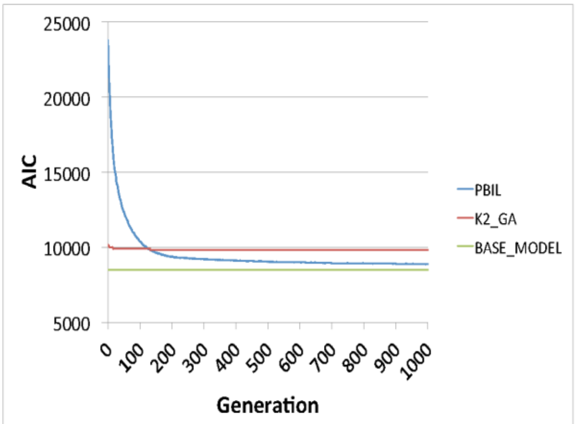


Fig. 7. Performance of the PBIL-based Algorithm

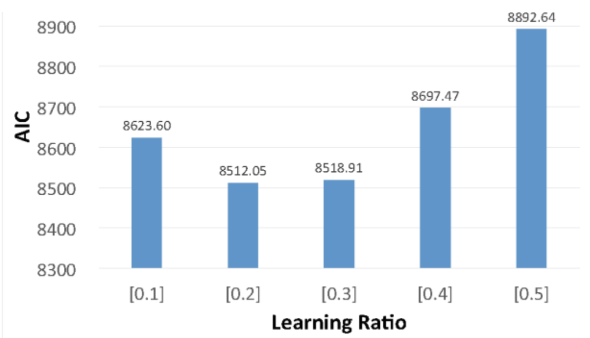


Fig. 8. AIC Scores under Variation of Learning Ratio

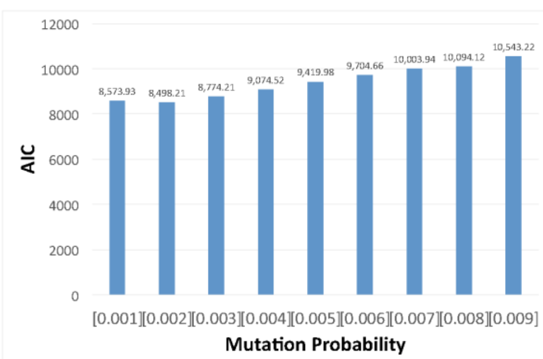


Fig. 9. AIC Scores under Variation of Mutation Probability

To avoid converging to the local minimum solution and to improve the performance of the algorithm, typically several mutation operations are inserted between steps (2) and (3). The most popular mutation operator is called *bitwise mutation* (BM) introduced by Handa [10], which apply mutations to each link in each individual, as described in the following step:

BM: For each individual in S generated in step (2), we flip each edge with probability p_{mut}. Namely, for each pair of nodes i and $j(1 \le i, j \le N)$, $v_{ij} \leftarrow 1$ if $v_{ij} = 0$, and $v_{ij} \leftarrow 0$ otherwise, with probability p_{mut}.

The other mutation operator we try in this paper is called *transpose mutation* (TM) introduced by [11]. This operation is proposed based on the observation that that reverse-edges frequently appear in the solutions. To avoid this, transpose mutation changes the direction of edges in the individuals produced in each generation. The specific operation inserted between steps (2) and (3) is in the following.

TM: For each individual in S generated in step (2), with probability p_{mut}, we do the following operation: we reverse all edges in the individual with probability p_{mut}, namely, $v_{ij} \leftarrow v_{ji}$ for all i and j.

In contrast to these conventional mutations shown above, our new mutation operator called *probability mutation* (PM) does not manipulate individuals produced in each generations. Instead, we manipulate the probability vector P to generate better individuals in the next generation, which is inserted between steps (4) and (5). The specific operation of this mutation is shown and in the following (See also Fig. 5):

PM: Apply mutations on the new probability vector P : For all pairs of events $(X_i, X_j), i \ne j$, we apply the following formula with probability p_{mut}, where the function $rand()$ generates a random value from range [0,1].

$$p_i^{new} = rand() \times b + p_i \times (1-b) \quad (2)$$

IV. Evaluation

A. Methods

In order to reveal the effectiveness of PBIL-based algorithms, we first evaluate the PBIL-based algorithm with probability mutation in comparison with K2 with its constraint (i.e., the order of events) evolved with genetic algorithms, which is a representative method among traditional approaches to learn Bayesian networks. In this conventional algorithm, we repeat creating Bayesian network models, in which its constraints (i.e., order of nodes) are continuously evolved with a typical genetic algorithm over generations, and output the best score among those computed ever. The results are described in Sec. IV-B. We next compare the performance of three mutation operators BM, TM, and PM applied to the PBIL-based algorithm. With this evaluation, we show that the new mutation operator PM proposed in this paper has good performance. The results are described in Sec. IV-C. In our experiment, we use Alarm Network [8] shown in Fig. 6, which is a Bayesian network model frequently used as a benchmark problem in this area of study. We create a set of 1000 observations according to the structure and the conditional probability of Alarm Network, and then learn Bayesian network models from the observations using those two algorithms. As the evaluation criterion, we use AIC, one of the representative criterion in this area. Namely, we compare the AIC values in order to evaluate how good is the Bayesian network models obtained by these two algorithms. As for parameters, we use $C = 1000$, $C' = 1$, $\alpha = 0.2$, $\beta = 0.5$, and $p_{mut} = 0.002$.

B. Result 1: Performance of PBIL-based Algorithms

The first result is shown in Fig. 7, which indicates the AIC score of the best Bayesian network model found with the growth of generations. In this figure, the AIC score of the original Alarm Network, which is the optimal score, is denoted by "BASE MODEL." The proposed algorithm with *probability mutation* (represented as PBIL in the figure) converges to the optimal score as time passes, whereas K2-GA stops improving in the early stage. We can conclude that the performance of the PBIL-based algorithm is better than the conventional algorithm in that the PBIL-based algorithm computes better Bayesian network models according to time taken in execution. Note that the running time per generation in the proposed method is far shorter than K2-GA; the difference is more than 250 times in our implementation.

Fig. 8 and 9 show the performance of the proposed algorithm with variation of learning ratio α and mutation probability p_{mut} in 10,000 generations. These results show that the performance of the proposed method depends on α and p_{mut}, which indicates that we should care for these values

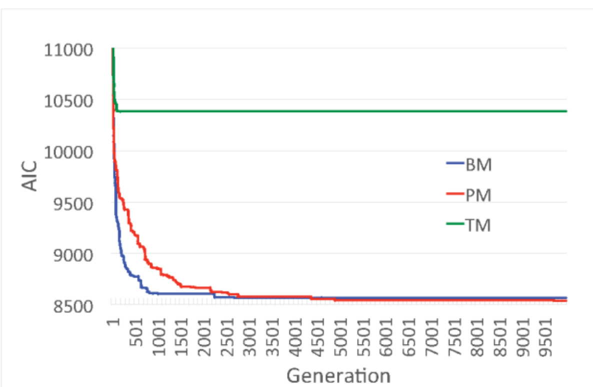


Fig. 10. Performance Comparison in Mutation Variations

to improve the performance of the proposed algorithm. Note that, from these results, we have the best-performance values $\alpha = 0.2$ and $p_{mut} = 0.002$, which are used as the default values in our experiment.

C. Result 2: Comparison of Mutation Variations

We further compared the performance of the PBIL-based algorithm with three mutations, bitwise mutation (BM), transpose mutation (TM), and probability mutation (PM). Facing on this experiment, we carefully choose the mutation probability of each method through preliminary experiments. For BM, we examined the performance of the mutation probability in range [0.001:0.2], and chose the value of the best performance, 0.005. For TM, we similarly tried the performance of the mutation probability in range [0.05:0.5], and chose 0.1 as the best value. For PM, from the result shown in Fig. 9, we chose the mutation probability 0.002, which is the same value as our first result shown in Fig. 7.

The result is shown in Fig. 10. We see that BM and PM continue improving as generation passes, whereas TM stops improving at the early stage of generation. Also, we see that the curve of BM and PM are slightly different where BM reach better scores in the early stage while PM outperforms BM in the late stage. This result shows that the newly proposed mutation operator PM is also useful especially in long-term learning of Bayesian network models under PBIL-based algorithms.

V. Conclusion

In this paper, we introduced the literature of PBIL-based learning of Bayesian network models, and proposed a new mutation operator called probability mutation that manipulates probability vector of PBIL. Through evaluation of these algorithms, we found that (i) the PBIL-based algorithm outperforms K2-based traditional algorithms with the long-term continuous improvement, and (ii) probability mutation works well under PBIL-based algorithms especially in long-term computation to obtain high-quality Bayesian network models. Designing more efficient search algorithms based on EDA is one of the most attractive future tasks.

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Sho Fukuda received his B.E. and M.E. degrees from Wakayama University in 2012 and 2014, respectively. He is currently working with Intec Hankyu Hanshin Co.Ltd. He is interested in Data Analytics with large data sets.

Yuuma Yamanaka is currently pursuing his Bachelor's degree in Faculty of Systems Engineering, Wakayama University. He is interested in Data Analytics and Machine Learning.

Takuya Yoshihiro received his B.E., M.I. and Ph.D. degrees from Kyoto University in 1998, 2000 and 2003, respectively. He was an assistant professor in Wakayama University from 2003 to 2009. He has been an associate professor in Wakayama University from 2009. He is currently interested in the graph theory, distributed algorithms, computer networks, wireless networks, medical applications, bioinformatics, etc. He is a member of IEEE, IEICE, and IPSJ.

Scene Integration for Online VR Advertising Clouds

Michael Kalochristianakis, Markos Zampoglou, Kostas Kontakis, Kostas Kapetanakis, Athanasios Malamos

Department of Informatics Engineering, Technological Educational Institution, Heraklion, Crete

***Abstract* — This paper presents a scene composition approach that allows the combinational use of standard three dimensional objects, called models, in order to create X3D scenes. The module is an integral part of a broader design aiming to construct large scale online advertising infrastructures that rely on virtual reality technologies. The architecture addresses a number of problems regarding remote rendering for low end devices and last but not least, the provision of scene composition and integration. Since viewers do not keep information regarding individual input models or scenes, composition requires the consideration of mechanisms that add state to viewing technologies. In terms of this work we extended a well-known, open source X3D authoring tool.**

***Keywords* — Virtual reality, web advertising, 3D technologies**

I. INTRODUCTION

ADVERTISING through the world-wide web has been gaining attention during the last decade in order to cover the needs of enterprises for promotion via the cyberspace. As 3D technologies become more ubiquitous, virtual reality (VR) advertising becomes an appealing possibility. VR allows full control over digital worlds that is, the potential for creativity without limits. Although this type of creativity has boosted fields relating to multimedia it is still rather immature as far as marketing is concerned. There has been research on the field such as evaluations that designate the advantages of enabling VR technologies. For instance, the impact of allowing users to interact with the virtual representation of products is significant both in terms of appeal, penetration and general product awareness [1] [2] [3]. One of the issues regarding the general application of VR approaches in advertising is cost. 3D content is in general more expensive to produce in comparison to more traditional multimedia such as video, audio, images and text. The design of models and composite scenes, visual effects and interaction inevitably requires technical knowledge and work that cannot be allocated in terms of projects with narrow scope, besides artistic design and work. Productive commercial VR solutions are typically produced upon platforms or engines.

Our approach in the field of VR in terms of the iPromotion project aims is to provide an online infrastructure that will allow advertisers to market products and services by building and exposing experiential environments for their end users. They will be able to include ads within web page banners or as web page pop-ups in terms of traditional online marketing but they would also be capable to produce immersive experiences through other interfaces, such as interactive widescreens or touch tables. Our system is design to support both the composition and the exposure of VR content by means of cloud-enabled storage and services. The advantages the new advertising paradigms are obvious; advertisers can build and distribute their content using central, online infrastructures. Through appropriately designed 3D worlds advertising can provide a direct representation of the ideas, messages or product characteristics based on exciting interactions that may take any wanted form ranging from multimedia stimuli to games, puzzles and interaction scenarios. At the same time, users or potential customers will be given the opportunity to take part in a simulated experience regarding the advertised goods.

In order to sustain the aforementioned scenario it is essential to provide users with the means to compose any desired virtual worlds that is, not only to provide them with sufficient amounts of VR content units that is, 3D models or scenes, and also with the means to the content for the composition of complex scenes or even worlds. Complying with established standards is a means to accomplish only the former; even if the provision of significant amount of content units can be based on offering standard, royalty-free or available complying content for our platform, the ability to build more complex content cannot not supported by any. The scene composition module of our platform is designed to provide this use case by adding visual controls to content units so that they can be managed in terms of broader environments. It takes advantage of the appropriate event models to store information about the position, size, scale and rotation at least, in order to create simple representations for complex worlds so that content units are reused by accessing the cloud of our platform [9].

The rest of the paper is organized as follows: Section II presents the related work in the field of 3D scene representation, the standards and the tools. Section III briefly elaborates on the research project that produced this work, the iPromotion VR platform. The section overviews the architecture and components of iPromotion, focusing on the aspects that offer contributions to the VR field. Section IV

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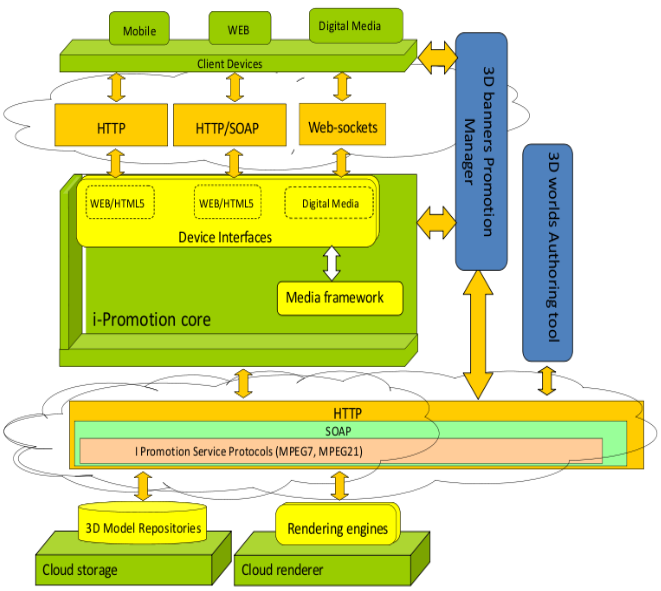

Fig. 1: the component architecture of the system

is the primary topic of this paper. Finally, section V discusses our conclusions and explores potential next steps in the development our scene composition software.

II. Procedure for Paper Submission

A. 3D technologies

The evolution of cross-platform web applications has triggered the use of XML-encoded textual files that provided a platform-independent solution for information exchange. In the field of two dimensional graphics, Scalable Vector Graphics (SVG) is an XML-based open standard that provides the necessary tools for development. SVG is capable to produce accurate results by describing vectors in XML tags. Graphics can thus be re-sized or zoomed without any loss of quality and can also be transferred in the same manner as any other XML-encoded textual files. The protocol can also utilize text annotations withing the images in order to provide supplemental functionality. Search engines or end-users can search such text annotations to retrieve content based on search criteria or individual needs. SVG is also a W3C recommendation [6] and can thus be integrated the Document Object Model (DOM) and eXtensible Stylesheet Language (XSL) besides other standards. Thus, interactivity and animation can be applied in SVG representations through object module manipulation languages such as Javascript.

X3D is a royalty free, open, ISO ratified standard for developing 3D graphics and also a run-time architecture to represent and communicate. X3D is developed by the Web3D Consortium [7] as the successor of the Virtual Reality Modeling Language (VRML). In X3D, representations use XML-encoded format and thus information is platform independent and ideal for use over the internet. X3D supports real-time communication and integration with web-service architectures, distributed networks, cross-platform applications, inter-application information transfer. It is modular by nature and is thus capable to support the concatenation or superposition of 3D components. The standard is capable to support, besides high-quality graphics, real-time interaction and audio-video sequences. The functionality of the standard is structured in layers called profiles that define the functionality subset that is to be used. The run time environment of X3D is essentially a browser engine that carries the rendering logic. The engine is released as a standalone application, as a web browser plug-in and as an open development project.

B. Scene authoring

The need to develop and combine X3D models and scenes within our platform led us to consider the available tools and their potential to be extended, maintained and used. The relevant technologies include X3D players, plug-ins, development environments and authoring platforms. A cohesive overview can be found in the pages of the WEB3D consortium. There is also an interesting comparison of the authoring and scene conversion tools in the paragraph that regards authoring. The table presented there compares most of the relevant tools that is BS Editor, SwirlX3D, X3D-Edit, Flux Studio and Vivaty Studio besides some conversion tools. The information is kept updated since it refers to the current versions of the software. One can observe a number of points. To start with, full profile is not completely supported by any authoring tool while it is “nearly supported” by BS Editor and X3D-Edit. Most tools are certified for the interchange profile and it is an easy task to retrieve this information and the detailed list of supported X3D components for each tool. Two of the authoring tools presented, Flux and Vivaty studio, are no longer active. Besides the information presented in the comparison by WEB3D consortium, a natural categorization for technologies regards their relation to the consortium that is and the details of the implementation. X3D-Edit relies on the NetBeans development platform and offers the Scene Access Interface (SAI) API in order to load and manipulate the scenegraph. BS Editor relies on a variety of technologies ranging from JAVA to proprietary ones and offers a software development kit (SDK) that can extend the capabilities of the tool. The core of the development kit also includes a scene manipulation API however, using the SDK is licensed. Blender is another interesting tool in the field of authoring released under the general public license. It offers a complete environment for model and scene manipulation, useful features for import/export, additional functionality such as game modes and full access to the source code.

C. Web advertising infrastructure

The component architecture of the iPromotion platform is presented in Fig. 1. The system implements a 3-tier serviceoriented platform composed of the following components:

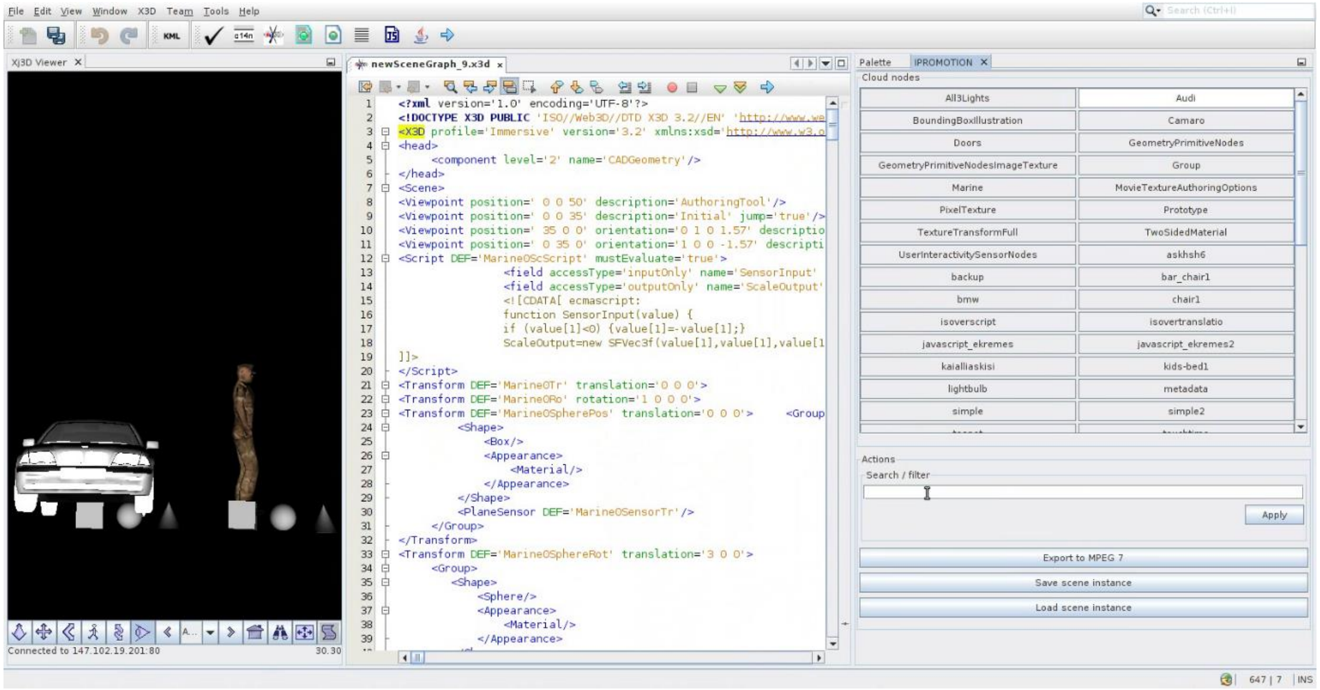

Fig. 2: the scene composition environment takes advantage of the X3D event model to implement scene management

- front-end services: based on HTTP, HTTP/SOAP and WebSockets, the system communicates with any type of device in order to adapt the rendering procedure to its capabilities using the mechanisms described in the previous paragraphs and also with any component within the architecture
- middleware container: it implements the fundamental framework that performs 3D rendering and interfaces with the presentation layer, the cloud that stores scenes, the MPEG-7 production service [8] and, last but not least, with high level tools such as 3D banners manager.
- cloud storage infrastructure: the repository of scenes and models repository is stored in a remote infrastructure implemented by as storage-as-a-service. The cloud supports transparent mechanisms for module search and retrieval over distributed processing technologies such as Hadoop and NoSQL databases [12].

Our work has been part of an online advertising platform infrastructure current under development under the iPromotion a research project. The aim of the project is to provide the all enabling framework and applications for online advertising based on VR technologies. The final outcome of the project is expected to support at least two high level use cases for online advertising. The first one will be targeting standard internet access from workstations, mobile or intelligent devices. Users will be provided with the opportunity to search online clouds of models and scenes and select any ones that interest them. Scenes will be transparently downloaded, presented transparently to the user who will be the capable to interact with the advertisement. The second use case will involve modern interaction interfaces that is, touch-screens, motion sensors such as the Microsoft KINEKT or ASUS XTION, and possibly wall screens or projectors. Users will be offered with VR environments conforming at least to the immersive X3D profile that supports 3D interactions and will thus be capable to interact with the scene using all the aforementioned interfaces. Both use cases will be supported by mechanisms for content-based search that take advantage of online MPEG-7 media location descriptors [4] for 3D scenes. MPEG-7 representation is also stored in the cloud along with the scenes. The transmission mechanism will conform with the MPEG-21 [5] standard in order to implement multimedia adaptation that is, to ensure that content can be played in the requesting devices. Finally, MPEG-4 is used to merge this information into unified 3D multimedia objects, incorporating information about digital and the actual scene description. Our infrastructures implement remote rendering of VR environments [10][11]. That is, 3D scenes are rendered on the server tier and end users receive video streams that have been adapted to the characteristics of their terminal devices as far as any characteristic is concerned (image quality, the frame rate). To this end, the open source Xj3D Browser has been ported to expose Axis2 Java Web service interface. A detailed description of the platform can be found in [13].

III. Composing Scenes

In order for the iPromotion platform to complete the cycle of 3D advertising production and service provisioning it is essential to support an authoring module that will allow scene authors or designers to produce models, scenes or worlds to be exposed by the platform. The authoring environment was required to be an autonomous desktop application environment but also to be able to exploit iPromotion services transparently that is, to use the scene repository cloud and the web services that facilitate scene creation, such as the services for scene description and retrieval. Considering parameters such as compliance to standards, technology excellence, development efficiency and organization we have chosen to use and extend the well-known X3D-Edit platform, already mentioned in section II that describes related work in the field. More specifically, X3D-Edit is released by the Web3D forum and is thus compliant with the spirit and the principle of the project. It is based entirely on JAVA and specifically on the NetBeans development platform, an important design characteristic since it offers all the benefits of the known window environment relieving the development process from the respective load while allowing efficient extension mechanisms through the creation of autonomous modules and plugins. X3D-Edit itself is modular by design since its codebase groups its functionality into distinct modules that group its functionality; KMLEditor, JOMWrapper, LookAndFeel, AppConfiguration, can be easily identified in terms of functionality and also in the code base, version 3.3, besides others. The tool is thus very easy to extend and also to compile since it exploits the build system of the NetBeans platform.

Fig. 2 presents the authoring tool extension of X3D-Edit that serves the necessary functionality for iPromotion. It is integrated within X3D-Edit as an autonomous plugin that exposes the functionality for iPromotion. The plugin implements a window viewpoint labeled “IPROMOTION” and is constructed as a separate NetBeans module, shown at the right in the figure. The panel on the left includes the port of the X3D viewer for JAVA. The main window of the tool is the X3D editor module used to compose X3D scenes and then load them in the viewer. The iPromotion panel presents a matrix containing all the scenes available from the cloud. The latter are selectable visual component so that they can be loaded. Users may also apply simple name matching in order to reduce the number of presented scenes using the input box bellow the scene matrix. Thus, after the wanted scene is located they are selected, fed in the viewer and then positioned as users will require. The new scene can be saved in the cloud transparently and can be loaded again for further processing. Each time a scene is saved, MPEG-7 indexing is transparently produced since the final scene output is submitted to the respective web service.

The main challenge behind the implementation of the aforementioned functionality is found in the inherent representation of scenes by X3D rendering modules, viewers. Such modules typically parse X3D input and do not discriminate among autonomous, integral 3D models that typically represent a single thematic object, which would be a very useful characteristic for our system as well as other ones. We have considered the alternatives for overcoming this problem; an elegant solution would be to construct a small framework that would be able to hold information regarding the state of the viewer that related to individual models being loaded even if there is no such notion in Xj3D rendering. The <x3d> tag is unique in every model and so is the <scene> tag. If the Xj3D viewer is to produce the outcome of model concatenation, they must first dispose the aforementioned tags, be processed and only then be fed to the viewer. This functionality can be implemented using both XML processing and the SAI API that supports methods for appending scenes in the one already presented by the viewer. In any case, the viewer would not be able to discriminate among the individual models it renders. Unless this functionality is included in the standard, the viewer can be set to expose information about each inserted model implicitly, event if it does not explicitly support such functionality. The solution we employed relied on visual controls in the form of basic shapes that have been inserted into the scene in order to provide feedback to the XJ3D runtime environment. Fig. 2 illustrates the visual dimension of the this mechanism; the cube, sphere and cone shapes behind the two scenes in the viewer, the car and the marine, are sensor nodes connected with the position, rotation and scale attributes of each scene with the aid of route elements in the first two cases and with the help of appropriate Javascript scripts in the latter. Thus, using standard X3D mechanisms, scenes are manageable and any environment can be built by adding more individual objects. This mechanism includes a number of details, the most important of which have to do with scene and sensor naming, listening to events, correct sensor positioning and then keeping the state of the viewer. Identifies must be named uniquely within scenes that is, all element definitions, DEFs, that relate to scene reference must be changed in real time. An efficient convention is to assign them their original names in addition to a suffix composed by the name of the scene and a number that counts how many instances of the scene have been loaded. This convention allows the authoring to maintain a structure, indexed by the unique scene instance names, holding the numbers that correspond to position, scale and rotation translations as returned by event listener mechanisms. Note however that, since the scene name is used as a key value to recover content it uses such as textures, images, etc, from the cloud, it must be maintained. Fig. 3 presents the implementation of the controls using X3D route elements that redirect numerical values from the sensors to the models they are to control using translation elements. As illustrated in the figure, the mechanism is implemented by means of X3D objects added in the scene. The names of Nodes correspond to the unique scene names suffixed with a string that identifies the sensor. Fig. 3 illustrates only the suffix for sensor node names however the implementation assigns names according to the aforementioned rule in order to implement control for any model. For the transformation of the size we employed the code illustrated in the script in order to convert vertical motion on the cone to scale information. Correct positioning of the sensors includes the computation of the maximum dimension of the scene in the Y-axis as measured from the center of the scene and the initialization of the position parameters for the sensors. This logic includes the identification of dimensions for large shapes and top level drawable objects and the transformations causing them to move, rotate, displace, etc.. The maximum dimension of the scene will define the position of the sensors so that they are visible and not hidden within space occupied by part of the object.

Fig. 4 presents parts of the output file that is stored in the cloud when a scene is produced. The format we have selected in order to incorporate composite multimedia objects based on 3D graphics is the MPEG-4 eXtensible MPEG-4 Textual format (XMT). XMT is XML-based described in MPEG-4 part 11 regarding scene description and application engine [14]. It allows us to describe the structure of multimedia scenes, by incorporating large parts of SMIL, SVG and X3D. Especially with respect to X3D, XMT uses an almost identical set of commands, making the two formats highly compatible. Besides representing simple or composite scenes, however, XMT also allows for the incorporation of more complex multimedia features, such as MPEG-7 descriptions and MPEG-21 rights management, all in the same structure. The top part of fig. 4 presents how scenes are described in terms of a world. The <es_descriptor> tag contains among other, the <streamsource> tag that defines the name of the scene which is also its index within the iPromotion cloud. Each <es_descriptor> defines a distinct scene that needs to be added in the viewer. The body of the XMT file groups all the scenes within the world within the <children> tag and keeps their position, rotation and scale as shown in the lower art of fig.4. This formalization allows scenes to be reused since complex scenes refer to simple, basic models and need not store additional X3D information. Models, that have not been created by combination of other 3D objects, do not need this kind of representation. For them the XMT information is absent from the cloud and it is never created; this is a means for separating composite and primitive scenes.

The mechanisms described in the previous paragraph are sufficient to allow the implementation of high level use cases that hide internal operations. Scenes are accessed through the iPromotion cloud API, and their manipulation relies on the SAI API. As mentioned in the previous paragraph, the implementation could rely on XML manipulation. However is an ISO standard and so is its binding to the JAVA language. We evaluated both approaches and empirically found that the former performed much slower than using the SAI API. Supplemental services, such as the creation and validation of indexing MPEG-7 information for the cloud, use relevant web services exposed by the middleware. Thus, users only deal with scene processing either graphical, or even textual through the X3D editor panel. Moreover, the tool exploits the editing characteristics X3D-Edit which supports all the X3D visual components. Another interesting characteristic is that the authoring tool is designed to allow the addition of textual meta-tags in the final scene. This information is incorporated into the MPEG-7 description and can thus be used for applying detailed search functionality. The searchable pieces of information will not be confined to textual meta-information; it will also include content descriptors for color, shape, texture and animation. As both the X3D and MPEG-7 standards are based on XML, the extraction of content description from scenes can be achieved through with XML-to-XML transformation.

IV. Conclusions And Future Work

The previous paragraphs describe a scene authoring and management tool designed to cover the needs of iPromotion, our virtual reality advertising platform. The primal use case that this software covers exceeds the basic scene creation and editing; the functionality we aim to deliver aims to provide o higher layer in 3D authoring by focusing on the concatenation of completed, autonomous models and/or scenes in order to create manageable 3D worlds. We have extended a valuable scene composition tool in the field, X3D-Edit, that relies on the Netbeans platform to offer scene manipulation functionality in moduls. We thus added a new window in the top level view of the tool that integrates iPromotion functionality transparently, more specifically, we employed the programming interfaces for cloud access and scene indexing. The former required the support of proper representations for the new types of scenes and the latter required the construction and communication with appropriate web services that extract indexing information. The core of the system however is the scene manipulation logic that keeps the state of the worlds constructed by users, that is the identification of individual scenes their normalization so that they can be fed into the XJ3D browser. Thus, a scene can be added multiple times; information about each instance is kept and all of them will be capable to access any resources originally available to them such as textures, images, audio, etc.. Scenes are controlled by visual objects properly positioned below them. These controls are accompanied with X3D and Javascript code that transforms their events to scene positioning, rotation and scale. The described work is currently in alpha stage that is, it is in progress. Future work will focus on all aspects of scene authoring. Since XJ3D browsers currently support access to online resources, scene elements using the cloud interface can be limited only to the necessary extend. The tool is following the evolution of the iPromotion VR platform and is expected to be tested against more elaborate models representing 3D environments. It will be evaluated for performance and usability.

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Michael Kalochristianakis is currently an associate lecturer and researcher at the Technological Educational Institution of Crete (TEIC), at the Department of Informatics Engineering. In the past I have been an associate lecturer for the Dpt of Applied Science at TEIC, for the Dpt of Production and Engineering Management at the Technical University of Crete and for the Academic Library at the University of Crete. He has also worked for the Research Academic Computer Technology Institute and Press "Diophantus" as an IT researcher/engineer and for the software industry as a J2EE programmer. Michael holds a Doctorate degree in Computer Engineering and Informatics, a Masters degree in Computer Science and a Diploma in Electrical Engineering and Computer Technology. Pieces of my work have been published in international peer-reviewed journals and have been presented at international conferences. He is also a reviewer for several academic journals.

Markos Zampoglou was born in 1981 in Thessaloniki, Greece. He graduated from the dept. of Applied Informatics of the University of Macedonia, Greece, in 2004. He received an MSc in Artificial Intelligence from the University of Edinburgh in 2005 with a Distinction. He was awarded a Doctorate degree from the dept. of Applied Informatics, University of Macedonia, Greece in 2011. Markos is currently an associate lecturer and researcher at the Technological Educational Institution of Crete (TEIC), at the Department of Informatics Engineering.

Kostas Kontakis is a graduate student at the Technological Educational Institution of Crete (TEIC), Department of Informatics Engineering pursuing his MSC. His primary interests include semantic web and ontologies. He has been with the Multimedia Content Lab for two years. Kostas holds a BS degree from the Department of Informatics Engineering.

Kostas Kapetanakis is an experienced systems administrator and programmer working for the Multimedia Lab. He is also graduate student at the Technological Educational Institution of Crete (TEIC), Department of Informatics Engineering. He is currently pursuing his MSC degree. Kostas holds a BS degree from the Department of Informatics Engineering.

Athanasios G. Malamos received a BSC degree in Physics from the University of Crete (1992) and a PhD from the Technical University of Crete in 2000. From 1997 to 2002 he was a research assistant and a researcher in the ICCS National Technical University of Athens. Since 2002 is with the Technological Educational Institute of Crete, at the Department of Informatics Engineering, as an Assistant Professor (2002-2006) and as an Associate Professor (2006 until present). Prof. Malamos leads the Multimedia Lab. He has been running EU and National funded research projects. He has served as program committee and reviewer for several international conferences and workshops. He is a reviewer for IEEE, Springer as well as for international journals that fall within his interests and he is a member of the WEB3D consortium. His research interests include multimedia services, virtual reality, 3D modeling and multimedia semantics.

Assessing Road Traffic Expression

Fábio Silva, Cesar Analide, Paulo Novais,

Department of Informatics, University of Minho

***Abstract* — Road traffic is a problem which is increasing in cities with large population. Unrelated to this fact the number of portable and wearable devices has also been increasing throughout the population of most countries. With this advent, the capacity to monitor and register data about people habits and locations as well as more complex data such as intensity and strength of movements has created an opportunity to contribute to the general wealth and comfort within these environments. Ambient Intelligence and Intelligent Decision Making processes can benefit from the knowledge gathered by these devices to improve decisions on everyday tasks such as deciding navigation routes by car, bicycle or other means of transportation and avoiding route perils. The concept of computational sustainability may also be applied to this problem. Current applications in this area demonstrate the usefulness of real time system that inform the user of certain conditions in the surrounding area. On the other hand, the approach presented in this work aims to describe models and approaches to automatically identify current states of traffic inside cities and use methods from computer science to improve overall comfort and the sustainability of road traffic both with the user and the environment in mind. Such objective is delivered by analyzing real time contributions from those mobile ubiquitous devices to identifying problematic situations and areas under a defined criteria that have significant influence towards a sustainable use of the road transport infrastructure.**

***Keywords* — Traffic Expression, Smart Cities, Computational Sustainability**

I. Introduction

CURRENT trends such as smart cities and the internet of things has focused attention towards the quality of living and well-being inside big cities . It is also believed that most people will be living inside cities until 2050. If true, such statement would predict the increase of road traffic in cities that were not neither originally designed nor prepared to handle such influxes of traffic. Ambient Intelligence (AmI) is a multi-disciplinary subject that is equipped with procedures that may help solving such problems taking advantage of fields such sensing systems, pervasive devices, context awareness and recognition, communications and machine learning. It is currently applied in a number of applications and concepts in fields like home, office, transport, tourism, recommender and safety systems, among others [1] .

Road traffic analysis is an expensive and time consuming task which traditionally involves direct evaluation and field studies to assess and evaluate the impact of the flux of traffic in certain cities. An alternative to this is simulation experiments provide possible scenarios under which some assessment can be made. However, the downside of simulation lies in the use simplified models that are thought to mimic reality when in fact they may differ to some degree. Ubiquitous sensorization may be used to assess current traffic conditions, avoiding the use of costly field studies. Example of ubiquitous sensitization can already be found in certain areas such as traffic cameras and smart pressure detectors to assess traffic flow in specific points. This sensing is limited to the area it is implemented and does not provide information outside its operating range [2], [3]. More complex studies can be made with portable ubiquitous devices that follow drivers either because there a sensing device in the vehicle or the person driving carries a portable sensing device able to capture data related to driving. The nature of mobile ubiquitous devices also enable the possibility of direct analysis of driver behavior and community habits (points of congestion, high speed hazardous corners, aggressive sites) assessed trough the statistical treatment of driving records and offer safer alternatives for navigation with such information. These models have a direct impact diagnosing the current state of traffic and traffic behaviors to each route that may be used in modern GPS navigation systems, as an additional parameters.

Other approaches for the use of ubiquitous sensing devices involve real-time safety assessment, in [4] and [5] where a set of indicators is used to assess driving safety. Such indicators take into consideration the time of reaction, vehicle breaking time and whether or not there is a collision course. Yet, the analysis is still limited to the visible surrounding area and activities such as identification of other vehicles within the nearby space with the help of video interfaces disregarding sources of information outside that scope. In transport applications inside an area also known as Smart Cars, the AmI system must be aware not only of the car itself and its surroundings, but also of the driver's physical and physiological conditions and of the best way to deal with them [6]. The driver's behavior is important with several authors proposing machine learning and dynamic models to recognize different behaviors in drivers [7]. There are also examples of applications integrating AmI and ubiquitous principles in driving and traffic analysis. In [8], it is described a monitoring and driving behavior analysis system for emerging hybrid vehicles. The system is fully automated, non-intrusive with multi-modal sensing, based on smartphones. The application

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runs while driving and it will present personalized quantitative information of the driver's specific driving behavior. The quality of the devices used to perform such monitoring have a direct relationship to the quality of the measurement, thus, in this case, it is the main source of measurement error which needs to be controlled and contained to known error values order to make this study effective to production use. Other advantages include the possibility to increase information quality and create new routing styles in existing navigation systems taking into consideration aspects such as driver's driving style or accident or hazardous events rate during the routing planning phase.

Other approaches to analysis of driving behavior can be found in [9] a mobile application assesses driving behavior, based on the identification of critical driving events, giving feedback to the driver. The I-VAITS project [6] is yet another example that pretends to assist the driver appropriately and unobtrusively, analyzing real-time data from the environment, from the car and from the driver itself, by the way the driver uses the different elements of the car, their movements or image processing of their face expressions. In [10], in the context of a car safety support system, an ambient agent-based model for a car driver behavior assessment is presented. The system uses sensors to periodically obtain information about the driver's steering operation and the focus of the driver's gaze. In the case of abnormal steering operation and unfocused gaze, the system launches proceedings in order to slow down, stop the car and lock the ignition.

An alternative approach to the use ubiquitous sensing is to gather information about the condition of the environment the driver is in, mapping it to further use. In the Nericell system [11], from Microsoft Research, monitors road and traffic conditions using the driver's smartphone and corresponding incorporated sensors, but it can also detect honking levels, road condition and potholes as an example.

In what refers to devices used, there are today a wide range of options that can be used. The most effective should be portable devices that are always present and can perform complex tasks while not requiring user's direct attention. In such list, there are devices like smartphones, smartwatches, and intelligent wristbands. Those offer the advantage of accompanying user from one situation to another, however there are devices that can be used that are more specialized such as the internal computer of a car. In this last case the object itself becomes part of the car which might increase its production cost while on the other hand multi-purpose portable devices might suffice to the work described.

The work described in this paper tries to enhance ubiquitous sensing for driving applications with the objective to support the concept known as sustainable driving. It requires the gathering of information about traffic condition but also, consciousness about sustainability dimensions such as environment, economic and social. With this in mind optimization should consider more than just economic aspects of driving, but also consider fuel emissions and social aspects such as driver's status, attention and driving style. Such work should complement existing other works and act as a platform for smart city traffic assessments. Moreover, the information generated by such system may be useful to third party systems which may use the knowledge base in their management applications and management systems.

II. Computational Sustainability

A. Computational Problem

The term computational sustainability is used by researcher such as Carla Gomes [12] to define the research field where sustainability problems are addressed by computer science programs and models in order to balance the dimensions of sustainability. It is accepted that the world ecosystem is a complex sustainability problem that is affected by human and non-human actions. In order to tackle these problems complex management systems should be put in practice in order to predict a number of attributes related to the sustainable problem at hand. Nevertheless, the pairing between computer science and the study of sustainability is as old as the awareness of sustainability and the availability computing systems. It is a fact that, as computational power capacity increased over time so did the complexity and length of the models used to study sustainability. The advent and general availability of modern techniques from artificial intelligence and machine learning allowed better approaches to the study of sustainability in a wide range of domains such as smart cities and transport systems.

Classical computational sustainability problems are not only found in smart grids, pollution, and distribution of energy but also city traffic. Considering the definition of sustainability and the topic of traffic expression, the use of computational methods to monitor and assess and optimize the transport efficiency are already used in systems today [2], [13], [14]. Nevertheless, the efficiency problem need to consider all dimensions of sustainability in order to become complete. The systems need to concern the optimization of not only traffic flow, economy and emission but also emissions, safety, and driver awareness.

In order to proceed to the collection of data and information required for the assessment of transport and traffic sustainability there are a number of topics under computer science that may be used. Perhaps, the most obvious would be the traditional methods of information acquisition through the sensorization of the environment and users, ambient intelligence, ubiquitous computing and information and data fusion. Less obvious techniques, concern the dynamic modelling of the environment and simulation of real world states when subjected to the conditions under study. The computational problem is therefore created by the means used to acquire this information and the resolution of the problem under the computational sustainability which include resource constraint optimizations, the satisfaction of dynamic models and preservation of statistical behaviors and actions.

B. Sustainable Driving

Traffic assessment is directly related to trending topics such as ubiquitous and pervasive methods that allow the balancing of economic, environmental and social factors needed for sustainable development. A new emerging and interdisciplinary area, known as Computational Sustainability, attempts to solve problems which are essentially related to decision and optimization problems in correlation to welfare and well-being. Due to its importance, some researchers have discussed and proposed quantification methods, and modelling process for sustainability [15], [16].

Often, decision and assessment are based on measurements and information about historical records. Indicator design provides an explanation on why such decisions are being made and it often uses information fusion to create and update its values. From a technological point of view, indicator analysis uses different and sometimes nonstandard data which sounds feasible by technological data gathering software that collect, store and combine data records from different sources. In the case of transportation systems, the assessment of the impact of a given driving pattern is made over sustainability indicators, like fuel consumption, greenhouse gas emissions, dangerous behavior or driving stress in each driver's profile.

Applications and systems that deal with this information acquisition and reasoning are already present in the literature. A system to estimate a driver profile using smartphone sensors, able to detect risky driving patterns, is proposed in [17]. It was verified whether the driver behavior is safe or unsafe, using Bayesian classification. It is claimed that the system will lead to fuel efficient and better driving habits. In [18], and in addition to car sensory data, physiological data was continuously collected and analyzed (heart rate, skin conductance, and respiration) to evaluate a driver's relative stress. The CarMa, Car Mobile Assistant, is a smartphone-based system that provides high-level abstractions for sensing and tuning car parameters, where by developers can easily write smartphone applications. The personalized tuning can result in over 10% gains in fuel efficiency [19]. The MIROAD system, Mobile-Sensor-Platform for Intelligent Recognition Of Aggressive Driving [20], is a mobile system capable of detecting and recognizing driving events and driving patterns, intending to increase awareness and to promote safety driving, and, thus, possibly achieving a reduction in the social and economic costs of car crashes.

In [21], an android application is depicted which makes use of internal vehicle sensors to assess driving efficient patterns. With information about throttle, breaking and consumption the application is able to provide driving hints in real time according to a set of predefined rule matrixes. In this case the application is focused on fuel efficiency. A more compressive study for the use of driving and traffic data can be found in [22]. This analysis considers the availability of data internal vehicle sensors, traffic data through internet services and historic driving patterns records to help the creation of more efficient navigation plans.

From the systems reviewed, there is clear focus on the lower level problem towards sustainable driving. The interest for the consideration of the sustainable problem across all of its dimensions is not the primary target of these systems but rather themes like safety, efficiency and driving profile through event detection. These applications do however fit in the category of computational sustainability as computational tool that may be used on a subset of the driving sustainability problem.

Our interpretation of the application of computational sustainability in sustainable driving is represented in figure 1, where sustainable driving is obtained through 3 types of problems that can be applied to each dimension of the classical definition of sustainability separately or in conjunction. Those 3 problems consider constraints optimization and reasoning problems, acquiring and storing information through sensorization statistics and machine learning procedure and building dynamic models that can express the state of the environment and its participants so that the impact of decisions may be assessed.

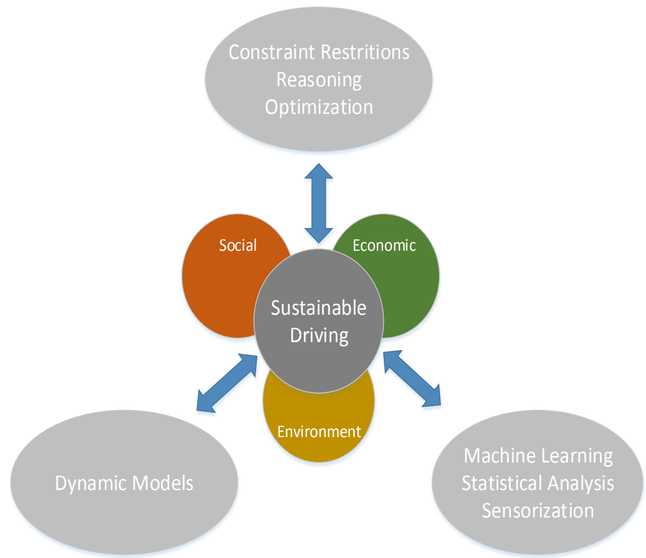

Fig. 1. Sustainable Driving Approach

In this work, the theme of sustainable driving will be addressed using a ubiquitous system for data acquisition integrated in a sustainability framework for the building of dynamic models that express the behavior of traffic and its conditions.

III. Driving Evaluation

A. PHESS Driving System

The People Help Energy Savings and Sustainability (PHESS) project is being developed to help drive awareness towards the need for sustainable and energy efficient behaviors [23]. The framework is based on distributed system of multi-devices that generate data towards the creation and maintenance of indicators in the platform [24]. In order to drive awareness, specialized modules were developed that target user attention, mood and engagement. Through a set of usage real world scenarios the platform is being demonstrated across different applications [25].

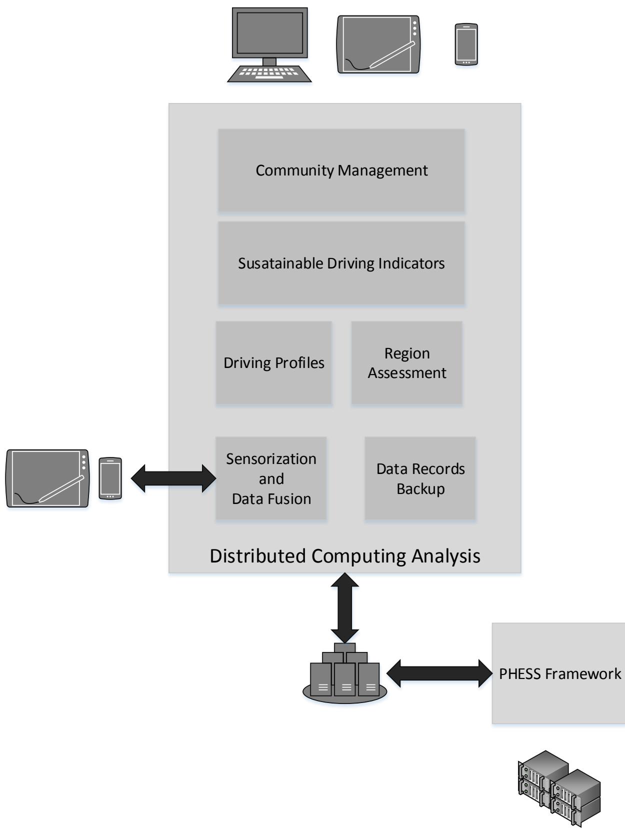

Fig. 2. PHESS Driving Architecture

In regards to the work presented in this paper, the driving scenario is being targeted. Figure 2, illustrates the system designed to monitor, assess efficiency and sustainability in driving actions. As a building blocks to assess sustainable driving the system uses both driving profiles from the data gathered while driving, event detection from the analysis of such data and indicators defined in the PHESS platform. The indicator definition is made with application both in the driving profile definition and the analysis of regions in cities. That procedure reduces complexity while it does not lose much of the information in the aggregation of data records and information and becomes more meaningful.

B. *Indicator Development*

In order to produce information about traffic flow and route safety it is necessary to gather information about relevant information about driving patterns. The focus of our analysis was derived from indicators accepted in related studies in the literature review. Towards this effect it was considered the following indicators:

- Average velocity;
- Average fuel consumption;
- Intensity of acceleration and breaking;
- Number of breaking and accelerating events per time unit;
- Standard deviation of velocity, intensity of breaking and acceleration and number of breaking and accelerations;
- Number of turn events based on curvature detection;
- Intensity of force exerted in the vehicle during turns;

All of the indicators defined and built upon ubiquitous mobile sensorization, thus limited to their sensing abilities. Even so, some of the indicator defined are obtained through simple statistical procedures over the recorded data like average speed, number of breaks and standard deviations. The intensity of acceleration and breaking events is a more challenging task. Due to the usage of mobile smartphones, sensor access is not easily controllable. Efficiency measures make data reading uneven in time meaning sometimes there is oversampling where others there is under sampling. In order to mitigate such problem the assessment is made using the linear slope from the line connecting an initial and final velocity over a period of time as presented in equation 1. Such slope provides a mean to assess intensity that is independent of the size of the time interval.

$$Slope = \frac{v_f - v_i}{t_f - t_i} \tag{1}$$

Number of breaking and accelerating events are measured in time windows, referenced as per unit of time. Defining an event window is helpful because only accelerations and breaking inside such window are considered and can be analyzed and compared between time windows.

Average fuel consumption is obtained from the fusion of user input data and the distance travelled. As an initial setup the user is required to configure the smartphone with a number of initial variables such as vehicle model and vehicle average consumptions. The aggregation of different vehicles in a large scale analysis makes this indicator more relevant for analysis.

Curve and turn detection is a special event due to characteristic and driving difficulty. Due to car handling, driving inside curvatures can present a risky task specially if driven at too much speed or under high breaking or accelerating intensity. As a consequence, for this analysis, a special strategy is employed which monitor the degree of curvature trough smartphone sensors.

$$\begin{aligned} Direction = & \tanh(\sin(\delta_2 - \delta_1) * \cos(\varphi_2), \cos(\varphi_2) * \sin(\varphi_2)) \\ & - \sin(\varphi_2) * \cos(\varphi_2) * \cos(-(\varphi_2 - \varphi_2)) \end{aligned} \tag{2}$$

Equation 2 demonstrates the formula used to track angle difference in the direction between two points. As the curvature becomes more intense the road curvature is identified as potentially more dangerous than others. The intensity of forces while driving inside curvatures is monitored using the intensity of the accelerometer vector, equation 3.

$$Intensity = \sqrt{Acc_x^2 + Acc_y^2 + Acc_z^2} \quad (3)$$

The indicator analysis uses a three level classification scheme based on the statistical occurrence of the indicator value being accessed. For the classification definition, quartiles are used as a mean to identify outlier data in each indicator and classify it differently. Consequently the procedure adopted was to order the sample data records and classify data between the 80-95% quartile as yellow events, the data above the 95% quartile as red events and the rest as green events. This leads to the assumption that most drivers will have an adequate driving style for the most of their trips. In table 1 it is presented, the classification for each indicator represented in this paper.

C. Driving Profile

The usage of roads can be affected by driver's driving patterns. It is accepted that some drivers have a predisposition to drive more aggressively than others and there are significant deviations in their behaviors. Our approach uses this thought to gather the driving records from a community of users to classify different driving patterns to different people and link that data geographically in later analysis. The driving profile is based on the indicator defined in this papers plus attributes that respect directly to the person's driving profile. Thus the list of driving attributes considers the indicator plus the list of attributes:

- Time of day;
- Trip average duration;
- Standard deviation of trip duration;
- Average maximum and minimum velocity per trip;
- Number of cars driven.

With those measures, a complete profile can be designed and executed in applications that monitor current driver's performance. In [26], [27] other parameters were used to collect data from ordinary drivers in real traffic situations, such as wheel rotation, engine speed, ambient temperature, use of breaks and fuel consumption. In these studies, GPS data was also monitored, where each driving pattern was attributed to street type, street function, street width, traffic flow and codes for location in the city (central, semi-central, peripheral). It was concluded that the street type had the most influence on the driving pattern. The analysis of the 62 primary calculated parameters, resulted in 16 independent driving pattern factors, each describing a certain dimension of the driving pattern. When investigating the effect of the independent driving pattern factors on exhaust emissions, and on fuel consumption, it was found that there already studies with a common number of factors amongst the literature. Due to the decision to implement a pervasive system over mobile sensorization the work here described will account the attributes that are able to be collected by smartphone applications.

While these attributes characterize driving in a long term analysis, such strategy might miss spontaneous events that occur sporadically. An example of such is a sudden break with high intensity. In order to deal with these one-off events, other attributes are of relevance:

- Force exerted in the car;
- Slope of the line connecting initial to final velocity during breaking and accelerating events;
- Degree of the curvature of the road and force exacted in the car.

It is important to stress that these attributes are already accounted in the driving profile because they are also defined as indicators in the PHESS platform.

D. City Analysis

The usage of roads can be affected by driver's driving patterns. It is accepted that, if the majority of drivers have a predisposition to drive more aggressively in certain areas than others, then those areas are more dangerous. Our approach uses this thought to gather the driving records from a community of users and use them to calculate potential hazardous spots inside cities. Most evaluations are made using standard driving attributes, matured in the literature over a number of studies across different authors and projects. This kind of analysis is only possible with a dedicated user community that constantly updates and makes use of the platform supporting these models.

There is information that is dependent on external conditions of traffic and not related with driving itself. The platform developed will try to assess external condition using context estimation from the data gathered. The strategy employed uses indicator data linked with geographical data to define such context information. The indicator data is aggregated over a squares of geographical regions and their average value is computed. The granularity of the assessment is dependent on the size of the squared region. Nevertheless, such approach with an appropriate level of granularity is able to assess regions with high congestions rates or with high average speed, as an example. In this case, the velocity recorded by users is aggregated inside each square of terrain. The same analysis is available for other indicators in this systems and displayed in the same manner. Value added information produced in the system is published using a range of public web services. These web services provide public information about current traffic and driving conditions as well as, modelling analysis based on the historical data available in the platform.

Aside from driving study, other analysis can be made with the help of context conditions. Such conditions include weather, traffic congestion and time of day, for instance. Each example can have significant influence on the safety and on the assessment of attributes related to driving. Aggressiveness and dangerous behavior has different meanings in any of these conditions and while some concepts are broad enough to be used by all, others are situation specific meaning that what is dangerous in one situation might not be in another. Usually, driving patterns are defined and associated to the speed profile of the driver, but it can be expanded to other variables, as gear changing, and big changes on the acceleration [27]. Experiments with communities are often used to provide real time analysis of geographic conditions and events, with examples of such in the Waze platform [14]. However, they are the lacking features of historic analysis and historical supported suggestions.

The aim of this work is to focus on intangible and soft attributes which we define as attributes that are not directly observed by data records but rather computed with techniques from static analysis and machine learning processes. Such attributes should be used to find hidden patterns of road usage that might be missed in standard traffic flow simulations. Examples of such errors in simulation include driving aggravation due to unforeseen events even with normal traffic conditions.

IV. Analysis and Discussion of Study Results

Although this work is not using the internal data from vehicle sensor system as in past research [26], the approach followed in this work uses smartphone data for ubiquitous and pervasive monitoring. Data gathering is made through sensors, which is pre-processed internally with data fusion methodologies to enrich data and provide richer information. The number of variables used to assess driving patterns is based on the indicators and driving profiles defined.

Using indicator assessment over normal car trips in the system it is possible to take note on each point detected by the GPS sensor the indicator classification. An example of such mechanism is present in figure 3.

Each view can be personalized taking into account all indicators or a subset of them according to their interest to the analysis. Using the indicator classification it is also possible to assess whether or not there are dangerous systematic behavior in each driver's driving profile. Such task may be accomplished by assessing each indicator present in the profile. Other approach would be to directly compare driver's inside the community by their driving profile attributes.

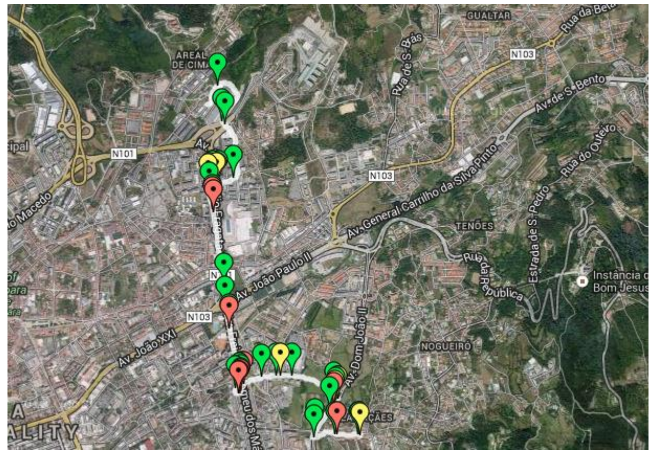

Fig. 3. Event Detection Based on Indictor Analysis

The model described in this article was tested as a complimentary module to a sustainability framework PHESS. Its aims are to produce and generate knowledge that can be used to perform decisions and suggestions that have a direct impact on sustainability and the sustainability of user's actions. More than a responsibility framework, it is intended to increase awareness to sustainable problems that arise from user's own actions and road usage by drivers.

Taking into consideration a test city with a community of 10 users, it is possible to assess the sample metrics and indicators defined. Using the strategy described in the section city analysis a demonstrative example of the region grid classification of indicator is made in figure 4. In order to analyze the classification and demonstrate that the scale has been appropriated to detect a small but significant set of yellow and red events. Such detection mechanisms can be improved with more technical data about dangerous events or even adjust the quartiles used for classification, nevertheless the proposed approach provides satisfactory results.

Each event is characterized in the map, and for the user it is possible to see the information relevant to that assessment. On the other hand, figure 4 does not provide event level explanation but rather a set of filters with each indicator defined that may alter the map zone classifications according to whether or not they are selected.

The map covered by the identification of low and high average speed squares is within the expected range but varies according the time of day, however the location of squares is preserved although with different averages. Our approach, identifies such metrics on daily basis but the identified spots are within 10% to 15% of the visible map.

As with the analysis on figure 3, the analysis present in figure 4 may only include a subset of indicators in its representation thus simplifying the analysis of the map.

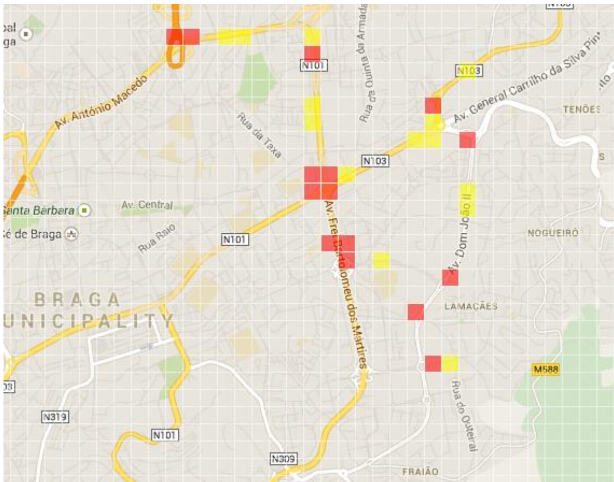

Fig. 4. Region Analysis

The results provided are based on web services which take information from the central distributed system to deliver information to graphical tools that display the information. In this case standard webpages were used.

While the results are satisfactory, future development should improve the social dimension of sustainable driving defining indicator directly associated with driver actions and emotions.

V. Conclusion

The use of pervasive devices already adopted by communities of users possess enough information and computing ability to build collaborative systems to tackle complex tasks. City traffic evaluation is one of such problems that are costly to audit and diagnose structural problem but can be simplified with crowd computing. Results are seem as satisfactory are reliable with the possibility to adjust according to specifics needs or needed improvement. The use of mobile sensors does constitute an additional effort to mitigate external influences such user involuntary movement, measurement and coverage errors. Nevertheless, the outputs generated in this platform were also found of relevance to the study of sustainability, where the intangible metrics and the structures employed to the indicator analysis pave the way to building sustainability assessing indicators able to join general purpose sustainability assessment frameworks such as the platform PHESS in discussion in this work.

In future iterations there are plan to update from grid analysis to road detection and road analysis becoming more accurate. Also, the validation of experiments on other cities are planned in order to prove both resilience and adaptation of the system. Integration of metrics found by this platform in common navigation systems are planned on the long term project, thus influencing routing options of people and acting as a true pervasive and ubiquitous object directing people away from dangerous situations into more comfortable and safe environments

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Fábio Silva obtained an MSc in degree in Informatics Engineering in 2011 from the University of Minho in Braga, Portugal. Currently, he is working towards his Ph.D. in Informatics at the University of Minho, Portugal. His current research interests include, Computational Sustainability, Energetic Efficient Systems and Multi-Agent Support Systems.

Cesar Analide is a Professor at the Department of Informatics of the University of Minho and a researcher and founder member of ISLab - Intelligent Systems Laboratory, a branch of the research center CCTC - Computer Science and Technology Center. His main interests are in the areas of knowledge representation, intelligent agents and multiagent systems, and sensorization.

Paulo Novais is an Associate Professor of Computer Sciences at the Department of Informatics, in the University of Minho, Braga, Portugal and researcher at the Computer Science and Technology Center (CCTC) in which he is the coordinator of the Intelligent Systems Lab. From the same university, he received a PhD in Computer Sciences in 2003 and his Habilitation in Computer Sciences in 2011. He develops scientific research in the field of Artificial Intelligence, namely Knowledge Representation and Reasoning, Machine Learning and Multi-Agent Systems, with applications to the areas of Law and Ambient Intelligence.

Neural Networks through Shared Maps in Mobile Devices

William Raveane, María Angélica González Arrieta,

Universidad de Salmanca, Spain

***Abstract* — We introduce a hybrid system composed of a convolutional neural network and a discrete graphical model for image recognition. This system improves upon traditional sliding window techniques for analysis of an image larger than the training data by effectively processing the full input scene through the neural network in less time. The final result is then inferred from the neural network output through energy minimization to reach a more precize localization than what traditional maximum value class comparisons yield. These results are apt for applying this process in a mobile device for real time image recognition.**

***Keywords* — Computer vision, Image recognition, Deep neural networks, Graphical models, Mobile device.**

I. INTRODUCTION

HYBRIFD intelligent systems have consistently shown benefits that outperform those of their individual components in many tasks, especially when used along neural computing [1]. In recent years, two main areas of computer vision have gained considerable strength and support: On one side, soft computing techniques based on non-exact but very accurate machine learning models like neural networks, which have been successful for high level image classification [7]. Contrasting these systems, computer vision techniques modeled by graphical models have enjoyed great reception when performing low level image processing tasks such as image completion [6]. In this paper, we combine both of these techniques to successfully classify and localize a region of interest within an input image.

We use Convolutional Neural Networks (CNN) [3] for the classification of image content. CNNs have become a general solution for image recognition with variable input data, as their results have outclassed other machine learning approaches in large scale image recognition tasks [4]. Paired to this CNN classifier, we use energy minimization of a Markov Random Field (MRF) [8] for inference and localization of the target within the image space. Graphical models such as this have been implemented in areas of computer vision where the relationship between neighboring regions plays a crucial role [2].

We review the implementation of this system specifically within a mobile device. With the increasing use of mobile hardware, it has become a priority to provide these devices with computer vision capabilities. Due to the high computational requirements, this need has mostly been met by outsourcing the analysis to a remote server over the Internet. This approach introduces large delays and is hardly appropriate when interactivity and responsiveness are paramount. Embedded environments have intrinsic architecture constraints which require algorithms to make the best use of the available computing capacity. The proposed system exploits this specific platform by reducing the overall required memory throughput via a parallel execution approach. This is achieved by applying layer computations over the entire image space, as opposed to running smaller patches individually, as is common with the sliding window approach normally used in this type of image classification.

The structure of this work is as follows: In Section 2, some background knowledge is reviewed detailing the functionality of CNNs and window analysis in general. We then introduce in Section 3 an optimized approach for the techniques previously discussed, including the architecture constraints that must be made to implement the proposed system. Section 4 goes over the discretization of the system and the inference process for obtaining the final output result. Section 5 continues with the results obtained from the proposed method and a brief comparison with other alternative approaches. Finally, Section 6 concludes by discussing the observations made and some additional applications where this system can be used in.

II. BACKGROUND

In this section, a brief description of CNNs and their layer types is given, as well as an overview of the traditional sliding window approach.

A. Convolutional Neural Networks

The network on which our system is based upon is a standard CNN. Figure 1 depicts the layer structure of such a network, and it is the reference architecture used throughout this paper to describe the concepts of the framework presented.

In the initial stages of the CNN, a neuron consists of a two-dimensional grid of independent computing units, each producing an output value. As a result, every neuron will itself output a grid of numerical values, a data structure in $\Re^2$ referred to as a map. When applying CNNs to image analysis, these

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maps represent an internal state of the imageafter being processed through a connective path leading to that particular neuron. Consequently, maps will usually bear a direct positional and feature-wise relationship to the input image space. As data progresses through the network,

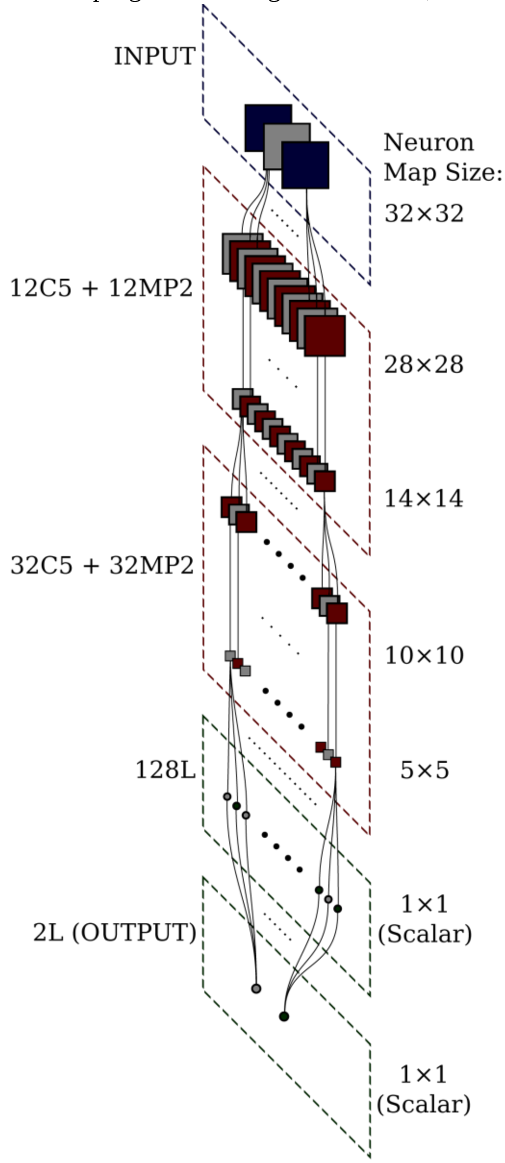

Fig. 1. A typical convolutional neural network architecture, with three input neurons for each color channel of an analyzed image patch, two feature extraction stages of convolutional and max-pooling layers, and two linear layers to produce a final one-vs-all classification output.

however, this representation turns more abstract as the dimensionality is reduced. Eventually, these maps are passed through one or more linear classifiers, layers consisting of traditional single unit neurons which output a single value each. For consistency, the outputs of these neurons are treated as1×1single pixel image maps, although they are nothing more than scalar values in$\Re^0$.

B. CNN Layer Types

The first layer in the network consists of the image data to be analyzed, usually composed as the three color channels. The notation$N_j X K_j$is used to describe all subsequent layers, where$N_j$is the neuron map count of layer$j$, $X \in \{C, MP, L\}$denotes the layer type group (Convolutional, Max-Pooling, and Linear), and$K_j$is the parameter value for that layer.

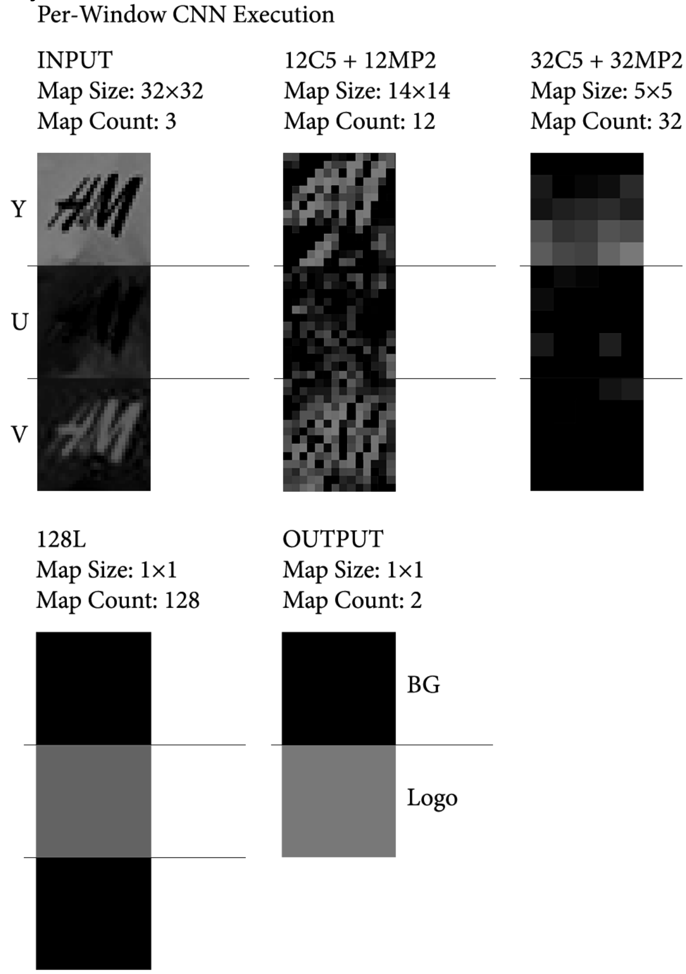

Fig. 2. Visualization of the first three neuron maps at each stage of the CNN. Note the data size reduction induced at each stage. The output of this execution consists of two scalar values, each one representing the likelihood that the analyzed input image belongs to that neuron's corresponding class. In this case the logo has been successfully recognized by the higher valued output neuron for class "Logo".

The first part of every$C \rightarrow MP$feature extraction stage is a convolutional layer. Here, each neuron linearly combines the convolution of one or more preceding maps. The result is a map slightly smaller than the input size by an amount known as the kernel padding, which arises from the boundary conditions of the valid convolution algorithm. It is defined as $(K_j/2) - 1$, where $K_j$is the convolutional kernel size of layer$j$. Therefore, the layer's map size will be given by$M_j = M_{j-1} - (K_j/2) - 1$, where $M_{j-1}$is the the preceding layer's map size.

A max-pooling neuron acts on a single map from a preceding convolutional neuron, and its task is to subsample a pooled region of size K_j. The result is a map size that is inversely proportional to said parameter by $M_j = M_{j-1}/K_j$. The data may then be passed to one or more additional $C \rightarrow MP$ feature extractors.

Linear layers classify feature maps extracted on preceding layers through a linear combination as in a perceptron -- always working with scalar values -- such that $M_j = 1$ at every layer of this type.

Finally, the output of the final classification layer decides the best matching label describing the input image. Fig. 2 shows the information flow leading to this classification for a given image patch, where the CNN has been trained to identify a particular company logo.

C. The Sliding Window Method

Recognition of images larger than the CNN input size is achieved by the sliding window approach. This algorithm is defined by two quantities, the window size S, usually fixed to match the CNN's designed input size; and the window stride T, which specifies the distance at which consecutive windows are spaced apart. This stride distance establishes the total number of windows analyzed W for a given input image. For an image of size $I_w \times I_h$, the window count is given by:

$$W = (\frac{I_w - S}{T} + 1)(\frac{I_h - S}{T} + 1) \rightarrow W \propto \frac{I_w I_h}{T^2}$$

Figure 3 shows this method applied on an input image downsampled to 144×92, extracting windows of $S = 32$ for the simple case where $T = S/2$. A network analyzing this image would require 40 executions to fully analyze all extracted windows. The computational requirement is further compounded when a smaller stride is selected -- an action necessary to improve the resolving power of the classifier: at $T = S/8$, 464 separate CNN executions would be required.

Fig. 3. An overview of the sliding window method, where an input image is subdivided into smaller overlapping image patches, each being individually analyzed by a CNN. A classification result is then obtained for each individual window.

III. Optimized Network Execution

The method proposed introduces a framework where the stride has no significant impact on the execution time of the $C \rightarrow MP$ stages, as long as the selected stride is among a constrained set of possible values. This is achieved by allowing layers to process the full image as a single shared map instead of individual windows. Constraints in the possible stride values will result in pixel calculations to be correctly aligned throughout the layers.

A. Shared Window Maps

CNNs have a built-in positional tolerance due to the reuse of the same convolutional kernels over the entire neuron map. As a result of this behavior, their output is independent of any pixel offset within the map, such that overlapping windows will share convolved values. This is demonstrated in Fig. 4.

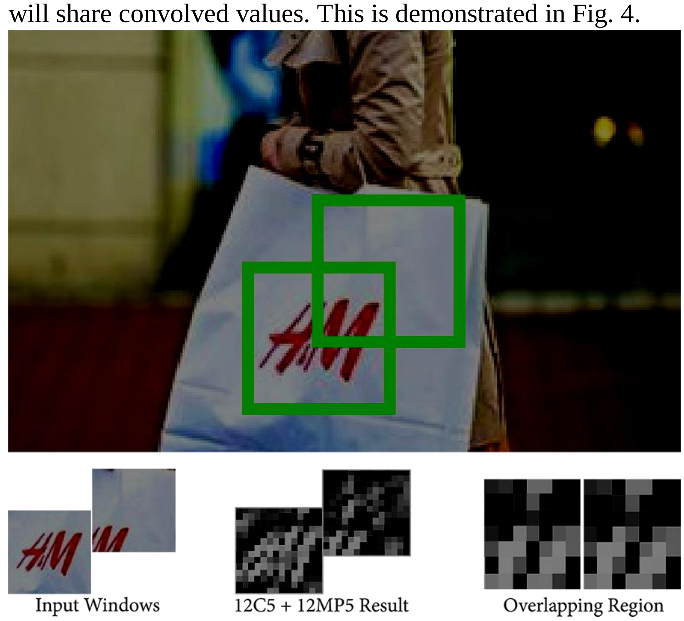

Fig. 4. Two adjacent windows extracted from an input image, passed through the 12C5 + 12MP5 feature extractor. A detailed view of the convolved maps in the overlapping top-right and bottom-left quarters of each window shows that these areas fully match.

This leads to the possibility of streamlining the feature extractors by running their algorithms over the full input image at once. Hence, each $C \rightarrow MP$ neuron will output a single map shared among all windows, where subdivisions of this map would normally match the outputs of the corresponding windows, had they been executed separately as in the traditional method. This greatly reduces the expense of calculating again convolutions on overlapping regions of each window. Figure 5 shows an overview of the shared map process, which passes the input image in its entirety through each stage of the network.

By doing this, the output layer now produces a continuous and localized class distribution over the image space, a result which contrasts greatly to that of a single classification value as was previously seen in Fig. 2. The output of this execution consists of image maps where each pixel yields the relative position of all simultaneously classified windows.

Similar to the per-window execution method, the intensity value of a pixel in the output map represents the classification likelihood of the corresponding window. Note how the relative position of the logo in the input image has been discovered after only one shared map execution of the network. An account of the window size and stride is also on

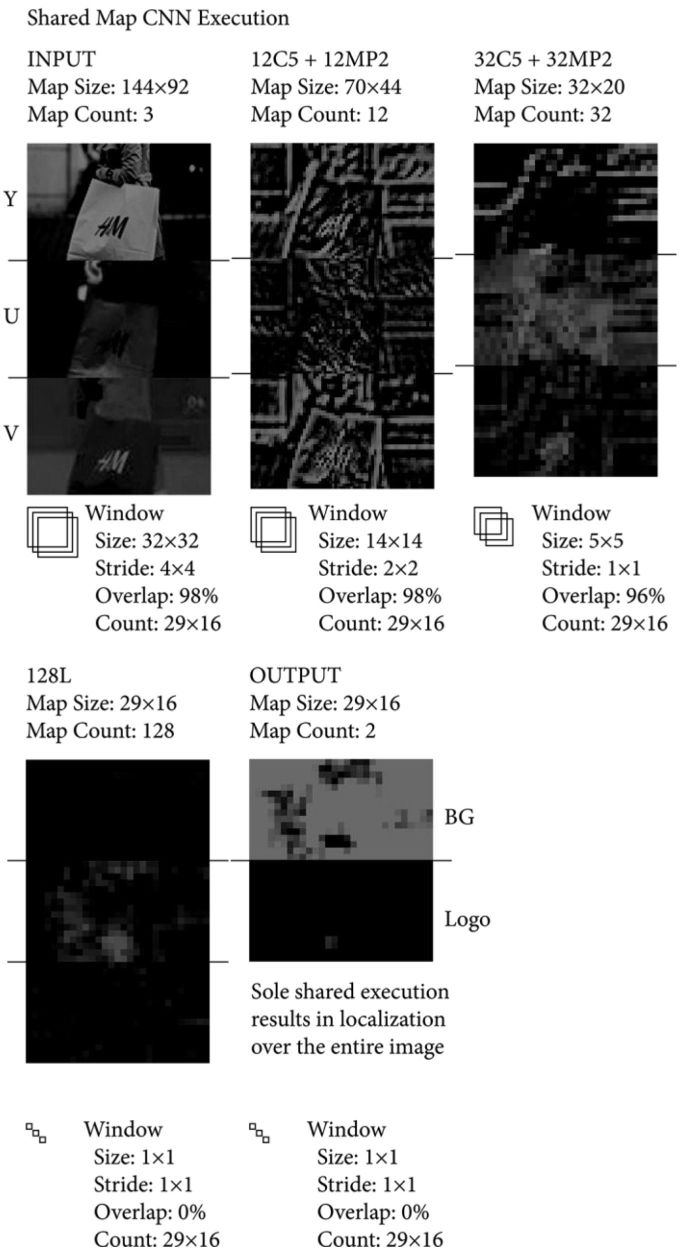

Fig. 5. The shared map execution method for a convolutional neural network, where each layer processes an entire image in a single pass, and each neuron is now able to process maps with dimensions that far exceed the layer's designed input size.

display, illustrating how it evolves after each layer, while the total window count remains the same. Here, the correspondence of each 32×32 window in the input image can be traced to each one of the pixels in the output maps.

B. Window Configuration

The operation of the shared map process relies greatly on the details of the dimensionality reduction occurring at each layer within the network. For this reason, it is necessary to lay certain constraints that must be enforced when choosing the optimum sliding window stride.

At each layer, the window size and stride are reduced until

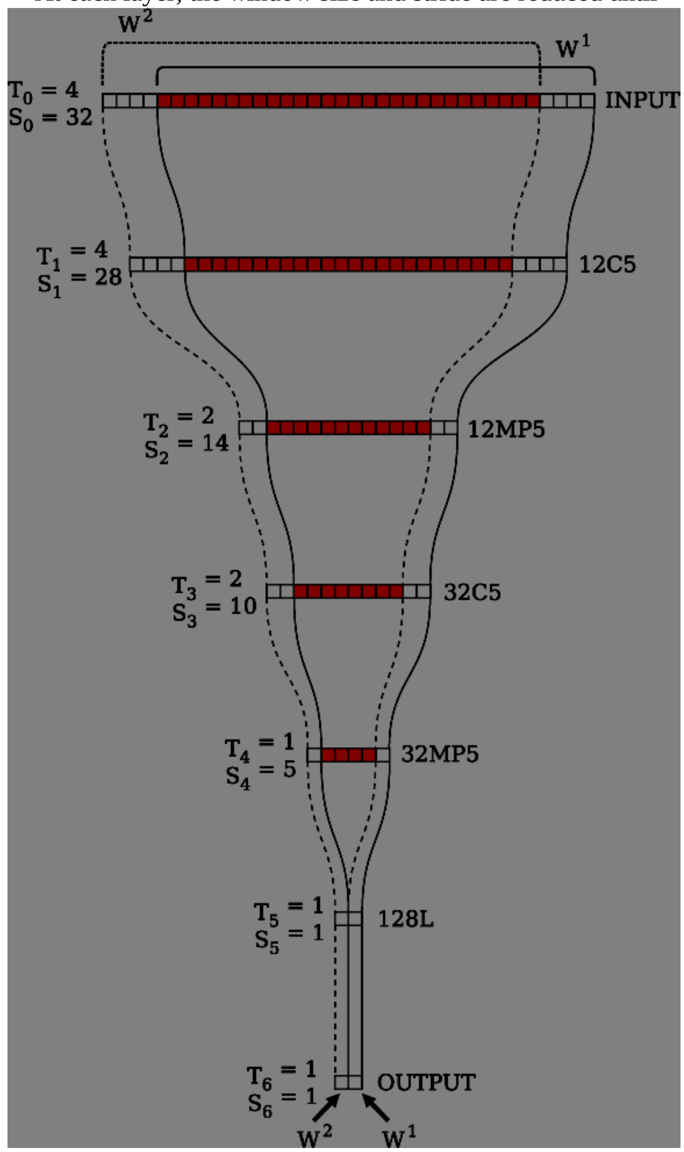

Fig. 6. The CNN layers and their effect on the window pixel space, illustrated in
one dimension for simplicity. Two successive 32×32 windows W^1 and W^2 are shown. Overlapping pixels at each layer are shaded. Starting with an input layer window stride $T_0 = 4$, the final output layer results in a packed $T_6 = 1$ window stride, so that each output map pixel corresponds to a positional shift of 4 pixels in the input windows, a relationship depicted by the column paths traversing all layers.

they eventually become single pixel values at the final linear layers. The amount of reduction at each stage varies according to the type of the layer and its parameters. All of these quantities can be found in a well defined manner as given by:

$$S_j = \begin{cases} S_{j-1} - K_j - 1 & if j \in C \\ S_{j-1}/K_j & if j \in MP \\ S_{j-1} & if j \in L \end{cases}$$

$$T_j = \begin{cases} T_{j-1} & if j \in C \cup L \\ T_{j-1}/K_j & if j \in MP \end{cases}$$

Where the window size S_j and its stride T_j at layer j depends on the various parameters K_j of the layer and the window size and stride values at the preceding $j-1$ layer. This equation set can be applied over the total number of layers of the network, while keeping as the target constraint that the final size and stride must remain whole integer values. By regressing these calculations back to the input layer $j = 0$, one can find that the single remaining constraint at that layer is given by:

$$T_0 \equiv a \prod_{j \in MP} K_j where a \in \mathbb{Z}$$

In other words, the input window stride must be perfectly divisible by the product of the pooling size of all max-pooling layers in the network. Choosing the initial window stride in this manner, will ensure that every pixel in the final output map is correctly aligned throughout all shared maps and corresponds to exactly one input window. Fig. 6 follows the evolution of the window image data along the various layers of the sample network architecture, showing this pixel alignment throughout the CNN.

IV. Discrete Inference of CNN Output

The output from the convolutional neural network as seen in Fig. 5 consists of multiple individual maps, where each one embodies a visual depiction of the relative confidence, per-class, that the system has for every window sampled.

The common practice to obtain a final classification from an output value set as seen in Fig. 5 is to identify which class has a higher output value from the CNN at each each window (here, each pixel in the output map). While efficient, results from this procedure are not always ideal because they only take into account each window separately.

Furthermore, maximum value inference is prone to false positives over the full image area. Due to their non-exact nature, neural network accuracy can decrease by finding patterns in random stimuli which eventually trigger neurons in the final classification layer. However, such occurrences tend to appear in isolation around other successfully classified image regions. It is therefore possible to improve the performance of the classifier by taking into account nearby windows.

There exist many statistical approaches in which this can be implemented, such as (i) influencing the value of each window by a weighted average of neighboring windows, or (ii) boosting output values by the presence of similarly classified windows in the surrounding area. However, we propose discrete energy minimization through belief propagation as a more general method to determine the final classification within a set of CNN output maps. The main reason being that graphical models are more flexible in adapting to image conditions and can usually converge on a globally optimal solution.

A. Pairwise Markov Random Field Model

Images can be treated as an undirected cyclical graph $G = (N, E)$, where nodes $n_i \in N$ represent an entity such as a pixel in the image, and graph edges $e_{ij} \in E$ represent the relationship between these nodes. If, for simplicity, 4-connectivity is used to represent the relationship between successive nodes in a graph; then each node will be connected to four others corresponding to its neighbors above, below, and to each side of the current element.

The output space of the convolutional neural network can therefore be represented in this manner through a graph. However, instead of describing pixel intensity values, each node in the graph represents the classification state of the corresponding window. This state takes on a discrete value among a set of class labels $c \in CL \equiv \{BG, Logo\}$ corresponding to the classification targets of the CNN. Thus, each node in the graph can take on one of several discrete values, expressing the predicted class of the window that the node represents. Fig. 7 displays the structure of such a graph.

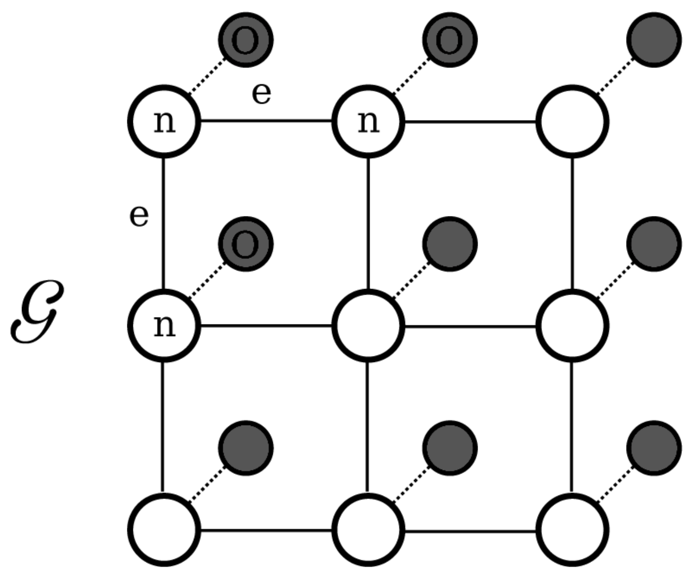

Fig. 7. A subset of the MRF graph G formed by the CNN output space, where each node n_i represents the classification state of a corresponding window analyzed with the network, whose outputs are implemented into this system as the observed hidden variables O. Nodes have a 4-connectivity relationship with each other represented by the edges e_{ij} thus forming a grid-like cyclical graph.

It can be seen that if nodes represent classification outcomes, there is a strong relationship between them. The reason is that continuity throughout a map tends to be preserved over neighboring regions due to strong local correlation in in input images. This inflicts a Markovian property in the graph nodes where there is a dependency between successive nodes. Therefore, this graph follows the same structure as an MRF, and any operations available to this kind of structure will be likewise applicable to the output map.

B. Energy Allocation

To implement energy minimization on an MRF, it is necessary to assign energy potentials to each node and edge. These energies are usually adapted from observed variables, and in this case, they correspond to the values of the output maps and combinations thereof. Therefore, MRF optimization over a graph G can be carried out by minimizing its Markov random energy R, given by:

$$R(G) = R(N, E) = \sum_{n_i \in N} \theta_i(n_i) + \sum_{e_{ij} \in E} \theta_{ij}(e_{ij})$$

Here, $\theta_i(\circ)$ corresponds to the singleton energy potential of node n_i, and $\theta_{ij}(\circ)$ is a pairwise potential between nodes n_i and n_j. Starting from the CNN output map observations, the singleton potentials can be assigned as:

$$\theta_i = \begin{bmatrix} \omega_i^0 \\ \omega_i^1 \\ \vdots \\ \omega_i^l \end{bmatrix}$$

$$\omega_i^a = \sum_{c \in C} \begin{Bmatrix} 1 - (O_i^c)^2 & if\, a = c \\ (O_i^c)^2 & otherwise \end{Bmatrix}$$

Where l is the total number of classes in set CL (2 in the sample CNN architecture), and O_i^c is the observed CNN value for window $n_i \in N$ and class $c \in CL$. In this manner, each ω_i^a value is an MSE-like metric that measures how far off from ideal training target values did the CNN classify window n_i as. Thus, a lower potential value will be assigned to the most likely class, while a higher potential value will be given to other possible classes at this node.

Pairwise potentials can be defined as:

$$\theta_{ij} = \begin{bmatrix} \delta_{ij}^{00} & \delta_{ij}^{01} & \cdots & \delta_{ij}^{0c} \\ \delta_{ij}^{10} & \delta_{ij}^{11} & & \delta_{ij}^{1l} \\ \vdots & & \ddots & \\ \delta_{ij}^{l0} & \delta_{ij}^{l1} & & \delta_{ij}^{ll} \end{bmatrix}$$

$$\delta_{ij}^{ab} = |O_i^a - O_j^b|$$

Where each value δ_{ij}^{ab} is a straightforward distance metric that measures the *jump* in CNN output values when switching from class a to class b between windows n_i and n_j. Thus, these potentials will be small if the same class is assigned to both nodes, and large otherwise. Fig. 8 shows all energy assignments per node pair.

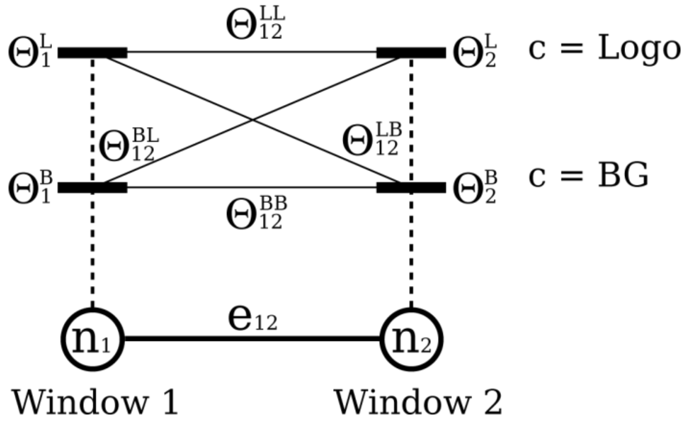

Fig. 8. A detail of the potential energies assigned to each of two nodes {n_1, n_2} connected by edge e_{12}. The singleton potentials Θ_i^a correspond to the energy associated with node i if assigned to class a, and the pairwise potentials Θ_{ij}^{ab} are the changes in energy that occur by assigning class a to node n_i and class b to node n_j.

It is worth noting that these θ_{ij} pairwise potentials between neighboring windows (nodes) are the only feature that sets apart this process from the traditional winner-takes-all approach which would otherwise be implemented through the minimization of the energy in the θ_i singleton potentials by themselves.

C. Energy Minimization by Belief Propagation

Applying Belief Propagation [5] to find the lowest possible energy state of the graph will now yield an equilibrium of class assignments throughout the image output space.

Due to the cycles inherent of image-bound graphs, a special variation of the algorithm must be used, in this case Loopy Belief Propagation [5]. This variation requires the minimization to be run several times until the solution converges and an equilibrium is found. However, due to various existing optimizations for this algorithm, this process is very straightforward and can be solved in polynomial time.

V. Results

The test application is developed for the Android mobile OS as an OpenGL ES shader which makes use of the available computing capabilities of the device GPU. The main logic of the system is placed within a fragment shader running the CNN per-pixel over a Surface Texture memory object. The test device is equipped with a quad core 1.3 GHz Cortex-A9 CPU with a 12-core 520 MHz Tegra 3 GPU. This SoC architecture embeds 1 Gb of DDR2 RAM shared by both the CPU and GPU.

The test system executes the same CNN architecture described in Fig. 1, except for the classification layer having 32 output neurons corresponding to one background label and 31 different logo labels. This network is exectued over 8 simultaneous 144×92 images forming a multi-scale image pyramid. The energy minimization technique as described in Section 4 is then applied, but over a 3D graph formed with 6-

connectivity between nodes such that each window is also aware of window classifications at the corresponding larger and smaller scale steps. Table 1 gives a summary of the results obtained from this setup.

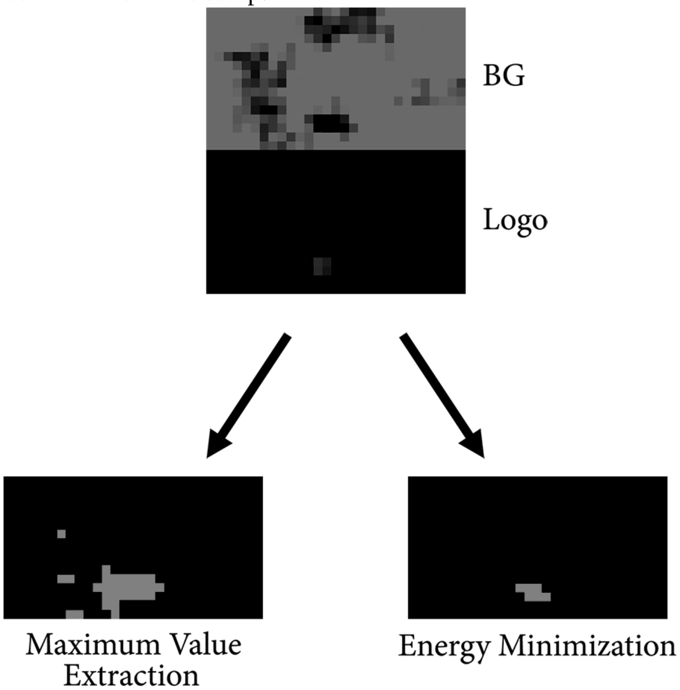

Fig. 9. Comparison of the final “Logo” classification and localization, applying the classical maximum value per class extraction vs. our proposed energy minimization inference method on the two CNN output maps introduced in Figure 5

It is of great interest to note the final 32×32 configuration. Regardless of the fact that there is no overlap at this stride, a 3.0 speedup is still observed over running the windows individually. This is due to the inherent reduction in memory bandwidth through the system's pipelined execution approach, where the entire image needs to be loaded only once per execution. This contrasts the traditional approach where loading separate windows into memory at different times requires each to be individually sliced from the original memory block -- a very expensive operation in the limited memory throughput of mobile devices.

Server platforms have a restriction in the PCIe bus speed between the CPU and GPU, but instead offer very fast local memory access within the GPU. As a result, these architectures would allow window extraction at lower relative latencies. The SoC architecture of mobile devices do not face similar CPU to GPU memory bottlenecks, as these chips are usually located within the same circuit. Their lower energy requirements, however, force local memory access to be radically slower. Therefore, this architecture favors the parallel usage of data blocks, a fact which the system we have presented exploits in full. As such, we consider it to be a mobile-first oriented algorithm, although it would offer likewise improvements in other platforms.

The results of the inference system are more of a qualitative nature, as it is difficult to objectively establish a ground truth

TABLE I
SPEEDUP RESULTS

T_0	W (L)	W (P)	OC	T (PW)	T (SM)	Speedup
4×4	464	3,712	98%	29,730	1,047	28.4x
8×8	112	896	94%	7,211	387	18.6x
12×12	60	480	86%	3,798	311	12.2x
16×16	32	256	75%	2,051	240	8.5x
20×20	24	192	61%	1,536	252	6.1x
24×24	15	120	44%	945	203	4.7x
28×28	15	120	23%	949	200	4.7x
32×32	8	64	0%	514	171	3.0x

Results of tests with several input layer stride T_0 configurations, from the closest packed 4×4 to the non-overlapping 32×32 layouts. A total window count at each pyramid level W (L), and over the full 8 level pyramid W (P), as well as the window overlap coverage OC per input map is given for each of the stride selections. An average over 20 test runs for each of these configurations was taken as the execution time in milliseconds for each of the methods described herein – the traditional per-window execution method T (PW), and our shared map technique T (SM). A speedup factor is calculated showing the performance improvement of our method over the other.

TABLE II
INFERENCE RESULTS

Algorithm	Accuracy	PPV	F_1
Maximum Value	0.942	0.341	0.498
Weighted Average	0.964	0.391	0.430
Neighbor Boosting	0.972	0.489	0.591
Energy Minimization	0.981	0.747	0.694

Results of various inference algorithms for the final classification, describing the Accuracy (TP + TN / ALL), PPV (TP / TP + FP), and F_1 (2TP / 2TP + FP + FN) metrics.

basis for such experiments. This system aims to localize classified windows, therefore it is subject to an interpretation of which windows cover enough of the recognition target to be counted as a true positive. Regardless, Table 2 gives an indicative comparison of the system against the competing techniques previousy described. Fig. 9 shows a visual comparison.

VI. CONCLUSIONS

A system for the optimization of convolutional neural networks has been presented for the particular application of mobile image recognition. The performance figures presented in Table 1 correspond to a device architecture which, at the time of this work, is a commonly available specification on end user devices. It must be noted that with the rapid growth that is being observed in mobile hardware capabilities, the effects of these optimizations are likely to grow in their significance. GPUs capable of new technology will extend the reach of the parallel-wise optimizations described. Relevant advancements in this area would include things such as heterogeneous parallel processing via OpenCL EP and zero-copy memory transfer between the camera and GPU through tighter SoC integration. General availability of such technologies will open an ever larger possibility of mobile computer vision opportunities.

Although a simple logo classification task was used here as a sample application, CNNs allow for many other image recognition tasks to be carried out. Most of these processes would have great impact on end users if implemented as real time mobile applications. Some examples where CNNs have been successfully used and their possible mobile implementations would be (i) text recognition for visually interactive language translators, (ii) human action recognition for increased user interactivity in social applications, or even (iii) traffic sign recognition for embedded automotive applications. Any of these applications could be similarly optimized and discretized by the system presented here.

In addition to the CNN classifier, the MRF model is very flexible as well and its implementation can be adjusted to domain-specific requirements as needed by each application. For example, a visual text recognizer might implement pairwise energy potentials which are modeled with the probabilistic distribution of character bigrams or n-grams over a corpus of text, thereby increasing the overall text recognition accuracy.

Furthermore, although the analysis of a single image has been discussed, this system is similarly extensible to multiple images processed together. The most common example of this is the analysis of a multi-scale image pyramid, something vital within mobile applications as variable distances between the camera and its target will cause the object to be observed at different sizes within the analyzed image. In such a case, the MRF would be extended to a 6-connectivity 3D grid, where nodes would be equally aware of window classifications at the corresponding larger and smaller scale steps.

Therefore, we believe this to be a general purpose mobile computer vision framework which can be deployed for many different uses within the restrictions imposed by embedded hardware, but also encouraging the limitless possibilities of mobile applications.

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William Raveane is a Ph.D. candidate in Computer Engineering at the University of Salamanca, Spain, currently researching mobile image recognition through deep neural networks. He has also worked for several years in private companies in various topics ranging from computer vision to visual effects.

María Angélica González Arrieta is a professor at the Department of Computer Engineering and Automation at the University of Salamanca, Spain. Her research interests are primarily in pattern recognition and neural networks. She is also a member of the BISITE research group.

An Effective Approach for Mobile ad hoc Network via I-Watchdog Protocol

Nidhi Lal

Indian Institute of Information Technology

***Abstract* — Mobile ad hoc network (MANET) is now days become very famous due to their fixed infrastructure-less quality and dynamic nature. They contain a large number of nodes which are connected and communicated to each other in wireless nature. Mobile ad hoc network is a wireless technology that contains high mobility of nodes and does not depend on the background administrator for central authority, because they do not contain any infrastructure. Nodes of the MANET use radio wave for communication and having limited resources and limited computational power. The Topology of this network is changing very frequently because they are distributed in nature and self-configurable. Due to its wireless nature and lack of any central authority in the background, Mobile ad hoc networks are always vulnerable to some security issues and performance issues. The security imposes a huge impact on the performance of any network. Some of the security issues are black hole attack, flooding, wormhole attack etc. In this paper, we will discuss issues regarding low performance of Watchdog protocol used in the MANET and proposed an improved Watchdog mechanism, which is called by I-Watchdog protocol that overcomes the limitations of Watchdog protocol and gives high performance in terms of throughput, delay.**

***Keywords* - MANET; Watchdog; AODV; Black hole; RREP; RREQ; RRER; Malicious node; PDR; I-Watchdog; Sequence number.**

I. Introduction

IN the mid of 1990's, Mobile ad hoc network became very famous topic in the research area of networking. Mobile ad hoc network is a wireless technology and it does not hold any infrastructure; nodes in the MANET environment are dynamic in character and do not relay on any topology. They are scattered in nature and do not rely on any central authority. In a MANET, [11] each node can take responsibility of a router as well as take a role as a host. The nodes in the mobile ad hoc network are linking and Communicate with each other all the way through the usage of radio waves. [1]MANET supports fast establishing of networks so they encompass very high degree of flexibility, the only necessity is to provide a new set of nodes with some degree of wireless communication range. [17]If the nodes are within the same radio waves wireless communication rang than they can communicate directly otherwise they can communicate with their respective destination node with the help of intermediate nodes.

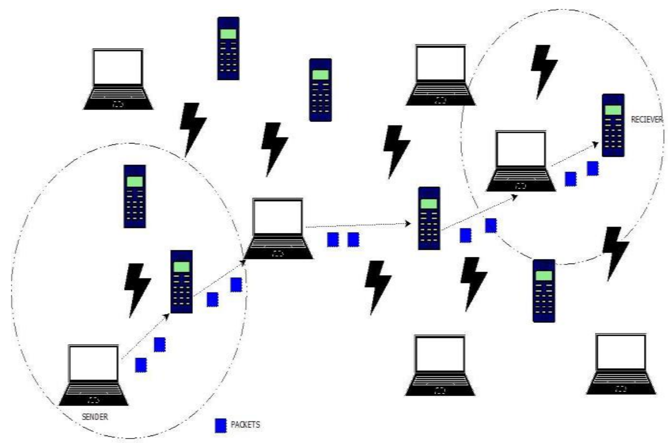

Fig 1. The sketch out of MANET

In the above figure, many numbers of nodes are in the network, in which, one is acting as a sender node and another one is the receiving node. Sender wishes to propel data packet to his subsequent receiving node. For initiating this communication, the sender can send these data packets via the help of intermediate nodes, which are within the communication range of the sender node. By following this strategy, the sender node sends all data packets to the respective receiver node. [2]There are various types of the mobile ad hoc networks, such like, vehicular ad hoc network (VANET) [12] that is used for making the communication between the vehicles, (IMANET) internet based mobile ad hoc networks which is used to link mobile nodes to network gateways and Tactical MANET which is used in the application of military. [3]Meant for routing of the packets among the mobile device nodes a routing protocol is obligatory. [37]The routing protocol should design and chooses in such a way that it provides high reliability, security, power efficient, avoid overhead and provide best quality of service as well as should consider the unidirectional links also. So by taking these points into account, there are various methodologies are proposed like, AODV, DSDV, DSR, CBRP. [4]AODV maintains route on the demand such that traffic of the network remain minimum and it uses distance sequence number for surety of the loop free route. [5] Security threats and packet loss due to transmission error are major

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challenges of the MANET. [18]Destination-Sequenced Distance-Vector Routing (DSDV) maintains a table for routing and follows the concept of bellman-ford algorithm, it is basically used to prevent the network from the formation of a loop. DSDV make sure that the network does not restrain any cycle or loop. DSDV has certain disadvantages like it is not power saving and does not worth for networks which are highly dynamic. [19]Dynamic Source Routing (DSR) is a source routing protocol which is similar to AODV but it does not contain latest updated information regarding the network therefore it leads to inconsistency in the routing tables. [20]A cluster-based routing protocol (CBRP) is a routing protocol in which, nodes of a network make a group and that group is called a cluster, after forming this cluster they uses a clustering algorithm to determine the cluster head among the nodes in that group. [30-32]A Mobile Location Aware Information System is also proposed for control of the presence of a non-intrusive by use of technologies which are based on the global positional system (GPS) and light weight indoor location system. [33-35]This technology can be used universally and applies very minimum cost. [5]Due to the decentralized environment of the MANET, they are constantly susceptible to black hole attack and the recital of the AODV routing protocol decrease. To triumph over this dilemma, Watchdog protocol with AODV is commenced which builds recognition of malicious nodes.

Watchdog protocol uses local information of the next hop node and overhears it. If it gets that it spending time of the packet is exceeded above the predefined threshold then it marks that node as malicious, this way Watchdog protocol detects malicious node in the network. [6, 10]Watchdog protocol has some disadvantages that it does not find link transmission error due to congestion in the network as well as it does not support high mobility of large number of nodes in the network and give a wrong report about the malicious node which eventually decreases the system throughput and performance. [7]Mobile ad hoc networks are more vulnerable to transmission errors than fixed wired network because of their wireless nature, environmental conditions, network congestion etc. In this paper, an improved Watchdog mechanism is presented which identifies the malicious node in the network as well as spots the network congestion. We give the name of this improved Watchdog protocol as I-Watchdog protocol. The proposed work is implemented in ns2-simulator and gives very high performance in terms of throughput, packet delivery ratio and end-to-end delay. Section-2 will describe the AODV protocol, Section-3 will introduce about some variety of security attacks, Section-4 describes the activity of black hole attack in the network, Section-5 will describe Watchdog protocol, Section-6 will introduce about proposed improved Watchdog protocol (I-Watchdog protocol) and section-7 is containing simulation parameters and Section-8 will contain comparison, results of Watchdog protocol and proposed improved Watchdog protocol.

II. AODV PROTOCOL

MANET applies Ad hoc On Demand Distance Vector (AODV) routing protocol for transmitting the packet from the source towards their particular target node. [8]AODV each point in time determine route when network wishes it. AODV bring into play route request message (RREQ) for creation the route request from source to target which enclose the distance sequence number. This communication is basically does neighbor discovery and it is broadcasting in nature. If the intermediary neighboring node have a path to the resultant destination, then it propels the route reply message (RREP) reverse to the source. If the intermediary adjacent nodes have no path to the destination then it generates reverse route entry towards the source and broadcast RREQ message to its neighbors. This course of action will be on recurrence until the destination route is not set up. Just the once the route is found to the target node then the RREP message is unicast from the current node to the source node and this RREP message include destination sequence number and hope count. Later than receiving the RREP message, source node brings up to date its routing table only in the provision when coming destination sequence number is bigger than the prior. Upon receiving on the several RREP, source opt for greater sequence number with smallest hop count and renew its routing table information. [22]In the AODV routing protocol, each adjacent node in the network background maintains track information about the status of the link by keeping an eye on the link and when there is found the splintering in link of the route then the RERR message is promoted by this node which detects the link breakage, to all the nodes in the network to broadcast this link status information. Figure 2 demonstrates the appearance of AODV routing protocol. Here, node marked by S represents a source node and node marked by D work as destination node.

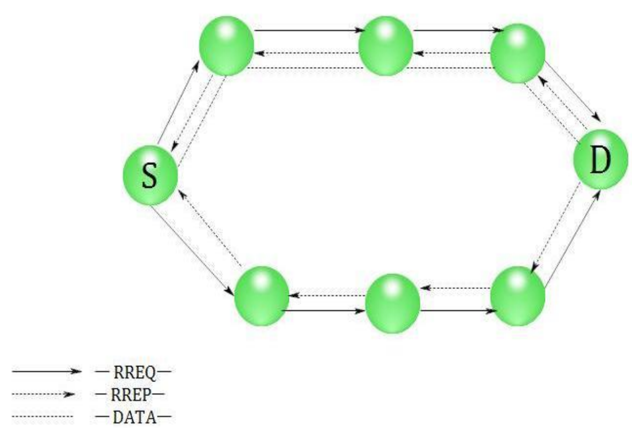

Fig: 2. AODV routing protocol method

III. VARIETY OF SECURITY ATTACKS

There is a range of attacks probable in MANET. [31] Because of the absence of any central authority and dynamic and distributed nature, mobile- ad hoc network environment can have a lot of security breaches and problems. Security does direct impact on the performance of the network because when the network is more secure then always there is a high possibility of successful transmission of packet from the sender to respective receiver. This will directly lead to high throughput and minimizes the end-to-end delay. But due to MANET is wireless in nature, there is always the possibility of attacks on the network. [21]A few of the security attacks are characterized below:

- BLACK HOLE ATTACK: In this attack, every packet which is sent out from the source towards the relevant target node, is dropping by black hole node. This attack is illustrated in detail in the section- IV
- PARTITION OF THE NETWORK: In this attack, a path is always present from the sender node to the respective receiver node, but nodes cannot communicate with each other.
- DENIAL OF SERVICE: In this attack, there is constraint on the nodes of a network for conveyance the packet as well as in receipt of the packet.
- SLEEP DEPRIVATION: [28, 36] In this attack, the nodes are forced to be sleeping, means to force for use its battery power.
- INFORMATION THEFT: [36] In this attack, the whole information which is reside inside the packet is read by unauthorized entity.
- INTRUSION: [36] In this attack, an unapproved person can have right to use services and those services are constrained to that entity.
- TAMPERING: [36] In this attack, Data is modified by an unauthorized entity.
- WORM HOLE ATTACK: [37] In this attack, basically the attacker node compromised with any host in the network and record the packet at one point of location and after tunneling to another location it again sends back to the network.

IV. BLACK HOLE ATTACK

MANET does not encompass any central authority and there is a lack of infrastructure so that is defenseless to black hole attack. The black hole attack is an attack on a network who hurriedly dwindle network performance by dropping the packets. [16]When a black hole node (malicious node) present in the network, it always advertises itself with the highest sequence number and minimum hop count. [23]Black hole node always tries to attract and capture the attention of the source node by ensuring them that it has the shortest path towards the destination node. The black hole attack is very dangerous in the network environment and it leads to the system to a denial of service (DOS) attack. When it obtains RREQ from the source node, it instantaneously propels RREP respond to the source enclose very large sequence number and lowest hop count. This is the nature of the black hole node that it tries to get attention in the network from source point of view, [17] that's why it advertises itself with very high sequence numbers. Upon receiving such RREP from this black hole node, source node thinks that it has valid fresh route to the destination because it have a high sequence number with minimum hope count and starts forwarding of data packets towards this black hole node. Upon receiving data packets, the black hole node drops all data packets and system performance degrades rapidly. Figure 3 shows the activity of black hole attack, in this figure red circles is used for denoting malicious node and green circle to represent valid nodes.

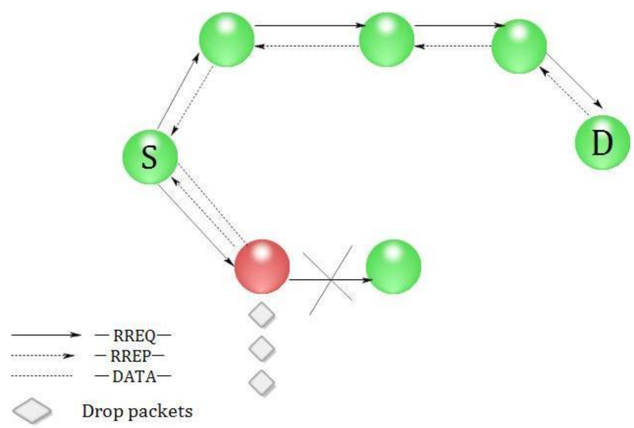

Fig: 3. The course of action of black hole attack

On top of figure, source node S launch RREQ to its neighbor node. The malicious node does not further send RREQ to its neighborhood node and propel RREP to source node S with high sequence number and least hope count. After getting such RREP, the source node sends data to this malicious node and malicious node drop all packets and system is in beneath the black hole attack.

V.WATCHDOG PROTOCOL

To avoid the problem and detection of this black hole attack, [9] Watchdog protocol is introduce. In this protocol, every node is work as an observer to watch the working of its next hope neighborhood node. It collects transmission information of this node and observes that node correctly forward to its next hope neighborhood node along with the correct destination route. [13]This protocol measures the sending time of the next hope node. If the sending time of the next hop neighbor is greater than the packet storing time and exceeds above some defined threshold of the network, then Watchdog knows that system is under black hole attack and it immediately mark this node as a malicious node. The Watchdog protocol announces the existence of the malicious node in the network by generating the alerts. The benefit of the Watchdog protocol is that, they make use of only local information and are proficient to spot the malicious node.

They can resolve the predicament of black hole attack which demonstrate the way to denial of service attack (DOS) in MANET network. [14]Watchdog protocol act as a very good intrusion detection system mechanism in the network. However, [15] there are certain disadvantages regarding to this protocol such that it decreases the network performance in terms of throughput, it does not support mobility with high number of nodes, and it doesn't detect the actual reason of the packet loss. To overcome these disadvantages of this Watchdog protocol, the improved Watchdog mechanism is proposed which perfectly distinguishes the packet loss due to congestion or due to the presence of a malicious node in the network. Our improved Watchdog protocol also supports a high degree of the mobility and enhances the performance.

VI. PROPOSED WORK

In this paper, the improved Watchdog protocol is proposed with some modifications to overcome the problem related to the early Watchdog protocol. This improved Watchdog protocol is very efficient to detect the actual reason for the packet loss. Because MANET is a wireless technology, mobile node devices of the MANET are independent to move anywhere so the mobility is very high and Watchdog protocol does not support a high degree of mobility but our I-Watchdog protocol supports a very large number of nodes with a high degree of mobility. Also, due to the wireless nature of the mobile ad hoc networks, they are more vulnerable to congestion and Watchdog protocol does not detect the network congestion and link error of transmission. It just observes that whenever the sending time of packet greater than the packet storing time, it sends alert in the system and marks the node as malicious. Watchdog protocol does not find the actual cause of packet loss and this leads to low throughput and system performance degrades. But proposed I-Watchdog protocol does not take a decision about the node very easily, because the packet loss also happens due to network congestion, it implements some modifications to the existing protocol. I-Watchdog protocol gives good results in throughput, packet delivery ratio and end-to-end delay as compared to Watchdog protocol. In the below figure shows the algorithm that we will use in the implementation of our I-Watchdog protocol.

ALGORITHM OF I-WATCHDOG PROTOCOL:

1. If (sending time of packet > Packet storing time) else go to step 8
2. Calculate d = sequence no of suspected node – sequence no of current node
3. If d is very large and within the range of suspected node's sequence number then go to step 4 else go to stop 7.
4. Then calculate % packet loss of suspected node to be malicious
5. If (% of packet loss > threshold of % packet loss)
6. Then Mark the suspected node as malicious
7. Else call local repair of link function
8. stop

In the above algorithm, Watchdog observes the next hope node activity. Whenever it detects that node's sending time exceeds the packet storing time then it does not directly mark node as malicious, it further checks for the sequence number. It calculates the difference which is denoted by d in the above algorithm, between the sequence number of suspected nodes and the sequence number of itself. If this difference d is very close to the suspected sequence number and it is very far from the sequence number by itself then it checks for the packet loss of percentage. For example, consider the below 2 cases:

- CASE 1:

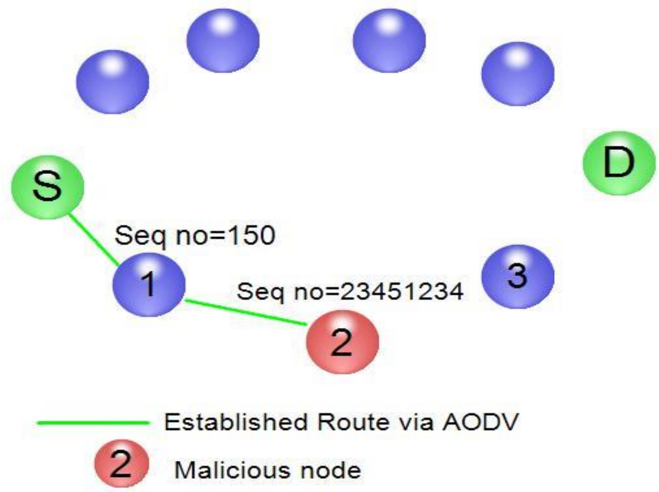

Fig 4. CASE 1

From the above figure 4, suppose node 1 act as a Watchdog and observes the next hop node that is node 2 and node 2 is suspected to be malicious because its sending time is exceeded over packet storing time. Then node 1 calculates difference d. Suppose node 2 is a malicious node so it contain a very large sequence number for example the sequence number of node 2 is 23451234 and sequence number of node 1 is 150 then difference d is evaluated to be d = (23451234-150) =>23451084, which is very close to the sequence number of node2 (suspected malicious nodes) and very far from node 1. After calculating this value of d, to ensure the suspected node is malicious it checks for the percentage of packet loss. If this percentage of packet loss has exceeded the predefined threshold value of percentage of packet loss then I-Watchdog protocol mark this node as malicious and send alert in the network about the malicious node. If suspected malicious node's percentage of packet loss is less than the threshold value than it does local repair link because it indicates that packet loss is due to the network congestion, transmission errors and the suspected malicious node is not malicious.

- CASE 2:

In case 2, when difference d is not close to the suspected malicious node as well as node which act as Watchdog, then there is a confirmation that node is not malicious and sending time exceeds the threshold due to transmission errors and congestion so local repair of link function is called. For example node 1 sequence number is 150 and sequence numbers of suspected malicious nodes is 170 then the differences will be d = (170-150) =>20, which is not close to 170 as well as 150. In this case, local repair of link function can be directly called. This algorithm of the I-Watchdog protocol gives better performance and high throughput.

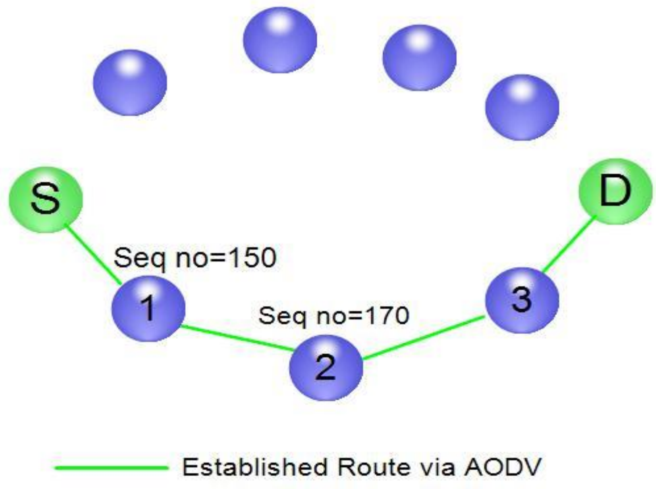

Fig 5. CASE 2

In case 2, when difference d is not close to the suspected malicious node as well as node which act as Watchdog, then there is a confirmation that node is not malicious and sending time exceeds the threshold due to transmission errors and congestion so local repair of link function is called. For example node 1 sequence number is 150 and sequence numbers of suspected malicious nodes is 170 then the differences will be d = (170-150) =>20, which is not close to 170 as well as 150. In this case, local repair of link function can be directly called. This algorithm of the I-Watchdog protocol gives better performance and high throughput.

Now for better understanding of implemented I-Watchdog protocol algorithm following figure shows a flowchart. This flowchart well describes about the mechanism of the improved watchdog protocol. It first calculates the difference d and then check this d is close to the suspected malicious sequence number or not. If it is in the range, then again check for the percentage of packet loss. If it is greater than the predefined threshold then it provides surety that the node is malicious. If d is not within the range of malicious node sequence number then it indicated that sending time exceeds the packet storing time due to the presence of congestion in the network and local repair of link function is directly called.

VII. SIMULATION

I-Watchdog protocol is implemented in network simulator (NS-2) in Ubuntu platform. In this paper, we are comparing the performance of I-Watchdog protocol with existing Watchdog protocol in terms of throughput, packet delivery ratio and end-to-end delay. The simulation parameters are shown in table 1 which we will use in the simulation of Watchdog protocol and I-Watchdog protocol.

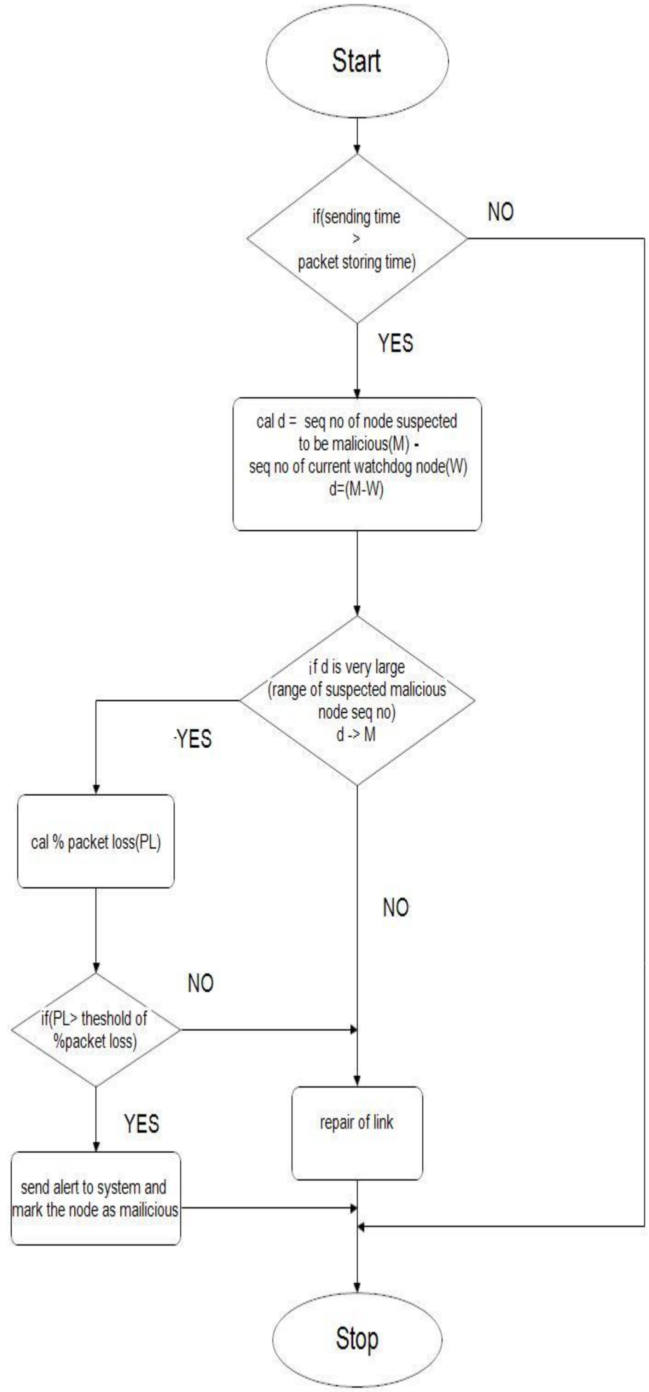

Fig 6. Flowchart of I-Watchdog protocol algorithm.

VIII. RESULTS AND COMPARISION

In this paper, I-Watchdog protocol implemented as an improved Watchdog protocol for mobile ad hoc networks. I-Watchdog protocol gives better results in terms of throughput, packet delivery ratio and end-to-end delay. Further, we will equate the performance of both the protocols by in terms of these attribute by plotting the X-graph in NS-2.

TABLE I
SIMULATION PARAMETERS FOR WATCHDOG

Sr no.	Parameter	Value
1	Simulator	NS-2
2	Channel type	Channel/Wireless channel
3	Radio Propagation Model	Propagation/ Two ray ground wave
4	Network interface type	Phy/WirelessPhy
6	MAC Type	Mac /802.11
7	Interface queue Type	Queue/Drop Tail
8	Routing procedure(protocol)	AODV
9	Antenna	Antenna/Omni Antenna
10	Type of traffic	CBR
11	Area (M*M)	500 * 500
12	Simulation Time	250 sec
13	No of Nodes	50

A. *THROUGHPUT*

The principal performance is measured in the relations of the throughput. Throughput is represented in bits per second (bps) and it is the number of packets which is received in per unit of time. Figure 7 represents the throughput of the Watchdog protocol.

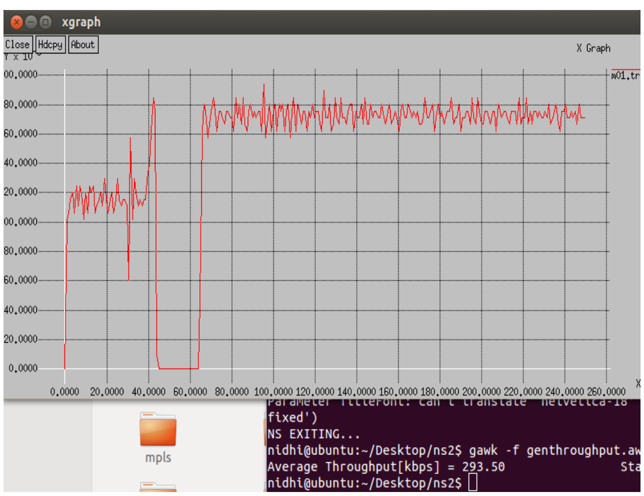

Fig 7. Throughput of the Watchdog protocol

In the above figure, shows graph of the throughput corresponding Watchdog with AODV protocol. The figure represents the average throughput of the system using Watchdog protocol is 293.50 Kbps.

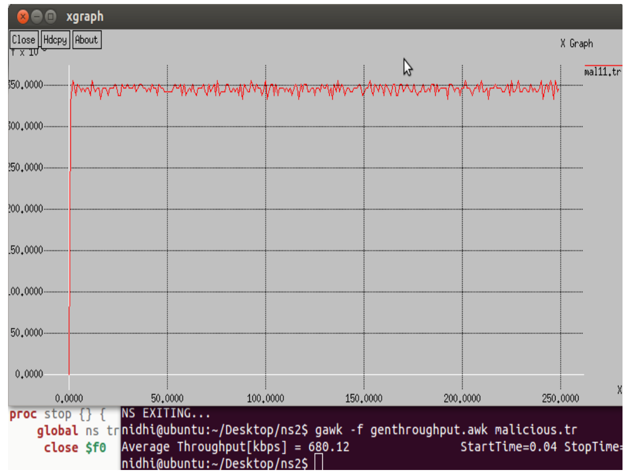

Fig 8. Throughput of I-Watchdog protocol with AODV

In the above figure, the graph for the throughput of I-Watchdog protocol is shown. It is clear from the graph is, the average throughput calculated for me-Watchdog protocol is very high and comes out to be 680.12 kbps, which is very high as compared to the existing Watchdog protocol.

B. *PACKET DELIVERY RATIO/FRACTION*

Packet delivery ratio (PDR) is the portion with reference to the data Packets received by the target node to folks propel by the source node. This evaluates the ability of the protocol performance and its efficiency.

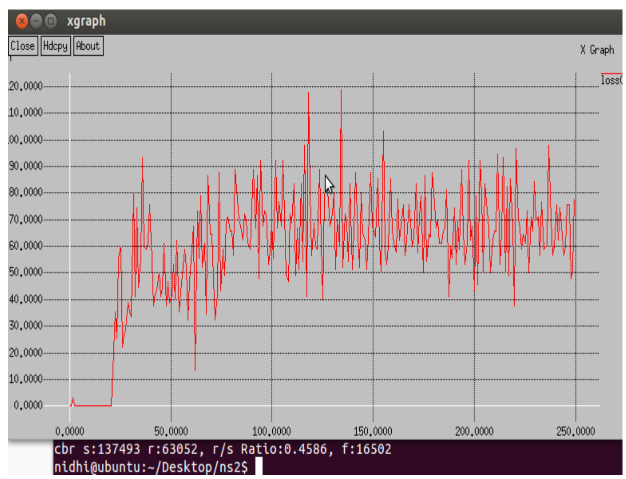

Fig 9. Packet delivery ratio of Watchdog protocol

It is shown from the above figure that the PDR of the system which uses the Watchdog protocol is less. The difference between the sending and receiving packet is 74441 means that 74441 packets are not received by the destination so that we can say the 74441 packets are dropped.

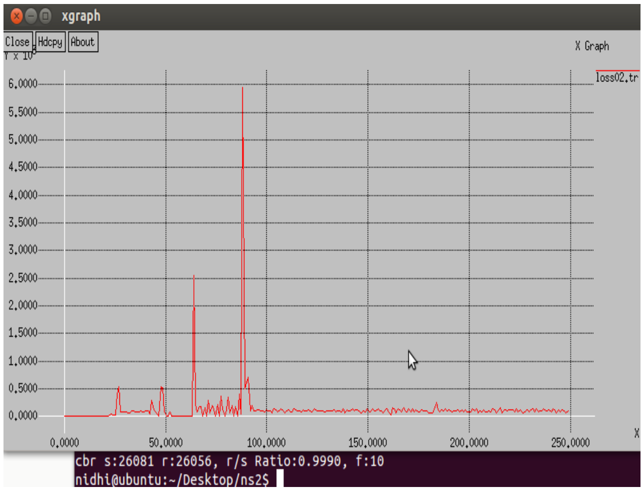

Fig 10. Packet delivery ratio of the system within Watchdog protocol

The figure shows clearly that the numbers of dropped packets are very few. The difference between the number of sending packets and the number of receiving packets is about 25, which is very less as compared to the Watchdog protocol. So that it is clear that the I-Watchdog protocol gives better results and performance than the existing Watchdog protocol.

C: *END-TO-END DELAY*

End to end delay is the quantity of the time which is occupied to sending packets from source to their respective destination to receive those packets. More delay can lead to low performance of the MANET and low delay is the indication of high efficiency and speed of the network.

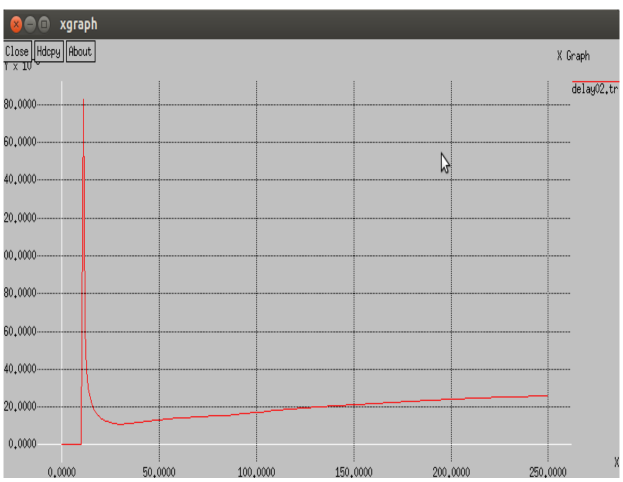

Fig 11. End-to-end delay of the network with Watchdog protocol

The above figure shows end-to-end delay of the network, and it is clear from the graph that it comes out to be about 80 ms which is very high and can highly degrade the system performance. It is fundamentally the total time, which is occupied by the network to send the all packets from source to destination. Here the delay is 80 ms represent the total time is 80ms to send packets from the source node to the destination mobile node in the MANET.

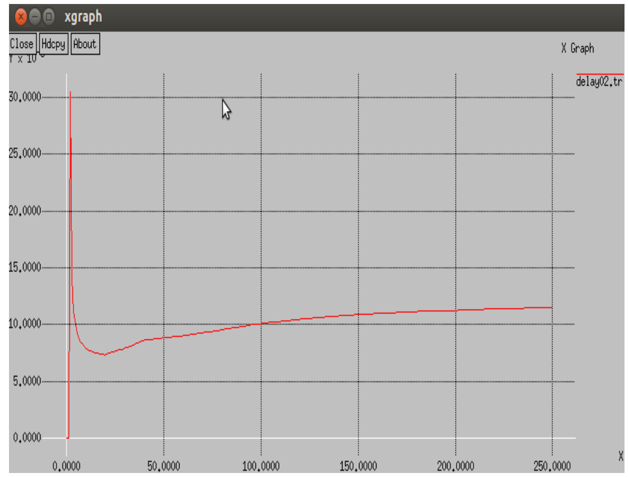

Fig 12. End-to end delay of the system using I-Watchdog protocol

The above figure shows graph of the end–to-end delay of the network which is time to sending the packets from source mobile node to the destination mobile node. The end-to-end delay is about 30ms which is represented by the above X-graph which is very low as compare to the existing Watchdog protocol. So that we can come into the conclusion that proposed I-Watchdog protocol [24-27] requires very less time to send packets from source to destination, it also drops very few packets because of PDR is high for I-Watchdog protocol as compared to existing Watchdog protocol as well as it gives very high throughput which enhances the system performance.

IX. Conclusion

MANET is a wireless ad hoc network which is infrastructure less, dynamic and distributed in nature. The attacks are the key sanctuary encounter of MANETs. However I-Watchdog protocol provides a way that can enhance the system performance and detects the congestion, transmission error, link error in the network. It gives high performance and supports a very high number of nodes and provides minimum delay with enhanced throughput. I-Watchdog protocol overcomes the limitation of the previous Watchdog protocol, results less number of dropped packets, high throughput and minimum delay. It can easily detect that the delay and packet drop event is occurring due to transmission error or any attack in the network. If it is due to attack, then an alert is generated by Watchdog node and broadcast information regarding malicious node in the entire network. If it is due to any transmission error then local repair of link function is called. I-Watchdog protocol supports very high degree of the mobility and also supports the dynamic and distributed nature of the MANET. The future work will be on the prevention of the packets from being alternation by the malicious node in the network, in such a way the main focus will be on the integrity and confidentiality of the contents inside the packet. For further enhancing security and efficiency, we provide some authentication techniques and repairing of link methods such that reliable delivery of packets from source to destination will take place.

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Nidhi Lal, is a M.tech student in the Area of Wireless Communication and Computing at Indian Institute of Information Technology, Allahabad. She received her graduate degree from Galgotias college of Engineering and Technology.

Design of a Mutual Exclusion and Deadlock Algorithm in PCBSD – FreeBSD

Libertad Caicedo Acosta, Camilo Andrés Ospina Acosta, Nancy Yaneth Gelvez García, Oswaldo Alberto Romero Villalobos.

Universidad Distrital Francisco José de Caldas, Bogotá, Colombia

***Abstract* — This paper shows the implementation of mutual exclusion in PCBSD-FreeBSD operating systems on SMPng environments, providing solutions to problems like investment priority, priority propagation, interlock, CPU downtime, deadlocks, between other. Mutex Control concept is introduced as a solution to these problems through the integration of the scheduling algorithm of multiple queues fed back and mutexes.**

***Keywords* — Mutex, PcBSD, SMPng, FreeBSD, Operating Systems.**

I. Introduction

OVER time operating systems have evolved to reach the progress that can be seen today: starting batch processing, which involved planning the next job to run on a treadmill until multiprogramming systems in which many users waited to be served. With the advent of personal computers has been generally allowing one active process and more resources to which access, then with the integration of more than one processor on a machine, appeared multiprocessing and therefore the concept of parallelism, which involves making one or many processes running on different processors at the same time, being assigned a process per processor. Such evolution is generated from finding that a perceived performance and user satisfaction is optimal.

One of the main functions of the operating system is making decisions about allocating resources to the various processes are in ready state and require access to the same resource; process scheduler uses the scheduling algorithm to make such decisions. Scheduling algorithms implemented in the kernel of the system depending on the environment in which they are seeking to improve the response time, proportionality, predictability, fairness and prevent data loss. [1]

In environments such as real-time or interactive problems may be found when concurrency occurs one or more processors; where processes wish to share the same resource difficulties are encountered when defining the time and the conditions under which each process makes use of the resource, looking in critical section only able to stay a process, ie, that the final result depends on who is running and when it does. This situation leads to problems usually involving shared memory, files, and resources in general (a resource is a hardware device or a piece of information) are generated, which leads to data loss or downtime CPU.

II. Mutual Exclusion And Deadlock

Mutual exclusion is born from the generation of the problems listed above with concurrent programming, seeking to ensure that if a process makes use of a shared resource processes exclude others do the same. However, sometimes the processes are performing internal calculations and other things that do not involve access to the critical section, ie, the part of the program that accesses the shared memory. What is desired is that the processes can operate in parallel to data sharing is optimized over time, as long as only one is in critical section. There are some considerations when performing a mutual exclusion algorithm using critical regions:

- There can only be a process critical section at a time.
- Must know the speeds or the number of CPU's.
- Only the process is in critical section may block other.
- There should be no downtime CPU, because no process can wait infinitely to be executed.

Another mechanism that avoids mutual exclusion is partially disabling interrupts on a CPU; however do user processes and may not be re-enabled that would kill the system, or if the CPU multiprocessing disabling performed cease to function. In the same way the method operates lock variables, in which when the lock is 0, the process can access critical section and when no one is 1; however has problems as to the mechanism mentioned above.

One of the latest implementations of mutual exclusion algorithms are the *mutex*, which allow to manage a resource or piece of code; is very helpful for thread sets that are implemented in user space. The mutex variable is a padlock that can be open or closed, which is represented by 0 if it is open and any other value if it is closed. When a process requires entering critical section checks whether the padlock is open and if so hard to run if it is not blocked until the process in that section is released, ie, the padlock opens. If several blocked threads, then one is selected at random to be the next to access critical section.

The mutex can be viewed from its behavior. As shown in Figure 1, a mutex is a padlock variable that can be open or closed and which may have one of the following behaviors:

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- Sppining: When you constantly look at the state of the lock to see if the resource is already released. In this case there are no interruptions, then time is wasted waiting for lengthy processes that took control of the resource.
- Blocking: When the resource is not changed to block and awaits the call of the appeal process had, by the time it releases.
- Sleeping: If the resource is not available, it puts the process to sleep until the resource is enabled.

For exceptional cases, the programmer can create a few extra conditions under which a process sends to sleep while the presented problem is solved.

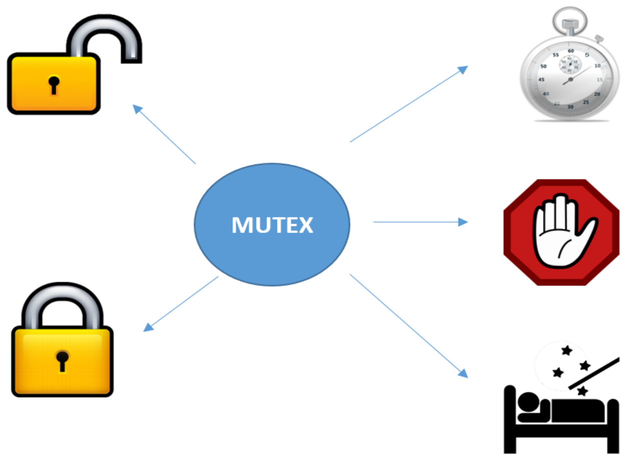

Fig. 1 - Representation of mutual exclusion.

In many cases computers have resources that can be used by only one process in the same space of time; if they run more, inconsistencies or errors occur in the information manipulated. Operating systems temporarily attach to a process exclusive access to certain resources; in cases in which a process one needs more than one resource, first makes the request, but when you need to access another and find that it is occupied by a process 2 which requires use of the resource using process 1; as both are waiting for the other release to free the resource you are running a deadlock occurs. This phenomenon could also occur between machines in the same network with shared devices such as scanners, printers, external drives, etc. [2]. Figure 2 shows more clearly the deadlock problem, with both processes P1 and P2, and two R1 and R2 resources that are left in a standby cycle, and retention of the release of resources.

Deadlocks are usually not preemptive resource linked, ie they may leave without being run over. In some cases there is a quantum that allows equality between processes and subtract the lifetime of the running process and then leave critical section; if it has been completed is deleted, if not, back to the tail of "ready" to run below the remaining time. Such resources may also have an associated priority, which means that in case a higher priority process needs the resource that is being used, use it and send the running process to a suspended list.

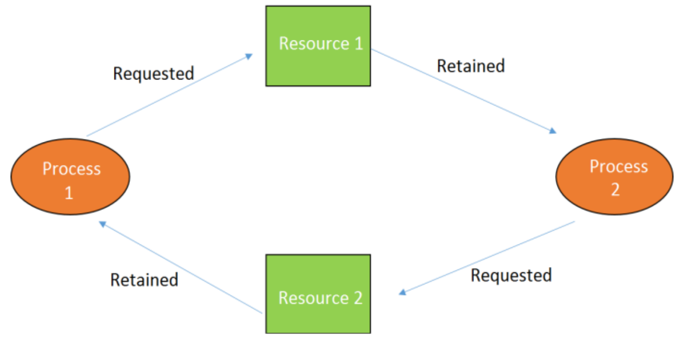

Fig. 2 - Representation of deadlock.

Currently the FreeBSD kernel supports symmetric multiprocessing (SMP), in which all Central Processing Units (CPU's) have a single connection to a non-uniform memory, implementing the Mutex Synchronization strategy as the primary method to manage short-term threads synchronization [3]. One of the desired characteristics for the mutexes design is that acquiring and releasing uncontested mutexes should be as fast as possible, which is one of the reasons for designing an algorithm that works in junction with the FreeBSD-PCBSD mutexes.

III. Design

On operating systems such as FreeBSD PcBSD have been implementing mutual exclusion algorithms increasingly trying to minimize the problems that arise concerning the allocation of resources to processes.

PcBSD is a desktop operating system based on FreeBSD, which provides stability and security in server environments; makes use of window managers and open source application installers of the same type. It is currently in version 10 call PcBSD Joule, which is used in the following analysis and implementation to be discussed later. [4]

A. Mutual Exclusion Algorithm in PcBSD

The implementation of the scheduling algorithms in pcbsd involves evolution in terms of versioning, as currently implemented in some types of which a mutex some extra functionality integrated avoid problems such as investment priority, priority propagation and interlock.

The current implementation emerges from the problems presented with KSE (Kernel Scheduling Entity) in multiprocessing environments that generated downtime CPU and deadlocks [5]; therefore, from version 5.0 of FreeBSD kernel restructuring is done in the way of working threads in such environments, implementing mutexes that lead to a kernel SMPng according to [6].

As mentioned in section 2, there are three types of behaviors associated with mutexes which are kept in the model proposed by the creators of FreeBSD development, ie that there are shared mutex as Spinning, Blocking or Sleeping. Additionally mutexes define four types of [7], which are defined below:

- Mutex: When access to data is located on 1 CPU and accessed by a single thread.
- RW Lock: When access to data is made with several threads on several CPU's, in which reading and writing is permitted, however, only one process can be in write mode, while many in read mode.
- Lock RM: is equal to the RW Lock, only varies in the fact that the reading time is optimized.
- Waitchannel: When a thread requires the use of another thread is assigned a stop expected to sleeping.

It is preferable to use a mutex Blocking that a mutex Spinning in most cases, there are only a few exceptions where the other is better.

Below in Figures 3, 4 and 5 shows the implementation of mutexes, which are encoded in the kernel of PCBSD.

```
struct mtx {
        struct lock_object      lock_object;    /* Common lock properties. */
        volatile uintptr_t      mtx_lock;       /* Owner and flags. */
};
```

Figure 3 - Defining the mutex structure.

The above structure is the /usr/include/sys/_mutex.h system directory.

```
/* Lock a normal mutex. */
#define __mtx_lock(mp, tid, opts, file, line) do {                      \
        uintptr_t _tid = (uintptr_t)(tid);                              \
                                                                        \
        if (!_mtx_obtain_lock((mp), _tid))                              \
                _mtx_lock_sleep((mp), _tid, (opts), (file), (line));    \
        else                                                            \
                LOCKSTAT_PROFILE_OBTAIN_LOCK_SUCCESS(LS_MTX_LOCK_ACQUIRE, \
                    mp, 0, 0, (file), (line));                          \
} while (0)
```

Fig. 4 - Definition of a mutex lock.

The lock and unlock functions are in the C++ library mutex.h, which are located in the /usr/include/sys filesystem.

```
/* Unlock a normal mutex. */
#define __mtx_unlock(mp, tid, opts, file, line) do {
        uintptr_t _tid = (uintptr_t)(tid);

        if (!_mtx_release_lock((mp), _tid))
                _mtx_unlock_sleep((mp), (opts), (file), (line));
} while (0)
```

Fig. 5 - Defining unlock a mutex.

B. Design of mutexes in multiple queues fedback to an environment PCBSD-FreeBSD

In conjunction with the scheduling algorithm of multiple queues fed back [8], we propose an extra control for handling mutual exclusion and deadlock through mutexes which we call Mutex Control. For the specific case of pcbsd-FreeBSD, this control within each scheduling algorithm was implemented as shown in Figure 6, allowing at the time of assessment step in a process for critical section, a mutex is assigned to it. All this for the purpose to have a better management and resource allocation to avoid problems CPU timeouts, deadlocks, interlocking, among others.

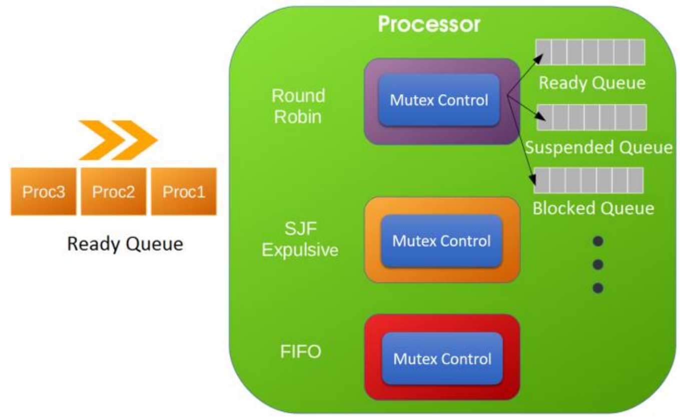

Fig. 6 - Environment and location Mutex Control

Design of Control made Mutex involves a simulated environment algorithm fed back tails, specifically built to allow the integration of mutexes proposed PCBSD-FreeBSD. In Figure 7, was able to visualize the proposed multiple queues fed back flowchart Mutex Control behavior.

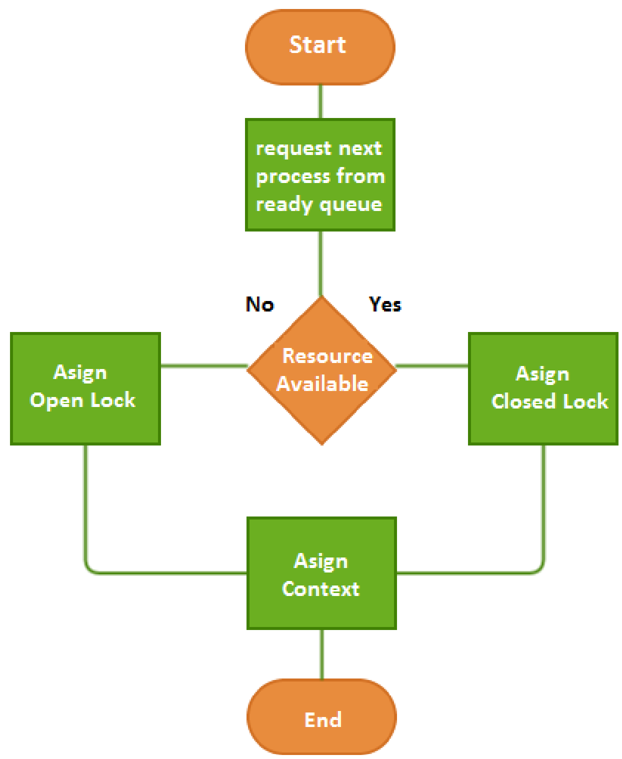

Fig.7 - Mutex Control Operation

The structure mutex proposal to integrate itself to queues fed back algorithm, is given as an adaptation of the libraries implemented in C++ Kernel PCBSD-FreeBSD, reflecting the main behavior that they exhibit a SMPng environment. Representation is in terms of Objects Oriented Programming and structural, in which a Mtx class, mtx_lock function and mtx_unlock function similar to structures in C++, mtx, __mtx_lock and __mtx_unlock respectively is created and seen previously in Figures 3, 4 and 5.

```
class mtx():
    '''
    Simple mutex class for locking resources
    '''
    def __init__(self, resource=None, owner=None,  lock=0):
        self.lock_object={"resource":resource}
        self.mtx_lock={"owner":owner, "lock":lock} #0 lock else unlock}


def mtx_lock(mtx):
    if mtx.mtx_lock["lock"]:
        mtx.mtx_lock["lock"]=0

def mtx_unlock(mtx):
    if not mtx.mtx_lock["lock"]:
        mtx.mtx_lock["lock"]=1
```

Fig. 8 - Mtx code implementation.

Integrating mutex controls the scheduling algorithms is performed just after receiving the next process in the ready queue and is given by an assessment of the resources needed by each process, allocation and release locks as can be seen in Figure 8.

```
proc=self.core1.roundRobinAlgo.readyProcesses.next()

#Create New Mutex
new_mtx=mtx(proc.resource, proc.name)
#Eval locking
if bIP.resource["type"] not in (core1resource,core2resource,core3resource):
    mtx_lock(new_mtx)
else:
    mtx_unlock(new_mtx)
#Assign Mutex to Process
proc.mtx= new_mtx

self.core1.roundRobinAlgo.blockedProcesses.append(proc)
```

Fig. 9 - Code implementing the Mutex Control

IV. Mutex Simulation

In order to simulate the coupled behavior of the mutex controller proposed, it was necessary to create an application by multiple queues fed back to incorporate into their calling from the processes queue on each core to mutex control in order to make the decision to change the context of each process (blocked, suspended and critical section).

Then several screens showing action working together mutex control through multiple queues fed back (multiprocessor) can be observed. It should be noted that although the simulation was designed thinking of ways to perform mutual exclusion in PcBSD-FreeBSD, an implementation of a mutex control style could be proposed in other operating systems (improving the effectiveness of the algorithms for SMPng environments).

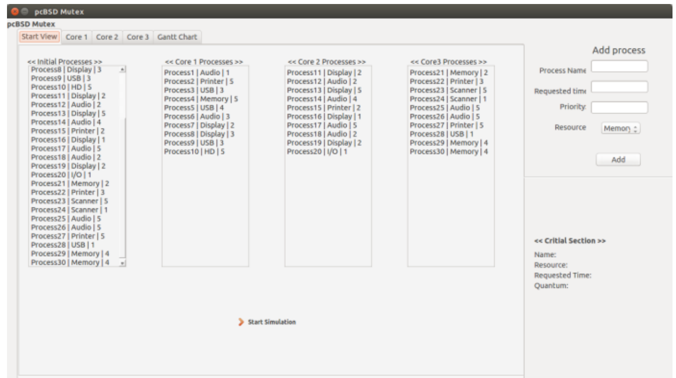

Fig. 10 - Assigning each core processes

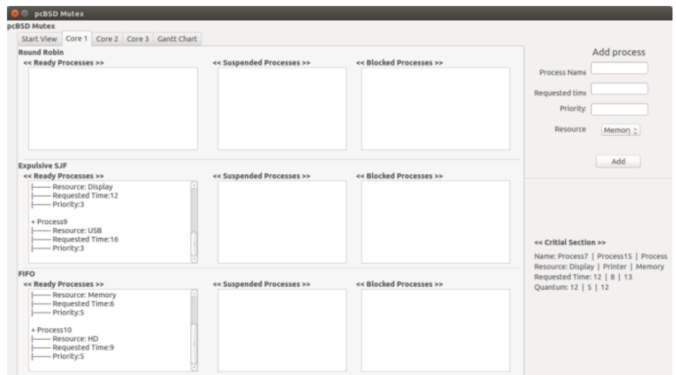

Fig. 11 - Core 1 running

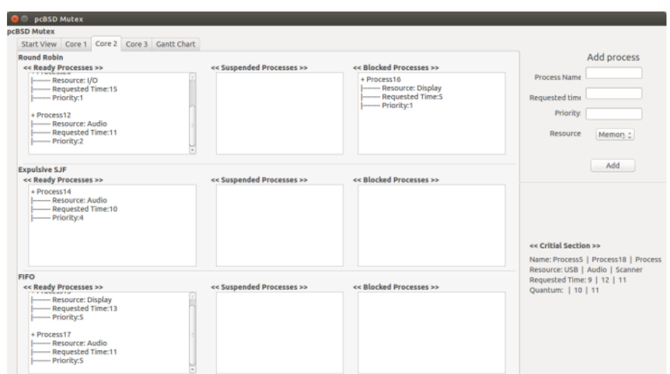

Fig. 12 - Core 2 running

Fig.13 - Gantt execution of algorithms

V. Conclusions

As previously mentioned, FreeBSD-PCBSD implements the Mutex Synchronization strategy as the primary method to manage short-term threads synchronization which in junction with the proposed algorithm improves the OS desired characteristics for the mutexes.

For each operating system there is a way to implement mutual exclusion that is best suited to your operation. Not always the most complex has better benefits.

Scheduling algorithms and mutual exclusion, require adaptations to environments smpng because it worked very well on a single processor environment, tends to have problems or inefficiencies in the management of resources and response times Multiprocessor.

The mutex control minimizes the problems that are presented to the planning algorithms in environments SMPng such as investment priority, priority propagation, interlock, CPU timeouts, and deadlocks, among others.

Integrating mutexes to implement multiple exclusion in PcBSD-FreeBSD operating systems for SMPng environments, represents major advantages implementation over other mutual exclusion algorithms.

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Libertad Caicedo Acosta is a final year student from Computers and Science Engineering at The District University Francisco José de Caldas of Bogotá, Colombia. She is one of the founders of the Python programming group created in 2011 at the same University, was an academic assistant for the Computers and Science program in 2013 and for the Complexity Group since 2011. She is currently working to get his B.Sc. It belongs to the research group GIIRA. lcaicedoa@correo.udistrital.edu.co

Camilo Andrés Ospina Acosta is a final year student from Computers and Science Engineering at The District University Francisco José de Caldas of Bogotá, Colombia. He is one of the founders of the Python programming group created in 2011 at the same University, and was an academic assistant for the Computers and Science program in 2013, He is currently working to get his B.Sc. It belongs to the research group GIIRA. caospinaa@correo.udistrital.edu.co

Nancy Yaneth Gelvez García was born in Pamplona, Colombia. She received the B.S. Systems Engineer in Colombian School of Industrial Careers ECCI and M.S. Science in information and communications degrees; Professor and member of the Curriculum Project in Systems Engineering from the University District and GIIRA research group. nygelvezg@udistrital.edu.co

Oswaldo Alberto Romero Villalobos was born in Bogotá, Colombia. He received the B.S. Systems Engineer also S.P. Software Engineer, S.P. Roads Design, Traffic and Transportation and M.S. Industrial Engineering degrees; Professor and member of the Curriculum Project in Systems Engineering from the University District and GIIRA research group. Mr. Romero has been Technical Director well as consultant and advisor to various agreements between the District Department of Transportation in Bogotá and the University District and municipalities in Colombia, also has been a consultant and architect for various software development companies. oromerov@udistrital.edu.co

Sphericall: A Human/Artificial Intelligence interaction experience

Frack Gechter[1], Bruno Ronzani[2], and Fabien Rioli[3]

[1]IRTES-SET, UTBM, Belfort Cedex, France
[2]Oyez Digital Agency
[3]Tharsis Evolution

***Abstract* — Multi-agent systems are now wide spread in scientific works and in industrial applications. Few applications deal with the Human/Multi-agent system interaction. Multi-agent systems are characterized by individual entities, called agents, in interaction with each other and with their environment. Multi-agent systems are generally classified into complex systems categories since the global emerging phenomenon cannot be predicted even if every component is well known. The systems developed in this paper are named reactive because they behave using simple interaction models. In the reactive approach, the issue of Human/system interaction is hard to cope with and is scarcely exposed in literature. This paper presents Sphericall, an application aimed at studying Human/Complex System interactions and based on two physics inspired multi-agent systems interacting together. The Sphericall device is composed of a tactile screen and a spherical world where agents evolve. This paper presents both the technical background of Sphericall project and a feedback taken from the demonstration performed during OFFF Festival in La Villette (Paris).**

***Keywords* — Live demonstration, Human/complex system interactions, Multi-agent systems, Physics inspired behaviours.**

I. Introduction

MULTI-AGENT systems are now widespread in scientific works and in industrial applications. They are characterized by individual entities, called agents, in interaction with each other and with their environment. Each agent is autonomous. It behaves following a set of rules that can be based on a complex representation of individual goals (cognitive agents) or based on simple stimulus/response local actions (reactive agents). In this context, local phenomena (interaction, behaviours...) lead together to a global system response that can be defined as intelligent. Multi-agent systems are generally classified into complex systems. The emerging phenomena cannot be predicted even if every component is well known.

Multi-agent systems are used in a wide range of applications such as artificial life/complex system simulation [11], [14], mobile robots [12], [13] and intelligent vehicle behaviour [17], smart energy networks [16]... Agents behaviours are generally inspired by physics [18] or biology, especially by social insects such as ants [19], termites, spiders [20]... This last inspiration source is also known as swarm intelligence [5], [6], [7].

Few articles deal with the Human/Reactive multi-agent system interaction issue. However, some recent works that deal with this issue in various contexts such as Human activity recognition [22] or Human/multiple robots interactions definition [23], start to appear. This scarce representation of this issue in literature is mainly due to the complex character of these kinds of systems where the global emergent properties are not easily predictable. In these kinds of applications, the main problem is to determine at which the level (local or global) the Human/agency interaction must take place. The local Human/agent interaction is easy to set up but its influence on the agency is hard to determine/predict. A global Human/agency interaction is hard to put into practice but is more easily predictable. Moreover, this interaction can be direct, modification of the agent behaviours, or indirect by modifying the environment perceived by the agents.

Sphericall has been developed to study the link between the Human being and the agency. It can be considered as a Human/Artificial Intelligence interaction experience, which puts the focus on several sensitive abilities (visual, tactile, and hearing).

The Sphericall device is composed of two main elements:

- A tactile surface aimed at modifying the music (effect, volume, pan,...) diffused to the intelligent system.
- The work of art, as itself, which emerges from interaction between music, which is controlled by a Human, and a reactive multi-agent system.

Agents, spread on a sphere, are autonomous entities which build/destroy skyscrapers, organic trees... depending on their musical perception. The artist can influence, but not totally control, the work of art by modifying the sounds and the music, which is sent to the system.

This paper presents both the technical background of the Sphericall project and a feedback taken from the demonstration performed during OFFF Festival (Online Flash-Film-Festival) and from a poll made among students, which

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have the habit of manipulating multi-agent systems.

The paper is structured as follows. First, section II draws a state of the art of multi-agent and of the Human/multi-agent system interaction issue. Then, section III will present the technical aspects of Sphericall project, dealing with the interactive interface on the one side and with the intelligent system on the other. Then, section IV exhibits results obtained after OFFF festival demonstration in La Villette (France). Finally, section V concludes by giving some future work.

II. State of the Art

A. Multi-agent systems

Since a couple of decades multi-agent systems have been used in a wide range of problem solving, modelling and simulation applications. These approaches are characterized by their capability to solve complex problems, while maintaining functional and conceptual simplicity of involved entities called agents. In many cases, multi-agent based approaches exhibit effectiveness in various fields such as life simulation [24], crowd simulation, robots cooperation [25] or vehicle control related to devices such as obstacle avoidance systems. The multi-agent systems design generally focuses on agents' definition (internal states, perception and behaviour,...) and/or on the interactions between agents and their environment using biological [19], [26], [27], [28] or physical inspiration sources [29], [30], [31]. One can find two main trends in multi-agent design: the cognitive and the reactive approaches. The cognitive approaches focus mainly on the agent definition and design. In this context, each agent is defined with high level reasoning capabilities and interacts with its mates in using high-level interactions such as explicit communication for instance. Among these approaches one can cite the consensus methods [41] or the belief-desire-intention (BDI) agents as used in [42]. Cognitive agent systems rely generally on a small number of agents. By contrast, reactive agent approaches are based on numerous agents, with small cognitive abilities (generally based on simple stimulus-response behaviours), and interacting intensively with each other and with their evolving area named environment. The role of the environment and its characteristics (dynamics, topology,...) are crucial in reactive approaches. As it has been explained in [32], [33], [34] the environment plays a key role in reactive multi-agent systems. Indeed, a reactive agent can neither handle a representation of the global goal of the system nor compute a solution to reach it. The environment can thus be considered as the place where the system computes, builds and communicates. Then, one can say that the intelligence of the system is not contained into the population of agents but emerges from the numerous interactions between agents and with their environment. This notion of emergence is central in reactive multi-agent systems and explains the interest of such systems for complex system control, observation or simulation. In [35], a system is defined to present emergent properties when phenomena appear dynamically on a macroscopic point of view as a result of interactions between system components at microscopic level. Moreover one can find several definition of emergence from the nominal emergence to the weak emergence and the strong emergence [36]. The main problem encountered is linked to the evaluation, measurement and prediction of emerging organization and/or properties. On the Human/system interactions point of view, the notion of emergence is the key element. Indeed, the challenge of designing a control interface for complex system relies on the ability to propose to the user an abstract interface, which enables him to manipulate and to understand the evolution of the system without knowing the interaction that occurs at microscopic level.

B. The Human/Multi-agent system interaction issue

The Human/multi-agent system interaction problem, and more generally, the Human/complex system interaction problem is a tough issue, which has been dealt with for a couple of years [1]. In multi-agent systems, one can consider two different categories depending on the reactive/cognitive aspect of the considered agents as described in the previous paragraph. The Human interaction, from the cognitive agent point of view, is more natural and easy to analyse. Since the cognitive approach tends to design agents which behave using high-level reasoning, decisional and/or perceptive abilities, it is then logical to consider the behaviour of the interacting Human at the same level of intelligence as one agent in [2]. Another way to specify the Human/Agency interaction is to consider the Human as a supervisor able to interpret the information furnished by each agent [3] or to translate Human gestures into control primitives [4]. The key indicator in such systems is the fan-out of a Human-agents team as defined by Olsen and Wood in [37], [38] to be the number of agents that a Human can control simultaneously. The examples, found in literature, deal mainly with Human-multiple robot interaction/control [23], [39]. In this context the fan-out for a Human/robots team can reach 18 homogenous robots [40].

In the reactive approach this issue is harder to cope with, since the number of agents involved can be as many as hundreds of elements. Indeed, the reactive multi-agent systems are based on numerous agents, the behaviours of which are triggered by numerous interactions. Generally, such systems are considered to be complex as referred to the definition given in [8]. Thus, it's hard to interact with the system because its complex nature makes its understanding impossible even if all local aspects are well known. In this situation, the external interaction has to be linked to the emergent properties because the influence is not directly measurable. In [9], several interaction strategies are defined. The Human/complex system interactions can be made by explicit control or by implicit cooperation. Explicit cooperation correspond to direct interactions with the local element of the system such as agents' behaviours or agent-agent interaction mechanisms. Implicit cooperation can be considered to indirect interaction through modification of the agents' environment. The feedback of these interactions is always made through global and indirect indicators. Finally, [10] studies the relation that can be brought to Humans by swarm systems.

Thus, one can separate the interaction effectors and the feedback representation on the one side and the complex system on the other. Effectors and feedbacks are abstractions of the real system for a better Human understandability. For instance, when driving a car, we manipulate abstract effectors (wheel, pedals...), which have a direct or indirect influence on the global system (engine, gearbox, wheels, tyres...). In this example, the feedback is made through a Human perception of the car behaviour. Following this two-side separation concept, the device presented in this paper is split into a tactile device, which plays the abstract effector role and the Sphere, which represents a visual feedback of what happens in the multi-agent system.

III. Principle

As previously said, Sphericall is composed of two devices.

- A tactile device, based on a multipoint capacitive screen. This screen can be considered as a mixing interface used by the Human so as to interact indirectly with the agency by modifying music characteristics (volume, pan...).
- A video screen representing a 3D sphere, which is the work of art built thanks to Human/multi-agent system interactions.

The next sections will describe in detail these two elements.

A. Interactive Interface

1) Technical tools

The tactile interactive interface is based on two libraries developed by Tharsis Software: SimpleSound and SimpleUI.

SimpleSound is a library aimed at managing sound devices. It provides programming elements to develop real time mixing tools. Thanks to this library several audio files can be read at the same time (In this case, the audio files are merged into an audio group). Their characteristics (volume level, pan...) can be modified during the reading of audio files as it can be made with a classical hardware or a software-mixing console. In addition, effects and information filters can be added. Information filters allow specific information on the signal such as output level, Fourier transform, band pass... to be obtained.

SimpleUI is a graphic library developed by Tharsis Software (see http://www.tharsis-software.com/ for more details) and based on OpenSceneGraph (OSG). This library allows adding, removing and manipulating various types of widgets such as buttons, images... For this project a physical layer, using Box2d, has been added in order to provide widgets with coherent physical behaviours such as inertia, collision management...

2) Appearance and behaviours

In the designed mixing interface, a circle represents each channel. Channel circles are grouped into a Group Channel. The volume of a circle is linked to its vertical position, its horizontal position defining the stereo position of the audio source (pan left/right). A short touch on a circle triggers the activate on/off function. Each group Channel has its own colour (blue and green for keyboards, bass and drums, pink and orange for the orchestra and the voices). The final interface used for the demonstration is composed of 21 channels spread into 5 groups. The circle can interact with each other through collisions. Thus, one can send one group in the direction of another. When the collision occurs the groups react as snooker balls, which collide each other and involve changes in volume and pan position. The same interaction can be made with channel circles inside each group (cf. Figure 1).

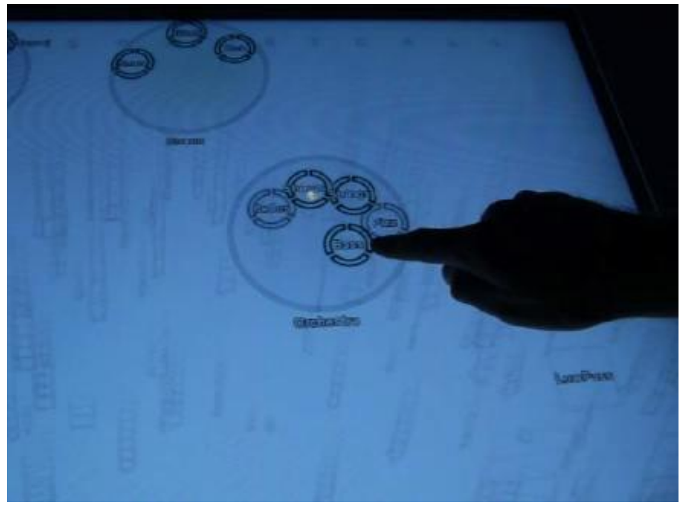

Fig. 1. Interactive Interface: Groups

Sound effects are represented by little coloured square buttons. The activation of them is the same as the one for the circles. The position of the square button in the interface field is linked to two parameters specific to each effect.

Finally, four classical buttons have been placed at the top left corner of the interface. These are for general purpose such as the rebooting of the Sphere and/or the rebooting of the mixing interface, sound effects visible on/off toggle, and 8-band equalizer on/off toggle (cf. Figure 2).

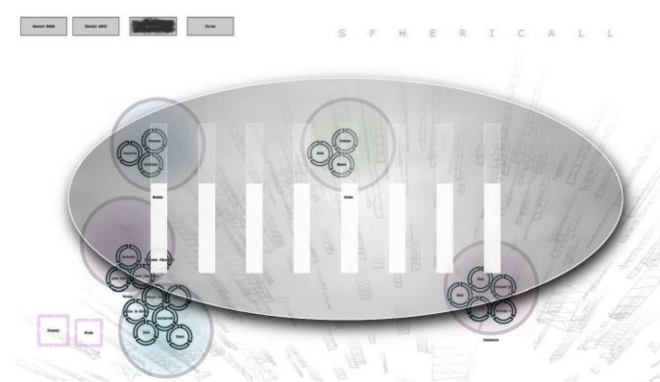

Fig. 2. Interactive Interface: Equalizer

3) Comparison with similar devices

The appearance of the sound control part can appear to be similar to some commercial tactile mixers such as Line6 StageScape or digital audio workstation tablet interfaces (V-Control, AC-7 Core...). However, these are generally a transposition, within a tactile screen of the functionalities of a standard mixer. In some exceptions, as in [15] for instance, the tactile mixer is coupled with a haptic device enabling the user to "sense" the sound.

The key difference in our proposal is the fact that the mixer already includes a multi-agent system. Each mobile element is an agent and behaves following interaction rules with other agents. For the moment the interactions between mixer-agents are simple collisions, but one can imagine changing them to use other interaction models such as gravitation-based repulsions. In this case, the interaction model will lead to an emergent behaviour of the channels and the groups similar to satellite orbits and involving influences on the diffused sound.

For the moment, we decided to use simple collision to make the mixer easier to use. Hence, the influence on the sound can still be considered as the product of the direct Human interaction (as in a regular mixer).

B. Sphere world

1) Environment

Instead of using classical planar environment for this experiment, we chose to provide to agents a spherical environment. This kind of environment is not widespread in agent related work because it requires the expression of influence forces, distances,... into spherical coordinate system which is not necessarily adequate in agents systems.

Since all agents move on the surface of the sphere, their coordinates consist only in a couple of angles q and f , r being always equal to sphere radius. (cf. Figure 3). The gravity relies then only on the variations of r . Thus, every element (perceptions, acceleration, speed, position...) is defined using a spherical coordinate system.

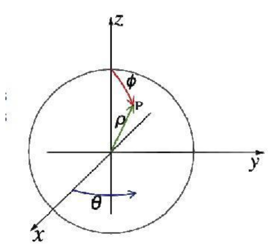

Fig. 3. Spherical representation of agent positions

For the localisation of the elements, and for the frustum culling, a QuadTree has been developed to manage the (θ, Φ) plane. (cf. Figure 4). This structure is generally used for 2D worlds. The main interest, in this application, is to allow a localisation of any entity with a logarithmic complexity. Moreover, even while maintaining a 3D representation of the world, the computation cost is very low since everything is computed as in a 2D world.

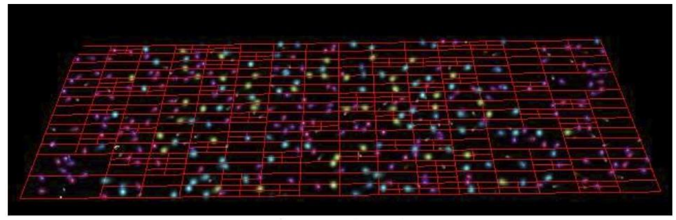

Fig. 4. Quadtree planar representation

Of course, the choice of such an environment implies several drawbacks. First of all, the management of the values of the angle on the limits of the cosinus and sinus functions make the continuity of the world hard to maintain when computing agents' movements. Besides, even if there is a bijection between the sphere and the (θ, Φ) plane, it is required to define a transformation function to translate measurements made on the plane into their equivalent in the sphere world.

2) Agents: role and interactions

Figure 5 represents the sphere agency organization using a RIO (Role, Interaction, Organization) diagram as defined in [21]. This diagram represents the different roles that can be played by agent (μ, γ, β, δ roles) and the interactions between these. The next paragraphs detail these elements.

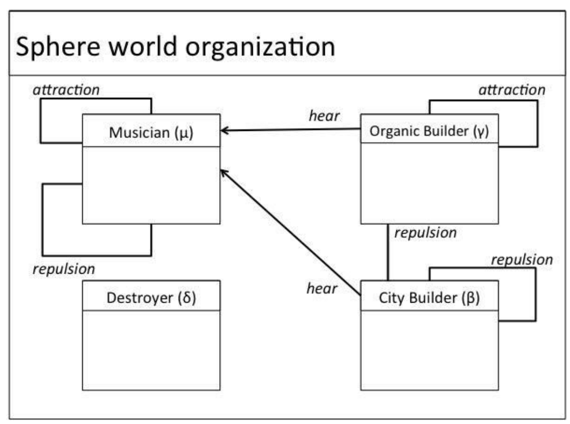

Fig. 5. RIO diagram of Sphere world

➢ Agents roles

- **μ role**

This role corresponds to the musician's role. Each musician is linked to an audio channel and emits the sound of it into the sphere world. This role can be considered as the link between the sound world (the mixing console) and the visual world (the sphere).

The agents which play this role, are attracted by other μ agents of the same mixing group. By contrast, all other agents, including μ agents of other mixing groups, are repulsed by them.

- **γ role**

This role corresponds to an **organic builder** role. Agents, which play this role, build organic structures (vegetable) into the sphere world. This role is sensitive to one specific μ role (i.e. one specific sound channel) by which it is attracted. The behaviour is similar to fireflies. A gauge is fed by the sounds that came from the associated musician. The nearest the musician is to the γ agent, the more the gauge is fed. When the gauge reaches its maximum value, an organic structure is built. During the construction of the structure, the γ agent is inactive. After this, the agent disappears and let the place to a new γ agent created randomly on the sphere.

The agents, which endorse this role, are attracted by the organic structure and repulsed by β agents (defined in the next item) and by their constructions (buildings).

- **β role**

This role is similar to the role of γ. The main differences are the following:

1. The structures built are big buildings similar to skyscrapers.
2. Agents, which endorse the β role, are repulsed by both β and γ agents.

- **δ role**

This role corresponds to destructors. Agents, which endorse this role, are attracted by skyscrapers, which they destroy when they are on them. When there are no buildings left, δ agents move randomly on the sphere.

In order to obtain good visual results, β agents are associated to bass, keyboard and drum sounds. Voices and strings are associated to γ agents. Hundreds of agents of each type are created to obtain the results shown in figures 7 and 8.

➢ Interactions

This section described in detail the different interactions used between agents. After this description, a summary of all interactions used in the sphere world is made in table 1.

- **Attraction**

The attraction law is a standard linear equation. The more the attracted agents are near to each other the less the attraction is important. This law is described by the following equation:

$$\overrightarrow{F_{A_iA_j}} = \beta . m_{A_i} . m_{A_i} \overrightarrow{A_iA_j} \quad (1)$$

This equation represents the attraction force applied to agent A_i due to the presence of agent A_j. In this equation β is a scalar multiplier, m_{Ai} and m_{Aj} are respectively the mass of agent A_i and A_j.

- **Repulsion**

Repulsion can be treated as a negative gravitationnal force between two weighted elements. As with natural gravitational force, repulsion depends on the $1/r^2$ value, where r is the distance between agents.

The following equation shows the analytic expression of the repulsion force applied to agent A_j taking into account the influence of agent A_i. α is a scalar multiplier that takes into account the environmental gravitational constant and the proportion of attraction compared with the other forces.

In practice, since the agents' environment is virtual, this constant allows us to tune the importance of the repulsion behaviour relative to the other forces. In this equation, m_i and m_j are respectively the weight of the agents A_i and A_j.

$$\overrightarrow{R_{ij}} = \alpha . m_i m_j \frac{\overrightarrow{A_iA_j}}{\left\| \overrightarrow{A_iA_j} \right\|^3} \quad (2)$$

TABLE 1
SUMMARY OF INTERACTIONS BETWEEN SPHERE ELEMENTS

	μ agent	**γ agent**	**δ agent**	**β agent**
μ agent	attraction/ repulsion	hear	x	hear
γ agent	x	x	x	repulsion
organic structures	x	attraction	x	repulsion
δ agent	x	x	x	x
β agent	x	repulsion	x	repulsion
buildings	x	repulsion	attraction	repulsion

3) Resolving dynamical equations

The position, speed and acceleration for each agent are computed in a continuous world.

The agents' dynamical characteristics are computed following the laws of the classical Newtonian physics. Each behaviour, applied to an agent, corresponds to a force, which influences its movement. The behaviour is selected according to the role endorsed by the agent and the roles of its nearest mates.

By applying the fundamental law of dynamics, we can compute the acceleration of each agent (cf. equation 3). Here, $\vec{\gamma}$ represents acceleration, m the agent's mass, and $\overrightarrow{F_b}$ the force resulting from behaviour b.

$$\vec{\gamma} = \frac{1}{m} \sum_{behaviors} \overrightarrow{F_b} \quad (3)$$

Introducing a fluid friction force defined, and integrating twice we obtain the following equations:

$$\overrightarrow{V_t} = \overrightarrow{V_{t-1}} + \frac{\delta t}{m}\left(\overrightarrow{F_{attraction}} + \overrightarrow{F_{repulsion}} + \overrightarrow{F_{friction}}\right) \quad (4)$$

$$\overrightarrow{V_t}\left(1+\frac{\delta t}{m}\lambda\right) = \overrightarrow{V_{t-1}} + \frac{\delta t}{m}\left(\overrightarrow{F_{attraction}} + \overrightarrow{F_{repulsion}}\right) \quad (5)$$

$$\overrightarrow{X_t} = \vec{X}_{t-1} + \left(\vec{V}_{t-1}\delta t + \frac{(\delta t)^2}{2m}\left(\vec{F}_{attraction} + \vec{F}_{repulsion}\right)\right)\left(\frac{1}{(1+\frac{\delta t}{m}\lambda)}\right)$$

(6)

where $\overrightarrow{X_t}$ is the position of the considered agent at time *t*, $\overrightarrow{V_t}$ its speed, $\vec{F}_{repulsion}$ the sum of all repulsion forces applied to the agent, $\vec{F}_{attraction}$ the sum of all attraction forces and λ the fluid friction coefficient of the environment.

C. Software implementation

The software implementation has been made under C++ following the class diagram presented in figure 6. Each agent involved in the sphere world inherits from the abstract class Agent, which defines the live() method. This method corresponds to the behaviour of the agent. Its purpose is to compute the equations (3) to (6). This method is overloaded in each specific agent so as to embed specific characteristics such as the forces involved by the role. The scheduler class is a thread loop that calls the live() method of each agent one after the other. The agent are linked to the Environment class which manage the positions of the agents on the sphere. The GUI part (not detailed in the class diagram) corresponds to the set of classes aimed at managing the graphical interface of the sphere. The link between the sphere and the tactile interface is made through the μ agents, which are associated to audio channels. They have state values named pitch and level, reachable by γ and β agents. Depending on these values, γ and β agents will react if it corresponds to their behaviours. A low pitch value is associated to low frequencies, triggering β agents behaviour and a high pitch value is associated to high frequencies so as to trigger γ agents behaviours. The level value is used to feed the gauge of the agents.

On the dynamical point of view, the `live()` method starts by sending the position of its associated agent to the environment. As an answer, the environment sends back a list of the nearest agents with their characteristics (position, type, pitch,…). Using this list, the agent chooses the forces to be applied and computes its acceleration, speed and position. Then, it updates its position in the environment. The scheduler can now loop on other agents.

The link between the sphere and the tactile device is asynchronous. The thread of the tactile device updates the pitch and the level values of μ agents each time it is possible depending on the music timeline. The time schedule of the sphere world is faster than the music time schedule so as to ensure a better reactivity of the sphere.

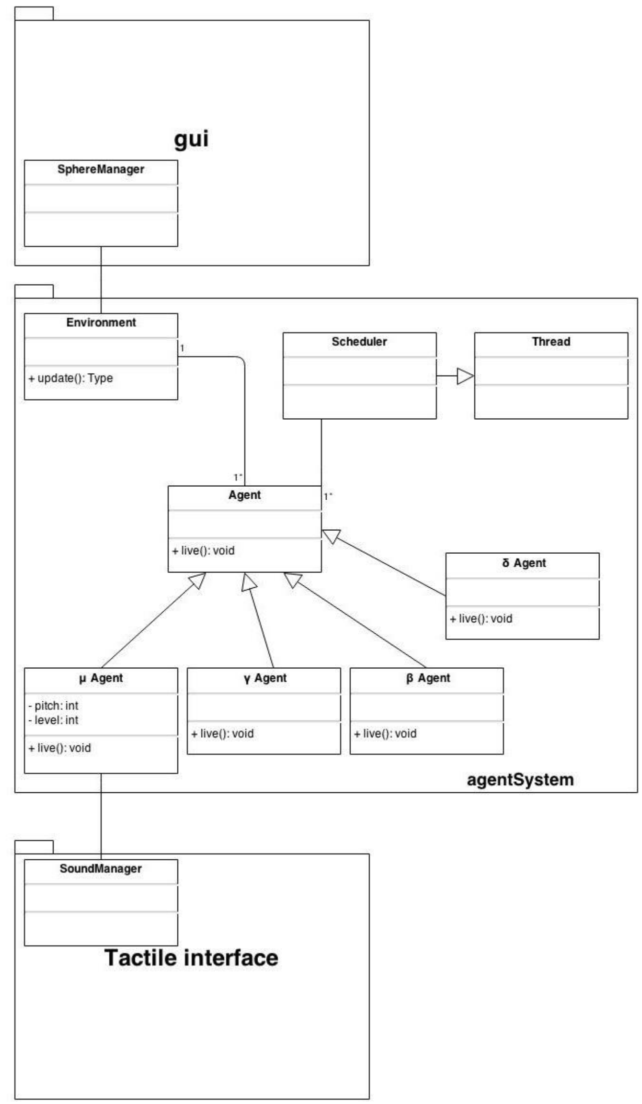

Fig. 6. Agents system class diagram

IV. OFFF Festival presentation

After a presentation of OFFF Festival, this section will draw on the results obtained during the demonstration.

A. OFFF Festival

Since 2001, OFFF (http://www.offf.ws/) festival has been held in Barcelona, becoming the globally recognized and trendsetting event it is today. OFFF Festival was initially the Online Flash-Film-Festival. After 3 years of existence, it became the International festival for the post-digital creation culture but kept the short initial designation. OFFF is spreading the work of a generation of creators that are breaking all kind of limits, those separating the commercial arena from the worlds of art and design; music from illustration, or ink and chalk from pixels. Artists, those have grown with the web and receive inspiration from digital tools, even when their canvas is not the screen came to the festival.

Fig. 7. Sphericall device

B. Sphericall demonstration

1) Global feeling

Our set fits perfectly with the general appearance of the festival area. The design of the device and the appearance of the Sphere are very attractive to the audience. The public doesn't hesitate to manipulate the device. The feedback on the mixing console use and on appearance is very good. The casual users succeed in manipulating the device easily and seem to adapt quickly to the relationship between the audio part and the mixing device. The use of the circular shaped buttons, which can collide with each other, adds an entertaining aspect as compared to the classical use of a mixing console.

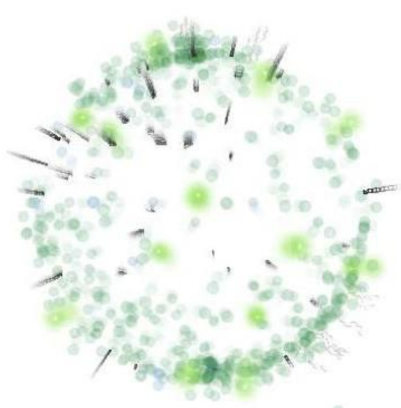

Fig. 8. Global illustration of the 3D sphere (reversed colors)

After a couple of minutes, the question on the link between the mixing console and the sphere arrives. Indeed, the link between the manipulation of the mixing console and the appearance of the sphere is not as direct as the link between the sound and the mixing console part. The relationship between these two components has thus to be explained. After a short explanation of the whole system, the casual users return on the table so as to try to figure out the side effects that occur on the sphere when manipulating the sounds. We estimate that almost 85% of the users found the interface easy to use even if in 70% of the cases they took more than 10 minutes to understand the relationships between the music controller and its effects on the sphere well. After 10 minutes, all the users were able to play with the sphere making abstraction from the tactile interface. After this, the user no longer looked at the mixing console but stared at the sphere world. If some effects are natural and easy to find (bass levels...) some other are subtler and need a deep investment in the use of the system.

From the technical point of view, the questions we encountered concern mainly the agents and their characteristics as compared to other techniques. Some artists, having already the habit of using interfaces such as *Processing* (http://processing.org/), *openFrameworks* (http://www.openframeworks.cc/) or *Cinder* seem to be very interested by the concept we have developed.

2) Analyse of the users' behaviour

The main innovation is in the way the user can interact indirectly with the system. By controlling, via this simple interface, the music and sounds produced, the user is actually linked with the whole artificial intelligence of the system, and, like a conductor, smoothly leads how the agents will act - and interact - thus how the scene is rendered. This is quite different from a standard "visualisation" plugin, where most of the time the colours and shapes rendered are directly calculated from the sound waveform.

The user faces a two-level interaction: as he may be used to, he directly hears the changes he makes in the music, but he also focuses on the consequences of his choices. This is different from a real-time strategy video game, where he knows how to control each unit, and expects them to behave exactly as he orders or from a passive 3D visualisation plugin, where everything is computed. His choices directly influence the behaviours of the agents, but without dictating them: the global result can be guided, but never predicted.

There is a permanent curiosity lightened in the user: it's a new approach for building interactions between Humans and computers, which leaves, when necessary, some parts of the decision process to the computer. We can for instance think about an interface with intelligent and independent components, which adapt to the user choices and habits.

The result obtained visually is the interaction between the Human and the Artificial Intelligence (AI) of the system. This experiments shows that, even without training sessions, the Human player is able to interact with a complex system provided the interaction device is simple enough. Moreover, the interaction device has to be based on notions and feelings already experienced by the user in another context. In our application, the visual result is obtained making the user play with sounds and not directly with the parameters of the AI.

So as to have more details on the use of the Sphericall device, other experiments were made with a set of students who used to manipulate multi-agent systems. We firstly proposed to the students a direct control through agents parameters manipulations. In this situation the control is less easy and the students, despite their knowledge in multi-agent system, had some difficulties to well understand the implication of each parameter change. By contrast, using the tactile device and the sound feedback, untrained users were able to easily manipulate the system. After this experiment, the students had filled out a short questionnaire. The goal of this questionnaire was to rate the easiness of the interface in terms of understandability of the link between manipulators and sphere. The questions were the following:

1. Is the manipulation of the agents parameters easy to understand?
2. Is the link between the parameters and the sphere appearance easy to understand?
3. Is the manipulation of the mixing control device easy to understand?
4. Is the link between the mixing control device and the sphere easy to understand?
5. Are the modifications of sphere appearance logical in relation with the change performed on the sound device?
6. Which kind of control do you prefer?

Students had to give an answer between 1 and 5 for the first 5 questions. (1 corresponds to fully disagree and 5 to fully agree). The results obtained with a set of 35 students are presented in table 2.

TABLE 2
RESULTS OF THE STUDENTS QUESTIONNAIRE.

Question	1	2	3	4	5
1	20%	26%	43%	8,5%	2,5%
2	43%	48,5%	8,5%	0%	0%
3	8,5%	14%	20%	34%	23,5%
4	2,5%	14%	26%	28,75%	28,75%

Table 2 shows clearly that not only the mixing console is easier to manipulate but also that it allows students to better understand the correlation between the sphere world and their manipulations. Of course, for question #5, more than 90% of the students prefer the mixing console to the direct parameter manipulation. These results show that the mixing console device helps the user to better understand the complex world of the sphere. In most of the cases, the user better understands the system with the abstraction as compared to the whole explanation of the entire system. Consequently, providing a well-chosen abstract interface makes the task of understanding the complex system easier. The example chosen there is a little biased because it is based on elements that are based on common knowledge and easy to understand. However, we think that this experiment gives interesting enough results to be explored in other fields more deeply.

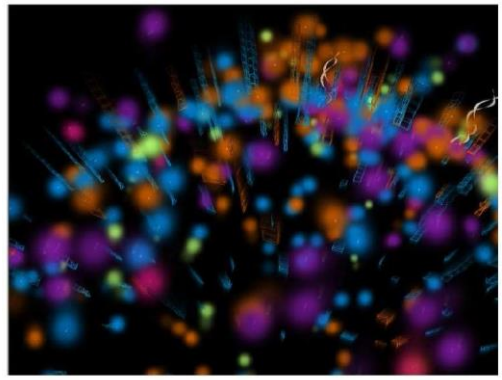

Fig. 9. Details of the sphere

V. CONCLUSION

This paper presented Sphericall, an application aimed at studying Human/agency interactions. The Sphericall device, composed of a tactile screen and a sphere world where agents evolve, has been deployed during the OFFF festival in La Villette. The two devices are developed based on the multi-agent paradigm. The tactile device differs from commercial tactile mixers on the fact that the result in music control is obtained taking into account both user manipulations and interaction behaviours of graphical elements. This tactile mixer can be considered as an abstraction of the complex world of the Sphere. The Sphere as itself is represented in 3D and allows the result of Human/System interactions to be shown. This deployment was a public success and allows having a great feedback on the deployment of such a device. The application is intuitive enough to permit a non-scientific public to interact with the artificial intelligence. Indeed, it’s hard to handle the complexity of such systems. The solution presented in this paper relies on an interface aimed at translating the complexity of the Sphere world into a more easily understandable effector unit. The feedback, as itself, is made through the Sphere representation. On the artistic point of view the results obtained were really appreciated by the public. A movie of this event is available at http://www.youtube.com/watch?v=iDEkBE6Cbz8.

We now plan to use the knowledge acquired through this experiment to other application fields such as authority sharing in complex decision systems. The two main targets we plan to deal with are the following: (1) Trying to increase the fan-out of Human-robot team using abstract multimodal interfaces such as the one used in Sphericall. To that way, we will focus our research work on the nature of the representation of the data and on the observation/interpretation of the Human behaviour. We are now exploring interfaces based on natural gesture recognition. (2) Trying to enable the manipulation of big databases using Sphericall-like interfaces. The main issues encountered are linked to the representation/manipulation of the data and to the introduction of queries using an abstract interface.

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Franck Gechter. After a Master in engineering and a Master in photonics and image processing from the University L. Pasteur Strasbourg I (France), F. Gechter received the Ph.D. in Computer Science from University H. Poincare Nancy I (France) in 2003, where he served as an assistant Professor from 1999 to 2004 and as researcher at “Laboratoire lOrrain de Recherche en Informatique et ses Applications” (LORIA) from 1999 to 2004. In 2004, he became Associate Professor in Computer Science at "Université de Technologie de Belfort-Montbeliard UTBM" and Systèmes et Transport Laboratory where he is member of the Computer Science: Communications, Agents and Perception Team. He works particularly on Reactive Multi-Agent models applied to problem solving, to decision processes and to data fusion. In 2012, he became also associate researcher to the Fuel Cell Laboratory (CNRS federation of laboratories) to focus on fuel cell systems simulation taking into account multi-level and multi-physics aspects. In 2013, Franck Gechter passed his Habilitation to Lead Research Work (HDR) at the Franche Comté University (UFC).

Bruno Ronzani: Bruno Ronzani got his master degree in computer engineering with an emphasis in virtual reality and artificial intelligence in 2010, from the University Of Technology of Belfort-Montbéliard, France. He now works as a creative technologist in the parisian digital agency Oyez, in parallel with his musical activities.

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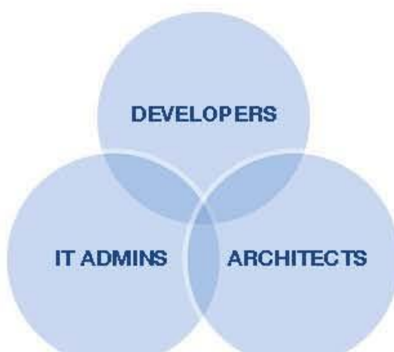

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