Toward a semantic based signage digital system: Mediactif

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***Abstract*—Digital signage systems distribute all kinds of information to specific locations, including retail stores, public areas and transportations. Thanks to the massive adoption of displays and wide application of wireless networks, digital signage can deliver targeted messages designed to accurately reach the passing audience and eventually influence customers. The aim of the MEDIACTIF project is to develop a new digital signage concept, using both human traffic modelling and compartmental behavior based on interests. The major issue we are facing as of now is that crowd motion has extensively been studied on particuliar test cases, on both macroscopic and microscopic levels, but it is lacking considerable social and personal inputs, which are significant for each site and scenario.**

Keywords–digital signage; real-time; network; sensors.

I. Introduction

The MEDIACTIF Project [1] has been started a year ago to propose solutions to different problems:

- Reducing the stress of fair visitors or airports clients by reducing crowd congestions and increasing the pedestrian flows.
- Giving relevant information to users and the operations team in real time.
- Offering a centralized system that may adapt signage to any situation.
- Increase security levels with adaptive signage (redirect pedestrians easily in case of emergency situations)
- Reducing global waste of both printed signage materials, but also aiming at a massive drop in the consumption of high toxicity materials like inks.

Partners on this project have different fields of expertise and some of them are facing day to day issues regarding their fixed or dynamic signage impact over people behaviors. They would like to efficiently inform clients or simply redirect them to a specific location.

The MEDIACTIF Project aims not only to display different contents on screens, but also to integrate multiple sensors in the processing loop. This would allow for signage adaptation depending, for example, on:

- crowd densities
- personal preferences
- commercial factors of interest
- specific or recurrent events
- previously computed models and statistics

These models should be driven by the analysis of previous sessions (when available) and will be enhanced with the sensors live input. To reach this aim, Mediactif system uses different kinds of sensors, a model engine and semantic tools.

II. System architecture

MEDIACTIF will be an adaptive and centralized system. All relevant data will first be collected by a specific module and will serve to compute crowd models. These will be used for crowd traffic prediction. They will act as the base module for all corporate models like airports and event organizers. It should also allow mobile services (free or not) for visitors via apps or web services. According to the state of the art regulations, it has to follow network standards to pilot existing digital signage systems and to communicate with its own devices. The back-office architecture is organized around communication, events and sensors management. For a fair, or for an airport terminal, it is possible to define basic events or rules (holidays, week-end, plane arrivals and departures) and associate, to each of them, fixed plans to anticipate crowd variations. Using key sensors values, it is possible to manage adaptive modes (last minute gate changes, system failure, human weaknesses, etc.). One of the key rules will be to immediately handle a crowd increase, but awaiting stabilization for a decrease.

III. sensors

Sensors, in MEDIACTIF, are to give relevant information concerning crowd observation. When dealing with human sensing, we can enumerate five different objectives: presence detection, counting, location, tracking an identification [2]. In the case of non instrumented people, for presence detection, simple binary sensors can be used : e.g., passive infrared (PIR), pressure sensitive tiles, electric field sensors and vibration sensors. Among the limitations of these sensors, we can highlight for the PIR sensor the fact that it can't detect an immobile person. Pressure sensitive tiles can't enable the distinction of two close persons (50 cm)[3] and vibration sensors are very sensitive to noise. Other non instrumented sensors, based on signal propagation, can also be used for our project: radio signals, acoustic wave, laser. More precisely, Radar, sonar and

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ladar are used, according to either the attenuation of the signal or the propagation time of the signal, to reconstruct an image. Ultra-wide Band (UWB) can be used for detection and localization [4], and in the case of radio propagation, the measure of the doppler effect is a mean to obtain movement detection. Camera is, of course, an appropriate solution for detection, identification, tracking, counting and people queue estimation, with appropriate signal processing algorithms [5][6]. For our project, the instrumented approaches we can use are either a device to device approach, with specific application developed on mobile phones, or the scanning of radio signals in the environment, such as WIFI signal [7]. In the case of device to device approach, the localization can be as precise as 20 cm with time of arrival (TOA) and time difference of arrival (TDOA) principles [8]. In the context of MEDIACTIF, the choose of the sensors will depend on the possibility to use instrumented or non instrumented systems. The more appropriate instrumented solution is the use of localization based on TOA/TDOA, coupled with area sensing. If we have to choose non instrumented solutions, the best solution would be the use of camera, coupled with dopplers sensors. In term of price, the solution with the lowest cost is the use of binary sensors.

IV. Crowd analysis and models

The major issue in handling pedestrians is to define accurate models valid for a wide range of topologies and flow densities. Models should also be realistic, robust against incomplete data, and of course computationally manageable. Pedestrian dynamics share some similarities with fluids, and it is not surprising that the first models of crowds were inspired by hydrodynamics or kinetics of gases. The main idea is to consider that the movements of a pedestrian in the crowd are similar to movements of a particle in a gas. Based on this assumption, it is possible to make use of tools from Newtonian mechanics to describe the behavior of a pedestrian by means of attractive and repulsive forces. The pedestrian is attracted toward a destination point, but at the same time repulsed by other pedestrians. Henderson found as early as 1971, from measurements of motion in crowds, a good agreement of the velocity distribution functions with Maxwell-Boltzmann distribution [9]. Social forces have been introduced by Helbing in a microscopic model [10] based on the idea that pedestrians have different perceptions about intimate/personal and social space, which leads to repulsive forces between persons. Cellular automata [11], [12], [13], [14] are another important class of models that are discrete in space and time. Most of these models represent pedestrians by particles that can move to one of the neighboring cells based on transition probabilities which are determined by the desired direction of motion, interactions with other pedestrians, and interactions with the infrastructure (walls, doors, etc.).

A. Rejected models

However, unlike Newtonian particles, persons have a free will and may want to avoid jams by giving up their preferred path when approaching a crowded area to find a new path. To take into account such strategies, microscopic models are to be extended well above the present state of the art. Stochastic behavioral rules may lead to potential realistic representations of complex systems like pedestrian crowds, however, parameterization and calibration of such models may remain elusive.

The aim of the MEDIACTIF project is to have an enhanced digital signage system. This implies that all signage could be updated depending on crowd behavior, external events... The key point is modeling the crowd behavior, using some key rules. That's why some models are not relevant for the project purposes:

- Particle mechanics based models : all pedestrians interact between themselves as particles. This model subset uses a collection of global rules. The problem is that pedestrians are not particles. To describe precisely the movements of a pedestrian with Newtonian forces, one usually needs pretty sophisticated equations of motion, which are hard to calibrate. Moreover, the movements of pedestrians during computer simulations look pretty artificial and sometimes obviously not realistic. It is impossible to direct individual entities when necessary.
- Fluid mechanics based models : at the beginning of '70s, Henderson worked on a fluid mechanics based modelization [15]. It was a global crowd modelization, with one set of rules for all particles.
- Cellular automaton models : the simpliest way of cellular automation is the deterministic model of Fukui-Ishibash.
- Predator-Prey models : crowd behavior could be modelized using Lotka-Volterra equation [16].
- Epidemiological models : some crowd events could uses this kind of rules. But, if it can be used for disease dissimination using communication means (plane, train, road etc.) it is far less useful for a commercial center or a fair.

In fact, any global equation based models doesn't fit because it is mandatory to distribute some comportemental rules to a set of pedestrian (like family, businessman, elderly people...). And then we decided to select an agent based model [17].

B. Tools

MEDIACTIF project implements 3 main functional elements needed for a crowd characterization : crowd analysis from sensors, model definition and use for prediction, and offline simulation.

C. Crowd Analysis

The first step to determine crowd behavior is to analyze its comportment in typical situations. Criteria choice is the most important thing to refine. In fact, these criteria must be the same for analysis but also for the model definition and of course for simulation.

To handle digital signage impact, it is necessary to consider the vision field of each pedestrian. If provided information is walking time to a specific place (20 minutes by the left way, 5 by the right one), its possible impact is only on pedestrians that have this information in line of sight. Depending on sensors, it is necessary to exploit every solution in Vision, Learning and Pattern Recognition to select crowd-scene key behaviors.

Some Smart Cities projects try to implement these kind of functionalites. For example, the Inria Project Lab City-Lab@Inria is currently under creation and studies information and communications technology (ICT) solutions to promote

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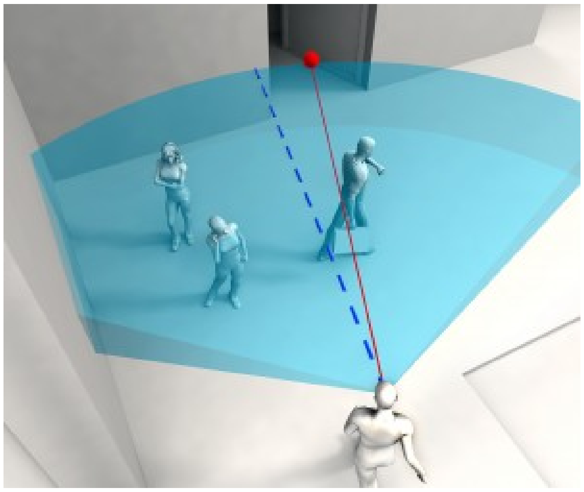

Figure 1. Vision Field Model

social and environmental sustainability and facilitate the transition to Smart Cities. Another example, CNR-ISTI in Italy: HIIS Lab develops a framework for improving the multi-device user experience in Smart Cities. This framework proposes a solution that extends existing Service Front Ends for Smart Cities and supports multi-device interaction by exploiting personal devices and public displays. It can be used to easily obtain interactive multi-device applications for different domains and in different contexts in Smart Cities including single or multi-user applications, indoor or outdoor environments and mobile and stationary devices. ([18][19])

D. Multi-agent Model

There are different kind of models, with their own algorithms [20] [21]. To manage the crowd as a group of individuals with their own interests, their own objectives, their physical characteristics, only the multi-agent models, individual-based, can match the needs of the project, with very diverse characteristics (airports, trade shows, fairs ...). A good model should be able to predict the emergence of known collective crowd behavior, such as lane formation or crowd turbulence.

The proposed theoretical model is based on a fairly simple concept [22]. The first step is to mathematically describe the visual information that a pedestrian can see in a crowd and how a pedestrian behaves in a crowd. For this, it is necessary to define the limits of the visual field and calculate the distance before colliding with other individuals and obstacles (see Figure 1).

The next step is to set two simple rules to adjust the trajectory of the pedestrian, especially its speed and direction based on the previously calculated visual information.

- The first one is to choose a direction of travel that minimizes coverage of vision without deviating too much from the point of destination.
- The second one is to set walking speed to maintain a safe distance to the nearest obstacle or individual.

These rules are called heuristics - a term describing cognitive science quick decisions that people do not think too much about their behavior.

The last step is to realistically reproduce a moving crowd in congestion situations, the movement rules are combined with the physical forces that occur during unintentional body contact.

E. Simulation

Crowd simulation is necessary to setup properly sensors and displays to provide an efficient sytem based on dynamic signage. Modelling is the basic tool for simulation. Numerical simulations of the model previously described is able to generate a large variety of collective behaviors, such as the spontaneous separation of opposite flows of pedestrians in bidirectional traffic. The model can also predict typical situation as bottleneck or congestion due to, e.g., a right angle corridor. The results are promising and seem far better than other simulators we evaluated. The evaluated tools integrate behavioral functions. They simulate an average behavior if an peculiar event occurs. But none of them integrates a behavior action when a signage change (for example : going left instead of going right if a congestion accurs):

- Anylogic [23]: used by many airports. AnyLogic provides complex solutions to plan, manage, and optimize pedestrian flows in public buildings like airports, railway stations, shopping malls, and stadiums. The software can evaluate the capacity of buildings and certain objects, find and avoid pedestrian bottlenecks, optimize business processes at service points, carry out evacuation planning, assess shopping area customer traffic, evaluate parking, roadway, and public transportation accessibility. But it is difficult to integrate vision in a model.
- SimWalk [24]: integrate some tools for external events like baggage, interconnection but no vision parameters nor signage simulation.
- Pedestrian dynamics [25]: Adaptation to dynamically changing (local) conditions. As in reality the situation can change during the simulation.
- Mass Motion [26]: This system is highly scalable for large crowds and for simulations scenarios that cover multiple days.
- CAST Pedestrian [27]: airport facilities solution but simulation doesn't handle external events.
- MATSim + Via [28]: The mobility data provided by Senozon, or the results of MATSim simulations in general, can be very large and do not give much away in the raw format. The analysis tool allows to easily extract important characteristics of the data in a short time. It is useful to extract main characteristic of a flow but is less relevant for crowd.
- Pedsim [29]: this simulator is in fact a library to create a specific simulation tool. There are many ”odd” comportment especially for right angle congestion .
- PETrack : pedestrian trajectory extracting tool using a video stream.
- JuPedSim : Jlich Pedestrian Simulator is an open source framework for simulating pedestrian dynamics. Several well-known models from the literature are implemented. It provides researchers and students preparing their projects an appropriate environment to

model and simulate pedestrian dynamics. This product is at an early stage and tests don't give better result the particle or fluid models.

To evaluate and predict behavior when using MEDIACTIF system, it is necessary to develop a simulator that handle characteristics of dynamic signage. Otherwise, there will be a simulation and prediction tool that will not give relevant results; as if for a crowd of rabbits using grass resource of a field, simulation use goat comportment parameters.There will be no chance to have results that are valid, consistent or usable.

V. SEMANTICS

A. Related works

1) Semantic inside signage digital systems: The display of contents adapted to users recently became a very attractive research field especially for business purposes. With the democratization of mobile phones and a continuous trend towards big data, particularly oriented on users preferences and inclinations, it is now easy to display personalized content [30]. One of the current objectives nowadays is to suggest places [31][32] or offers [33] best suited to each user. With the smartphone applications ecosystems, it is now relatively easy to get users' information and then use state of the art methods like collaborative filtering [32] or model based recommendation methods [31].

The challenge now is to propose the same recommendation efficiently on common displays in generic areas while over the years 2000, researchers focused only on screens in specific contexts like for instance offices [34] or inside sport halls [35], etc.

Another difficulty arises in taking into account groups and not only single users as primary targets: past recommendation algorithms were well adapted to single users but are falling short for groups. [34], [36] and [35] attempted to solve this shortcoming using very simple methods like averaging each users' scores.

Thus, making precise recommendations to a group of users still proves to be quite challenging. Moreover, attempting to make these on regular displays and not only on mobiles is adding an extra layer of complexity since it becomes more complicated to obtain individual inputs, not even accounting for the actual up difficulty to keep abreast of the content to display [37]. Search engines, are not only good alternatives to data mining methods since they remove sparsity issues, but also allow us to easily add, update and delete content in real time with little to no impact on the searches. Therefore, in this project, we attempted to use a search engine inside a digital signage system to drive content suggestions for single users as well as groups.

2) Pedestrian navigation on display screens: The MEDIACTIF project aims partly at helping pedestrians to navigate correctly both indoor (inside buildings [38], for demonstrations, conferences...) and outdoor (in towns, subways [39]...) [40]. Usually, mobile phone applications are used for this particular job. The obvious advantage is that we are able to get information such as a destination by simply asking a user, and then to compute the most appropriate path for him to get there. It is still slightly basic and user centric, thus implicating multiple display screens seems like a natural evolution. When a user passes in front of a display, his mobile phone can share his destination with the display. Then the display can show an updated map with proper redirections calculated in real time [41] and corresponding to the present geographical location [42]. Some researchers are even trying to mix the previous methods of collaborative filtering in order to guide users to their destinations and potential Points of Interest (POI) [43].

This is precisely what we are focusing on in the MEDIACTIF project : to allow for some people flow regulations.

B. Pertimm

Pertimm is providing a search engine to major e-commerce customers. The idea here is to integrate Pertimm's search engine inside the global system in order to not only regulate people flows but also to suggest activities corresponding to people desires and of course, having the possibility to select points of interest suited to both a group of person as well as single users. Therefore, the development is following a three steps approach: We will first create a basic system of search recommendation only based on simple queries in order to integrate Pertimm inside the system. Then, we will expand the functionalities with content based recommendations. Finally, we will upgrade the previous solution in order to create a system based on collaborative filtering for multiple users.

1) First step : basic search.: To enable the system to use the search engine as a basic search, it is necessary to first use devices that enable users to make search requests. Indeed, with absolutely no knowledge about the user, it is not possible for us to generate any appropriate request/answer. Thus it is necessary to let the user drive the system. This is actually how most digital signage systems currently work. Let us picture a user in a mall, looking for a particular shop on a store locator device (usually some big table/screen). He has the ability to make keyword requests about shops to look for either by brand, categories, interests... Using MEDIACTIF, we would not want to rely only on this particular vision. The idea is to make automatically pre-recorded requests to display suitable contents on screens even if the user has not shown any particular interest so far.

Explanation of the first experiment (vestiaires)

2) Second step : content based recommendation.: Content based recommendation is a method that only uses past users interests in order to propose new points of interest[44][45]. The idea is to extract characteristics of ones' history in order to match characteristics of the new suggestions. On this particular part, Points of Interest (POI) have to be described usually with natural language and keywords (that can be figures). Then, selecting them usually involves a keyword matching algorithm, sometimes combined with a frequency method.

To allow this, we then need to know users previous interests. Thus, we plan to make users fill a form at a particular time (e.g., when they buy their tickets for an exposition). Each interest on the form will then be indexed and the suggestions will arise from a confrontation with the global points of interest index (stands, restaurants...with their description).

When one user needs a suggestion, we will look for a relevant characteristic inside all his interests and we will query the search engine to find one or multiple matching POIs. Though it is perfectly suited to mobile phones, with regular display screens, people will be rarely standing alone in front of it. Therefore, the search engine has to deal with several users.

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The idea is to consider these users as a single one. We plan to look for their main shared interest characteristics and use it as a query token.

With this kind of recommendation, we would eventually suggest to foreign people a typical french restaurant in the area if most of them like french cuisine. The major drawback here is that we need users to be compliant and fill in a form.

3) Third step : collaborative filtering.: The objective is to suppress any user implication inside the system by implementing pure collaborative filtering. Collaborative filtering is currently the most used recommendation method. It works by saving every users points of interests inside a matrix [46][47] and creating similarity matrices by comparing each user one by one. Once a score of similarity is computed, suggestions to one user coming from other similar users can be given.

We plan on using Pertimm search engine to simulate this process: we will index every user with its POIs and then use search engine methods like catalogs to generate recommendations. Using a search engine will allow us to avoid the calculations and storage of big matrices.

Still to obtain users POIs, we need to be able to follow them and store their behaviors. We plan to do so with a phone application, storing queries and locations.

For the group perspective, we will create a dummy user with POIs driven from the majority of the users as will suggestions be. As a result, we will be able to combine collaborative filtering with previous content based method to obtain recommendation [48][49].

VI. CONCLUSION

The MEDIACTIF Project is at its very early stages of development. Surely some critical points must be solved first. Models must be setup to take care of the different usage scenarios considered so far (fairs, airports, etc.). We must handle people behaviors depending on tangible parameters (time, events, etc.) but also on unquantifiable parameters like personal interests. Another point to solve is indoor localization. A multimodal approach is planned using physical sensors and networking (Wi-Fi) though we are also looking at other options based on mesh networks.

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