MEDIACTIF

A dynamic, centralized and real-time digital signage system for smooth pedestrian flow control with arbitrary topologies

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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. Digital signage, including Digital Out Of Home, is a natural evolution of the old sign painting business. 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. This is the major issue we are facing as of now: crowd motion has extensively been studied on peculiar 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; mesh.

I. INTRODUCTION

The MEDIACTIF Project [1] has been started a few months 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 adapting 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.

As the literature is quite extensive on traffic management systems, and also because of a gathered experience on this field, it will serve as a basis to this project.

We will first talk about the general purpose of the system, followed by an overview of current traffic systems. Then we will focus on standards for four identified areas of interest before briefly going over the current architecture we are considering. We will also slightly talk about additional services considered for the system.

II. GATHERED DESIDERATA

Presently, digital signage systems handle different media sources and dispatch them to a pool of selected screens. Information can be static (map, pictures, static adverts [2]), dynamic (flight departures and arrivals), animated (film trailers, animated adverts). Obviously, any combination of these previous elements can be displayed on the same screen using defined scenarios. Different applications are currently being considered and worked on:

- Public information: area map, dynamic pathway, exit roads.
- Communication channels: static and dynamic signs, mobile apps, kiosks, social/collaborative interactions.
- User experience and environment enhancements: use of mobile/apps as a natural extension of signage, dynamic path finding, and profile adapted suggestions, interaction with the digital signage information system.
- Behavior influence: events propagation and advertising, customized information, lunch/dinner indications, etc., based on activities, objectives, profiles and customer interests.

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

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These models should be driven by the analysis of previous sessions (when available) and will be enhanced with the sensors variations/data constantly.

The needs considered can be so far classified in the following categories: users, operations, security, and environment.

A. *Users*

In a fair or in an airport, a good way to reduce stress is to reduce the global walk time and crowding. “Way finding” digital signage can be used to allow for optimal pathways for everybody. MEDIACTIF would like to provide a comfortable walk by dynamically adapting path suggestions with adaptive signage closely linked to affluence sensors. It will not only allow for “navigation” but also provide real time information (a potential stress factor for some).

Users will be provided with different kinds of extra information which may influence their behaviors. An example of this would be to push restaurant information to some visitors before lunch time to eventually allow them to eat before the rush hour. These data can be fully public and basic (restaurant opening hours or placement), more practical (remaining available seats), but could also influence the subject (inducing the need of a meal with restaurant discounts, tastings at specific stands, etc). Advertising has also been considered as a part of a future remunerated service.

B. *Exploitation*

As usual for such a complex system, the first approach is to centralize, at least in a first iteration, all information gathering. Doing so it will be easier to process all sensor values gathered in real time and compute relevant actions in order to update displays.

All computed information will be attached to different scenarios or strategies. Basic information would consider of fixed maps and schedules which will cycle with other somewhat basic type of data. Each “screen” will be displayed for a specific amount of time and cycle according to the crowd estimation also in concordance with past statistics, or specific times for lunch or particular events.

This basic mode will be later on enhanced by an adaptive algorithm. Depending on unexpected events, pathways congestions, specific commercial deals, maps will be adapted to drive people efficiently and ensure a general fluidity.

During each fair or over a period of time for airports or different clients, every bit of data (crowd movements, computed from cameras and sensors, positioning of opened desks, active or inactive zones, which will pose problems to a global fluidity), will be collected in order to generate new model revisions.

For corporate users, the benefits of such a system are not negligible:

- Fair organizers will be provided a tangible prediction of the flow of persons at their exhibition based on to the simulations and past data characterizations.
- Possibility to quantify the impact of any layout modification on the traffic flows.
- Commercial trade centers or security offices will be able to anticipate influence of any departure or arrival of a flight, depending on destination or origin. They would also be able to manually pilot path redirections to offer a better service.

They ideally should have access to tools allowing them to qualify and quantify any kind of influence on people traffic interaction.

C. *Security*

Security management takes a great part in MEDIACTIF. In case of fire or emergency, digital signage can be used to redirect people to the nearest exits or safe routes. Obviously all displays must embed a security mode, with an autonomous mode and power supply.

The second security mode we are considering is to allow for easier and faster interventions for dedicated services: in case of an emergency with a person (malaise for example), we would want to adapt the signage around an area to drain the crowd and offer a clean pathway for emergency.

Once again, here, the main advantage regarding the security sector, is to allow for a traffic fluidity in order to avoid stress and nervous feeling.

D. *Environment*

VIPARIS, one of MEDIACTIF’s partners, is in charge of the ten most important congress and exposition centers in the Paris area. It accounts for around 330 fairs, more than 100 spectacle representations, 150 conventions and 620 enterprise events driving more than 11Milion visitors each year. In Paris, one fair produces a mean of 200m^3 of waste, especially printed signs and posters. Not only this number is quite high, but these prints also use highly toxic inks which are difficult to recycle. Considering even only 1000 events per year for our area, we could suppress at least 200 000m^3 of waste per year using fixed or mobile reusable displays, etc.

III. EXISTING URBAN TRAFFIC CONTROL (UTC) SYSTEMS

MEDIACTIF will base its first iterations on the experience and results gathered with a urban traffic lights control system. Many systems are deployed all around the world, handling specific drivers’ behaviors. So far, traffic control systems can either be distributed or centralized, using plans, local adaptation or be traffic responsive [3].

So far, we have settled on static and scheduled models as entry level rules, which will be influenced by real-time adaptive algorithms later on.

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A. Fixed time systems

The method used to calculate timings defines the objective that the system will seek to minimize. This is often used to reduce network vehicle delays. The designer can optimize different parameters of the network to attain different objectives. Although the timing can be biased against the main traffic movements, it can generally be restrained by adjusting the splits at critical junctions.

Fixed time systems cannot respond dynamically because they use pre-calculated timing plans. They also are unable to respond automatically to incidents. This implies that they are unfortunately not suitable for situations with any variability pattern. In fact they cannot adapt to any change in traffic patterns. The Traffic Network Study Tool (TRANSYT) in UK was a system that used this technology [4].

B. Plan selection systems

Plan selection systems use fixed time plans, but select which plan to use according to sensors data, rather than by timetables. However, this type of system has not proven to be any better than simple time-of-day implementations with fixed time plans. Plan selection systems have the same advantages and drawbacks as fixed time systems.

C. Plan generation systems

Plan generation systems generate their own fixed time plans from sensors information and implement them. These systems are way less under direct control from exploitation people. In theory, this kind of system could respond to unexpected incidents, but in reality, their degree of freedom is too small to allow them large enough changes in order to respond effectively. The Sydney Co-ordinated Adaptive Traffic System (SCAT) uses this technology [5].

D. Traffic responsive centralized systems

Traffic responsive systems are fully dynamic. The system is based on a central server and communication to controllers. The advantages of responsive systems are that they can respond to traffic demand, day to day variation, unexpected events and traffic evolution. A responsive system adjusts its control depending on sensors inputs. A centralized system has the advantage that all the relevant information, from sensors but also from system is fully centralized and available. Centralized traffic management systems offer also a better reaction to events and a better efficiency [6].

SCOOT (Split, Cycle and Offset Optimisation Technique) [7][8] in UK and GERTRUDE (Gestion Electronique de Régulation de Trafic Routier Urbain Défiant les Embouteillages) in France are traffic responsive centralized systems.

E. Traffic responsive systems with distributed processing

The features and advantages of distributed responsive systems are basically the same as those of centralized responsive systems. A major difference is the communication system used. A centralized responsive system has continuous communication between each controller and the central server. A distributive system has a router module and each controller is connected to neighboring controllers. Messages can be passed between any machine or controller to others, routing the message by intermediate controllers when necessary. A distributed responsive system should be able to work with a route guidance system, but interaction is much more complicated than for a centralized responsive system. PRODYN in France has been implemented and tested on the Zone Experimentale et Laboratoire de Trafic de Toulouse (ZELT) [9][10]. OPAC (USA) and UTOPIA/SPOT (Italy) implements this architecture. It was a mesh like implementation, years before mesh network was fully formalized.

MEDIACTIF will provide a prototype implementation for a “people responsive centralized system”, and intends to enhance the system using a distributed architecture.

The major evolution compared to a UTC system is people, more particularly individual behaviors. Cars drive on separate ways, each line going in a specific direction, whereas crowds are more hectic. Another difference is the response time of the system. A car traffic (with a max speed of 50 km/h) real-time system uses a 1 second internal cycle. It is at the moment not easy to establish a correct value for crowd behaviors.

The type and positioning of sensors, as well as a crowd dispersion model will take a big part in a sub module evaluation during the project. Some partners already have an extensive review of different products and technologies which will help us get a good grasp of what to avoid at least.

IV. STANDARDS AND TOOLS

A. Digital signage standards

The ITU published a whitepaper [11] in which Synchronized Multimedia Integration Language is cited as "a key standard for the digital sign industry," and that it "is increasingly supported by leading digital sign solution providers." It is reported in [12] that SMIL players are deployed for nearly 100,000 screens in year 2011, and a single software provider has won three major projects, deploying more than 1,000 SMIL players over the same period of time for each one.

POPAI has released several digital sign standards [13] to promote "interoperability between different providers". The objective of these standard documents is to establish a foundation of performance and behavior that all digital sign systems can follow. The current sets of standards published by POPAI are:

- "Screen-Media Formats" to specify compatible and supported file formats.
- "POPAI Digital Sign Device RS-232 Standards"
- "POPAI Digital Sign Playlog Standards V 1.1"

- "Digital Control Commands"
- "Industry Standards of Digital Sign Terms"

MEDIACTIF will try to use existing digital signage appliances, if already installed. Some airport terminals are already equipped for arrival/departure schedule information. These systems will be operated using communication standards (HTML5, SMIL, SOAP, REST). For new contracts or area, the MEDIACTIF Project may have to define its own digital signage system that will:

- be standard compliant
- use different communication channels: IP (wired and Wi-Fi), wired and radio RS232, etc.

B. *Crowd motion modelling*

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 reasonable 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. Henderson found as early as 1971, from measurements of motion in crowds, a good agreement of the velocity distribution functions with Maxwell-Boltzmann distribution [14].

In microscopic models, each individual is represented separately. In contrast, in macroscopic models, different individuals are not distinguished. Instead, crowd densities are at play, usually a mass density derived from cumulative locations of persons and also a corresponding locally averaged velocity of this density.

Social forces have been introduced by Helbing in a microscopic model [15] based on the idea that pedestrians have different perceptions about intimate/personal and social space, which leads to repulsive forces between persons.

Cellular automata [16][17][18] 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.).

However, unlike Newtonian particles, persons have a free will and may want to avoid jams by changing their preferred path when approaching a crowded area, find a new path, even if it is not the preferred one. 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.

Following Maury [19], models can also be classified according to their stiffness. Soft congestion models are applicable when the distance between individuals becomes smaller, while hard congestion models propose solutions in the case of physical contacts between individuals (when people are packed, the overall motion is perturbed by the fact that two persons may not occupy the same place at the same time).

Mainly, we have to focus on congestion in crowds in motion [19][20][21].

This poses a non-trivial modeling problem as we not only have to characterize a general walking behavior for users, but also have to take into account the fact that contacts are usually avoided and mostly not anticipated when they occur. We will probably limit our model in the first iteration to basic constraints raised by the environment and goals derived from a specific location: the expected behavior will be surely different between a person in an airport terminal and the same person at a fair. Thus we have to consider that each individual will move according to its current desires though we cannot exclude any spontaneous irregularity. Also the model has to be considered on both a microscopic and macroscopic level: the initial goal of the user will drive its original direction and velocity on a macroscopic scale while the interaction with its environment (other users or the physical structures defining the area map itself) will be evaluated at a microscopic level.

The other phenomenon to take into account is the fact that not only does a small congestion affect the behavior of a single individual but a wider one tends to have an effect on a group motion at a global scale. At the same time we can also consider that an individual, with common sense, will tend to avoid high density areas when possible.

We currently are reviewing the literature on this particular problem to find a suitable modeling possibility for different scenarios and are considering multiple options, such as neural networks, pure statistical models but also a quite interesting representation of crowds as fluids to which fluid dynamics theories could be applied.

C. *Positionning terminals in mobile computing*

To offer precise services using smartphones, it is necessary to be able to pinpoint a position with a good precision. There are different techniques available using wireless positioning [22]. The smartphone collects the received signal and compares the computed vector to the vectors previously recorded along the walk. It is also possible to measure the distance between mobile terminals [23] or fixed access points.

Presently, some companies are testing such techniques to position their staff inside the different airports areas using either Wifi or Bluetooth low energy depending on the smartphone (Android or iOS). We are also looking at emerging solutions such as IEEE® 802.15.4/ZigBee® technology positioning options and also some recent announcements made by STMicroelectronics with the

LPS331AP, an ultra-compact, absolute piezoresistive pressure sensor which advertises for *"3D indoor positioning and enhanced GPS in portable devices"*.

D. Crowd sensors

In order to minimize costs at first, we will mostly try to use the infrastructure already in place. For some places, this includes a camera network covering almost all areas of interest. The video feeds will be analyzed in real time using OpenCV, an open source computer vision library. Once integrated with a digital representation of the concerned areas it will allow us to characterize at least individuals movements and crowds formations, or as mentioned earlier fluid mechanics of each area. Though it will not specifically generate any particular quantitative data, it will serve as our main source for the crowd dispersion management models and redirection protocols in case of emergencies.

For the numerical part (initially mostly for fairs), we have already considered a deeper integration with the organizers to be able to monitor the ticketing desks streams.

For both sectors we will also surely use counting sensors based on different technologies (pressure, video, radio) to be able to monitor efficiently all concerned area and be able to generate appropriate reactions to any event.

V. ARCHITECTURE

MEDIACTIF will be an adaptive, 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 primal 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.

As an integrated platform, we must offer different tools for different users and/or operation modes:

A. Front office tools

At the early stage, conception tools, like a computer assisted design software, are needed for designing sensors placements and optimize screens positioning to the site topology. Sensors values should be able to be controlled from the interface and a synoptical backplane view must be able to display a synthetic survey of the whole physical implementation. It will allow for enabling/disabling sensors, forcing states or displaying specific messages.

Basic behaviours will be held by computed plans using models but adaptive rules will mostly be managed by the use of programming languages. Scilab [26] will be the original programming tool suggested, handling each controller separately and also each area globally. As an interpreted language, it proves more convenient to program specific rules and test them using the included web interface as a frontend. Once the tuning phase is finished, files will probably be compiled and integrated as executable application inside the backend system for performance and confidentiality reason.

B. Backoffice tools

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 take a crowd increase immediately into account, but awaiting stabilization for a decrease.

C. Data management

During an event like a fair or even on a 24/7 schedule for the airport case, the system will store key data, time stamped in a big data server, which will later on be used to compute a new model version adapted to a specific location.

The first system model will surely be an a priori model, based on knowledge and extensive statistics. During operations, real time data and predictions will be compared and analyzed, with a set of specific events and conditions. For the next fair, a new refined model will be setup and tested with all past data. The objective is to minimize differences between model prediction and real situation. Unexpected events will be removed to compute a new model.

Based on physical and goals differences between each particular location, models will evidently be different in the long run but can be tuned for specific events based on similarities.

D. Tools for operations users

MEDIACTIF has to stand as a complete system for corporate users.

Taking the airport scenario, such a system must firstly reduce walk time and crowd generation/increase but it could also have a more commercial aim, especially for shops. Today, it is quite impossible to evaluate the influence of an arrival or a departure over shop businesses. With this system, it will be possible to anticipate these events and adjust an adequate commercial response.

For fair organizers, the situation is quite different. It is necessary to ensure a global fluidity in the alleys but also to maximize visitors just before a congestion level is attained.

We also want to be able to help organizers in designing their fairs and anticipate the temporal and spatial distributions of global and local traffic flows. Consequences are evident: scaling a fair with an optimized topology and pathways, identifying probable critical spots and times for congestions, lowering the stress and improving the security, while enabling new business models based on deliveries of quantitative predictions and actual traffic flow measurements.

E. End users/passerby benefits

For the end user, benefits are much more concrete. First, a reduced walk time and/or a better walk fluidity decreases the perceived fatigue. This not only avoids the greater part of stress but can lead for a global increase in the positive perception of the fair and/or a longer stay, which could translate in more business opportunities. Another direct benefit is relevant and up to date information for any unexpected events.

For commercial or enhanced services, end users can also have individual and exclusive information or vouchers on their smartphone depending on each and everyone's profiles. Signage for a business man with luggage will not be the same as signage for a family.

Another example would also be to handle access points like car parks or cash desk locations. Of course this implies a refined management of every parameter of a particular site and a better anticipation, avoiding manual transit time measures.

F. Commercial tools

MEDIACTIF is not only a Digital Signage System. It can also be considered as an engineering commercial methodology.

It can be used as a conception tool for commercial purposes design, crowd modelling, fair design, etc.

Localization, path finder, thematic itineraries, specific profile handling (disables people, families, etc.) can be managed with the right plug-in on the system.

VI. SERVICES

MEDIACTIF is a dynamic Digital Signage management system. But it can also be considered as a bartering platform. It can establish relationships between different operators like restaurants, advertising and media companies. The system offers data and capabilities to address users' needs which can be driven through services by external operators.

We plan to offer different levels of services, from low level like security to high level like data exchange.

The first level to handle is security. Even if the system is down, or if there is no communication to controllers, signage must work fully independently to indicate at least a fixed map and fire exits during a defined time.

The first enhanced mode would be to offer a basic plan to allow users pathway indications.

In case of a failure from the central server or in the transmission of data, controllers can work with fixed time scheduled plan, displaying basic signage information for each programmed schedule. Controllers are then considered as autonomous.

In the "centralized plan selection mode", the central server and data transmissions are up. Plans are computed and controllers are synchronized to provide a basic signage based only on the model.

The "centralized traffic responsive mode" will have computed plans with synchronized controllers and sensor data handled to provide a full adaptive system. It also includes an enhanced security mode to manage security intervention of paramedics, police or fire men in case of serious unexpected events (illness, fire, robbery, etc.).

The last level is the real bartering platform. It includes commercial services like advertising, external high level information (number or remaining seats in a restaurant, extra waiting room in an airport terminal, etc.) and paid services for end users.

Digital signage systems can also work together to contribute to a large network. Specific time slots on the displays can be sold off to different partners, for example via auctions. This concept is known as a digital sign exchange [24][25].

It is also interesting to integrate smartphones as part of digital signage. Information displayed on these devices should be more specific depending on user profiles. Some information like pathway or localization could be free of charge, but some others must remain profitable like restaurant reservation or VIP services.

The whole system perimeter can be different depending on corporate users' wishes. The basic localization is the fair itself or an airport terminal. But it also can include peripheral areas that generate all incoming flows of people like cash register, passport control desks, car parks, all points of arrival.

Here, the key point will be about the zoning itself: each zone must have a complete consistence for human behavior. Car parks never generate the same crowd congestion as a passport control desk, for example.

We perceive MEDIACTIF as a crowd management system, however it must mainly be an engineering method: by understanding crowd phenomena, human behaviors and interactions, we can propose to equip an area with sensors and displays to generate the relevant information at the right place and time.

VII. 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.

A first basic prototype with real experiment is planned at the beginning of year 2015.

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