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Master's thesis

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CITIUS: Design and Implementation of a Context Aware Digital Signage Infrastructure for the Public Transport

Graduate School of Media Design,

Keio University

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A Master's Thesis

submitted to Graduate School of Media Design, Keio University

in partial fulfillment of the requirements for the degree of

MASTER of Media Design

Nahuel Matias Salcedo

Thesis Committee:

Associate Professor Kazunori Sugiura	(Supervisor)
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Abstract of Master's Thesis of the Academic Year 2014

CITIUS: Design and Implementation of a Context Aware Digital Signage Infrastructure For the Public Transport

Category: Science/Engineering

Summary

The present thesis introduces the design and implementation of a novel signage infrastructure, amalgamating contextual information with an engaging audiovisual presentation. CITIUS is a web-based location aware digital signage system capable of providing navigation and emergency information as well as animated advertising in real time to the public bus service. Through four real field experiments carried out between May 2013 and March 2014, the system was implemented and tested in real buses at the campus of the National University of Singapore. After the evaluation, it is concluded that based on the objectives of autonomy, scalability and portability, CITIUS can consistently provide navigation information and high quality content to users over prolonged periods of time with minimum external intervention. Furthermore, from the results of the feasibility study it is also concluded that under certain circumstances it is possible to reduce the network traffic by over 80% by regenerating and rendering motion graphics in real time using HTML5 to the detriment of pre-rendered videos, without affecting the presentation quality.

Keywords:
ITS (Intelligent Transport Systems), LAS (Location Aware Systems), Digital Signage, Motion Graphics

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1. Introduction

During the past decade, the advertising industry has been in constant transformation due to the introduction of digital technologies. In particular, the field of digital signage requires attention as a new articulation between audiovisual language and interaction in public and private spaces. Digital signage presents itself a relatively new media for information and most importantly, as a new advertising channel [1]. Recently, the use of digital signage has grown exponentially, and much of it may be due to lower costs of creating infrastructure as well as the fact that users are becoming more familiar with digital communication tools. In this thesis, it is proposed to contribute to the digital signage field by developing and implementing CITIUS (Communication Infrastructure of Transport Information for Universal Service), a novel digital signage infrastructure for the transportation with the following characteristics: autonomous, scalable and portable.

Nowadays, a great deal of digital signage systems are used to provide public information, entertainment and advertising. In contrast with traditional signage, the possibilities offered by digital signage extend from providing compelling audiovisual content to interactive experiences. But perhaps the most relevant underlying aspect of digital signage is that it allows targeting consumers according to their context, something often considered the holy grail of advertising. Digital signage is not as incipient as it might have been five or ten years ago, and there are already numerous implementations that make good use of the consumer targeting that digital signage provides. There have been also successful applications based on the location of the consumers all over the world. Nevertheless, the field of mobile location-aware digital signage still remains widely unexplored, especially of those architectures oriented to the public bus service.

This opens an interesting space to question why if it is commonly acknowledged that targeting users according to their content is essential, mobile digital signage systems[1] continue to minimize the importance of the precise location of the users and instead emphasize the time aspect. In other words, *when* is more important than *where*, and in cases such as the public transport, the opposite might need to be considered. The concept of CITIUS is to go the other way around: *to offer content according the precise location of the users*, and to build everything else on top of it.

But above this basic theoretical core there is a whole architecture to design, and designing a novel digital signage architecture today is a great challenge to say the least. It is no longer enough to connect a few screens to a network and create a playlist. Users are more aware of the technology that surrounds them and digital signage architectures should be up to par if they pretend to be used. It is not acceptable to provide outdated content, so constant renovation of the content is a must. An option to overcome this problem would be to update the contents manually, but it is unpractical and above all expensive. For this reason, CITIUS is *autonomous*, meaning that it updates the content of the signage over the network according to contextual information such as position, time and road conditions in a way that can reduce external intervention to a minimum.

The architecture must also be robust. A system that stop working at the first inconvenient with the network connection can be considered unreliable by the users and directly ignored the next time. Because of this, CITIUS puts emphasis on bandwidth economy, trying to generate the majority of the content in real time and minimizing the use of big pre-rendered files. But the tricky part is that it is also not acceptable to present low quality content. It is no longer enough to present content like static images, or even a slideshow. Compelling audiovisual content has to make use of complex audiovisual tools. This system aims to provide compelling audiovisual content by making use of advanced real time animation, which allows at the same

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[1] See Chapter 2: Related Works

time an opportunity to modify the content either manually or automatically with ease.

The architecture must also be *scalable*. It must be able to connect not to just one type of specific terminal but to a great variety of computers and mobile devices. Regardless of the initial implementation of CITIUS inside buses only, it must be ready to expand to other public transportation services and to interact with mobile devices when the opportunity comes along. For this reason, the front end is web based, and design of the interface was elaborated with adaptability for different resolutions as well. For this, the HTML5[2] standard was adopted.

It is proposed then from this point, to go deeper in the description what is understood from digital signage, its relation with advertising and the market, to be able to identify cases where the system presented by this thesis can be of help.

1.1. Digital Signage

Digital signage can be defined as a "system of electronic displays connected to the network and placed either outdoors, indoors, in public spaces or the public transportation" [2]. From this definition it is possible to deduce that digital signage is not merely an application of technology, but an out-of-home media itself. In fact, it represents a new dimension in media: "it is the fourth communication media, after the television, computers and cell phones" [3].

Digital signage can be seen at use in places such as airports, railway stations, large scale outdoor spaces, hotel lobbies, retail shops, stadiums, inside offices and even in trains or taxis. This media is also used to offer information such as weather conditions, news, emergency messages and to make other public announcements. In terms of advertising, digital signage makes targeted advertising possible. In fact, another possible definition of digital signage is as a "synonym of ubiquitous advertising" [3] which means advertising anywhere, at any time.

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[2] See page 6

Schaeffer defines digital signage as an answer for advertising agencies, innumerable global advertisers and retailers, as well as their vendors "each of which is faced with huge challenges to remain relevant in the minds (and the eyes) of the consumer audiences it must address daily in order to move its business forward" [4]. Following Nakamura, digital signage looks attractive for advertisers because 1) they can present audiovisual content, 2) the time and place can be specified and 3) each screen can be controlled independently. First, differently from traditional signage, it opens the game to rich multimedia content. Second, and this might be one of the most important aspects of digital signage for advertising, is that it is capable of targeting and segmenting consumers by for example, their location or the time. And third, since each screen can be managed independently it is possible to present different content in each, according to the context.

Another key aspect of digital signage is that it has a relatively low cost of creation, distribution and installation in contrast with traditional signage. Particularly when distributing the signage, it might become very expensive to hire a team that manually changes the signage every time it needs to be updated. This is greatly reduced when using digital systems, and because they are connected to the network, they can be updated more easily and at a reduced cost. Additionally, since the content in digital signage is electronically updated, there's no need to waste resources such as paper, counting as an extra benefit for the environment.

The digital signage market has been growing constantly during the past decade. According to data provided by Digital Signage Consortium, the market of digital signage in Japan is expected to worth over 1 trillion yen (approximately 98 billion American dollars) by 2015, to be divided among hardware providers, network carriers, content creators, system engineers and advertising companies. To put a practical example of the market of digital signage in the transportation, the companies JR East and JR West commercialize advertising space in digital signage inside their trains by selling 30 second advertising slots. Every advertisement is repeated every 15 minutes. The commercial is presented in 6 screens per train, in a total of 500 trains for two weeks, for which the advertiser is charged 3.250.00 yen according to Mitsubishi Heavy Industries. This example demonstrate that there is great potential for monetizing still unexploited spaces in the public transport, such as the bus service.

1.2. The Next step: Location-aware, web-based and in real time

In order to contextualize and allow for a better understanding of the problems and objectives of this research, it is key to quickly review and explore deeper in the concepts from which CITIUS is aiming to innovate.

Digital signage terminals can be categorized according to the location where they are installed (or "point of use"). By definition and from an advertising perspective, there are three different type of locations where digital signage can be available: "point of sale (POS), Point of Wait (POW) and Point of Transit (POT)" [5]. Point of Sale describes the place where the consumer is near the product and can make a purchase (i.e. at the cashier of a convenience store). Point of Wait is where the consumer is waiting for a service or product, for example the waiting room of a hospital. Finally, Point of Transit is that where the user is moving from one point to another and is exposed to the signage for a very short period of time (i.e. when transiting a train station). Interestingly enough, there are points of use that are still not considered in the current bibliography, like those installed in the public transport and which because of its characteristics, limiting them into any of these three specific categories becomes problematic.

For example, it might be plausible to define a digital signage installed inside a train car as POW since the consumers are waiting for the train to arrive at its destination, but how should a system installed in a bus be defined when the bus can carry the consumer directly to the POS? This particular case becomes relevant to this research not only from a theoretical perspective but also as a practical implementation.

In this sense, it is also key to establish the difference between two concepts that at first sight may seem interchangeable but in reality have considerable differences: CITIUS is conceived as a location aware digital signage architecture. While the terms location based and location aware are sometimes considered similar, location based systems are stationary (for example a DSS in a mall where the target has particular buying preferences), while in location aware systems the user can actively receive information according other contextual factors (current location, time, weather, etc.). It was decided to design CITIUS as a location aware system, as it is considered the best way to provide content at the right place and time.

Another important aspect where CITIUS aims to innovate is in the platform that it is developed. According to the Digital Signage White Paper 2013 [2] "HTML5 brings expectation to present not just text, but also graphics and streaming, making use of databases, all over the browser. To present everything over the browser means that the content can be accessed through different devices such as smartphones, tablets and smart TVs among others, having no need to program a specific application for each. Think about HTML5 based digital signage systems means that virtually every device can become a signage display". Besides the portability factor mentioned by the white paper, HTML5 allows for more complex content management, and provides excellent tools to develop high quality animated graphics in real time, such as WebGL, which is why this standard presents itself as an ideal platform to develop CITIUS.

Although not seen connected to digital signage in the bibliography, it is proposed to add and explore the concept of motion graphics, since it is a notion that helped both throughout the process of planning and development of CITIUS, and it played an important role in motivating this research. Content quality and in particular that of the presentation is of great significance when producing advertising. As a communication tool, DSS needs to be appealing in order to sustain the consumer's attention [6] and aesthetically pleasing in order to have a positive effect on sales.

Motion graphics are defined as "a dynamic, non-narrative, non-figurative, visual communication method using motions" [7]. Motion graphics make use of video, film, animation, photography, illustration, typography and music, but any of these can't be considered motion graphics unless it uses elements of design in order to communicate a message [8]. Text and typography needs to be addressed as well, since when in combination with animation it can transmit a tone of voice, character features and emotional states [8]. Because of this reason, adopting the concept of motion graphics to think, discuss and develop a novel digital signage system becomes useful.

1.3. A twist in the workflow of content production for DS

There is no simple or definite answer to which is the best workflow to produce audiovisual content for digital signage. According to the characteristics of the system, the workflow will differ. For example in signage systems where the consumer intervention is not required, either video or still images are used whereas for interactive applications the most widely utilized solution is to design the content utilizing game engines. It is proposed to explore and analyze the positive and negative points of each of the three methods.

The most popular option, and the most utilized solution among the systems reviewed for this thesis[3], is to present the content as images with little or no animation and combine them with text. The advantage of this method is that updating the content is relatively easy and cheap, and since the data that needs to be transferred is very small it doesn't generate much problems in terms of bandwidth usage. However, the presentation quality of this method is very poor and animations are limited to simple transitions.

The second option, which is widely used in high quality audiovisual production in general, starts by either capturing or generating the source material (filming or creating 3d animations for example) into pre-rendered units. These units will then be composited and post produced, adding special effects, titles and making any other additional modification that might be required. The next step is to finalize the film and deliver it to the distributor or the advertiser, who will deliver the content to the The advantages of this method is that the production quality that can be achieved is very high. The downside is that as video, there is no simple modification possible and content can get outdated very quickly. If any amend or update to the information presented in the content is needed, it will be necessary to go back to compositing

[3] See 2. Related Works

table or even to production/filming/designing the sources again. Most importantly, for this same reason this method reduces the chances of autonomy and interactivity to a minimum.

The third option is to utilize a game engine such as Unity[4] to create an application where the users can interact with the objects on the screen. With the spread of interactivity in the signage business more and more systems are opting for this option. In game production, designers and animators create the elements that will be included in the engine, and programmers create the interactivity. The most interesting aspect of this method is that it can create high quality audiovisual content while also allowing interactivity. The downside are the costs and the production time.

It is proposed then to adopt a hybrid method. By a combination of CSS3 animation and 3D WebGL it is possible to create compelling animations in forms of templates that can be updated very easily and at a low cost. This solution renders the content in real time in a similar way, allowing to create compelling animations in 2.5D with CSS3 or full on complex 3d animations with WebGL.

1.4. Motivation

I have worked in the motion graphics industry for six years. More specifically in the field of graphic design and animation for the advertisement industry. During my last period I could observe a trend in the production of contents, which was first oriented mainly to television and that started shifting into other media, such as the Web, mobile applications and digital signage. Nevertheless, the content production process remained the same. All the content is designed and rendered at the studio, to be then delivered as a finalized piece to the advertiser. This means that when modifications are needed (which happens in most cases) it is necessary to render the content all over again, something which takes money and time for advertisers, and is a very unrewarding experience for creative content creators. I grew particularly

[4] 3D Game engine Unity. Available at http://unity3d.com/

interested in this aspect, asking myself: “wouldn’t it be great if it was possible to provide good quality audiovisual content rendered in real time?”

1.4.1. WHY THE PUBLIC BUS SERVICE IN SINGAPORE?

It is appropriate to explain the reasons behind the decision of creating a digital signage system for the transportation and to evaluate it first in the city of Singapore. Transportation signage offers a variety of particular advantages such as provide compelling navigation. In terms of advertising, it offers the possibility of repetitive contact with the user reinforcing the message. There’s also the so called “recency” effect which means that the contact with the product can take place right before the purchase, making the decision making process easier.

There are also advantage for bus drivers who are required to do many operations manually. For example, in Japan, bus drivers have tasks such as guiding the users by using their microphone, change the fare display and change the audio guide. Of course, since there is no way of identifying the bus precise position, drivers have to do this operation constantly. This adds up when the main task of the driver is to drive safely and in a timely manner. This combination of advantages of transportation signage and current issues with the navigation, make a signage system for the public bus service an attractive idea.

In terms of location, there are several reasons that motivated the selection of Singapore as the place to carry out the real field experiments. The most relevant is that in Singapore the bus service represents 60% of the total public transport market. Aside from this, while in Singapore there are already good solutions to get bus information from outside the bus such as PublicTransportSG, but there’s no on-bus information system. Added to this fact, the National University of Singapore Kent Ridge Campus (occupying 1.5 km2) has its own internal network of public buses with 6 different lines, of which most run every day of the week. This presented as a great opportunity to test the system in a real environment.

The sponsor of this research, Mitsubishi Heavy Industries, was in charge of the development and implementation of the ERP system[5] in Singapore. At the moment they are developing the next generation of ERP, which will require the installation of a GNSS/CN location device (branded OBU by MHI) in every vehicle that it's part of this program. It is expected that a first stage, all buses and taxis in Singapore will have the OBU installed, which is a great chance to develop location aware applications for the public transport in that city.

1.5. Problem Formulation

Even though the digital signage industry has been growing steadily, there are issues that still remain unresolved. First of all, in order to be fresh and interesting, the production of contents in digital signage must be done on a regular basis. Since the contents are most of the times created by a graphic designer (also known as content designer) this can be time consuming and therefore costly. Because of this, it is believed that new digital signage systems should be context aware, articulating data from the network together with context information, which would allow to update the contents automatically to some extent. Even though more recently digital signage systems have started offering an option to include widgets that connect to the internet to retrieve data dynamically, without a doubt this solves the problem only in part.

It is considered that the next developments in digital signage should consider making use of web technologies to allow multi-screen and multi-device support. Because of this it is necessary to develop the system utilizing HTML5. Additionally, the content presented on digital signage systems must be appealing in order to attract and sustain user attention. For this reasons, it is proposed to develop a visually appealing representation of the data utilizing motion graphics.

Finally, while network capabilities have improved quite a lot recently, the costs of maintenance and operability remain high. Furthermore, even when networks are

[5] Please see 3.3.2. for details about the Electronic Road Pricing

efficient many digital signage systems suffer from deficient use of the available bandwidth, leading to an elevation on the costs of maintenance in a best case scenario, or to an unsatisfactory operation in the worst. Because of this, there is room for improvement in the usage of the network infrastructure. Additionally, it is required that the system can be scalable and robust, even when it consists of big amount of terminals that may inadvertently be inactive.

With these premises, this research aims to answer the following questions:

- Is it possible to utilize current web technology to develop an autonomous digital signage infrastructure for the bus service in Singapore that provide content dynamically according to its precise position?
- Can the content be rendered in real time and still sustain a high standard of quality?
- Can the network bandwidth usage be optimized by using motion graphics rendered in real time instead of pre-rendered video?

1.6. Models

- An autonomous location aware digital signage architecture can be created utilizing web technology.
- Rendering the content in real time can greatly reduce the network load in a digital signage system.
- It is possible to reproduce high quality motion graphics in real time.

1.8. Personal contribution

I was the main responsible for the development and implementation of CITIUS and its subsequent updates under the direction of Professor Kazunori Sugiura and Professor Masaaki Sato. I participated in the planning and preparation of each of the real field experiments, traveling to Singapore to conduct the first and the fourth, while supporting Professor Sugiura and Professor Sato from Tokyo during the second and third. I also designed the interface and the graphic package for the system (layout, logotype and palette) at the different stages of development.

I elaborated the dummy content for the events, including 3d animations. I participated of numerous meetings with sponsor's representatives (Mitsubishi Heavy Industries) both in Singapore and in Tokyo to discuss the ongoing development and next improvements. I was responsible of creating the promotional material (including audiovisual material documenting the system working in a real environment) which at the moment is being used by ourselves, NUS and Mitsubishi Heavy Industries. I participated in several public presentations (supporting MHI executives) introducing the system to prospective buyers.

At early stages of development (until the 1st real field experiment) I got invaluable support from Yasuhito Tsukahara (KMD Doctor's 4th year) whose previous work served as reference to develop CITIUS and who guided me during the first stage of design, also developing the OBU parser; and Takahiro Nemoto (KMD Doctor's 4th year) who accompanied me and guided me during my first trip to Singapore and logged the position information inside the vehicle during the 1st real field experiment.

The following table is chronological description of my direct contribution to the CITIUS real project starting from February 2013, when I presented the first research proposal to Professor Sugiura.

Table 1: Chronology of activities

Date	Activity	Details
2013-02-06	First proposal presentation (draft)	Title: "Develop and implement a web browser based digital signage system capable of presenting real time 3d animation"
2013-03-10	Final proposal presentation	TItle: "Develop and implement a location aware, visually appealing web browser based

		multimedia signage system in the public transportation service of Singapore”
2013-05-05 To 2013-05-17	First Real Field Experiment	Trip to NUS (Singapore). Set up of the real field experiment environment and presentations to VIP.
2013-07-26 ～	Development the 2nd Stage of the application	Implementation of a database system. Implementation of sound. Redesign of the interface.
2013-07-20	Proposal for thesis submitted	“Dynamic Content Display Platform for Location Aware Digital Signage”
2013-07-26	KMD Plenary Meeting	Presentation of the concept of the system and initial results of the experiments
2013-09-07	Second Real Field Experiment	Remote support over Polycom with NUS of the set up and installation in charge of Professor Sugiura and Professor Sato (NUS).
2013-09-10 ～	Development the 3rd Stage of the application	Implementation of CSS animated events. Implementation of new bus route.
2013-11-17	Third Real Field Experiment	Remote support over Polycom with NUS of the set up and installation in charge of Professor Sugiura and Professor Sato (NUS).
2013-07-26 ～	Development the 4th Stage of the application	Development and implementation of real-time rendered 3D events. Minor modifications to the event structure.
2014-02-28 ～2014-03-01	Demo Presentation at KMD Forum	Presentation of the concept of the system and advanced results of the experiments
2014-03-12	Fourth Real Field Experiment	Trip to NUS (Singapore). Set up of the real field experiment environment and presentations to VIP. Demonstration to prospective buyers.

2. Related Works

Even though there have been numerous projects on digital signage as well as location-aware services [9] [10], those who address the problems that emerge when creating a mobile location aware digital signage system and which results were published as papers in journals or conferences, are scarce and outdated compared to non-academic works. It is necessary then to survey not only academic papers but also these real implementations, making focus particularly in those that took place in Asia.

2.1. Fukuoka Experiment[6][7][8]

The Digital Signage Fukuoka Experiment was a large scale test carried out from 2010-12-23 until 2010-02-17 in the City of Fukuoka, Japan. The experiment consisted in connecting over 500 digital signage displays that were already installed in different places such as stores, train stations and public spaces and installing some new inside buses. The experiment included displays inside 3 bus units belonging to Nishi-Nippon Railroad (西日本鉄道株式会社) for which they created "Bus channel" (バスチャネル), an application developed by GIFU DS OPERATION LTD. (岐阜乗合自動車株式会社様). For this review, only the implementation in

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[6] Available at http://wirelesswire.jp/Todays_Next/201310302138.html

[7] Available at http://k-tai.impress.co.jp/docs/news/20131030_621491.html

[8] Available at http://www.digital-signage.jp/case/detail_31.html

buses is considered. The screens showed information for tourists and visitors, emergency information and advertising according to the time. The main target of the bus were people living in Fukuoka and visitors.

About the technical aspect of the implementation, the communication between the terminals and the server was done via IP cast. As Nakamura explains “for buses which function in wide areas inside a prefecture, wireless technologies such as cellular or Wi-Fi are not effective in terms of cost or coverage area”. And about the Fukuoka Experiment: “There are real experiments to develop a bus signage system by creating a wireless channel utilizing radiofrequency. A program specially created for the buses is created and delivered to them. When downloading the program, the presentation of the content can be adjusted according to the road or the time” [11]. This system is then based on scheduled presentation of content which updates periodically over IP cast. While news information was updated once per hour, the rest of the information was updated once a day.

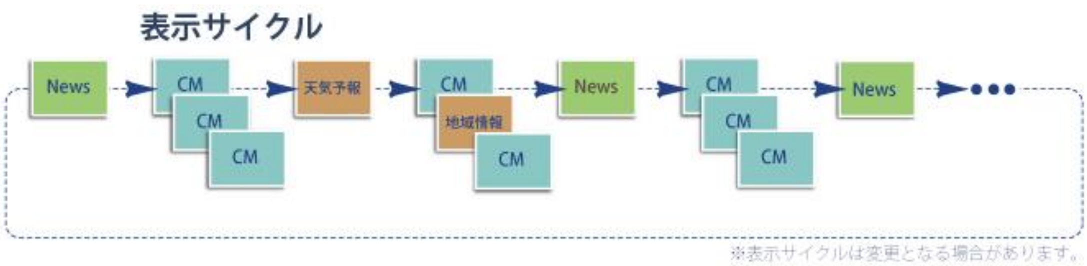

Figure 1: Bus Channel Display Cycle[9]

While the Fukuoka Experiment aims to provide digital signage for buses, major differences with CITIUS have been identified. First of all, the location factor was minor in the Fukuoka Experiment. While this system allows to set different content for every route and time, the content does not update constantly according to the current position of the bus, which is one of the most important aspects of CITIUS.

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[9] Available at http://www.lecip.co.jp/gdsk/bc_zenkoku.htm

This lack of detailed position awareness inevitably impedes offering time-constraint promotions and discounts.

The second big difference is the wireless technology utilized. While the Fukuoka Experiment utilized IP broadcast to update the content, every CITIUS terminal is connected to the Internet over 3G, which allows to request and download the content progressively as the bus moves, allowing for a shorter delay (in the range from 1 to 2 seconds) between updating the content and seeing that change reflected on the terminals. It is considered, nevertheless, that utilizing IP cast might be a good solution for long distance buses, or anywhere else where 3G access is difficult. CITIUS was developed to be utilized in buses inside Singapore, a highly urbanized city where 3G utilization is possible, allowing for applications with a larger variety of functions.

2.2. O2O experiment

Even though it was carried out over 6 months after the first of the real field experiments of CITIUS, for its characteristics, it is relevant to review and analyze a recent experiment called O2O [10][11][12]. The O2O experiment consisted in the installation and evaluation of a bus location system within the city of Okayama, Japan, from 2013-11-15 to 2014-05-29. The experiment was funded and carried out by KDDI together with Ryobi Holdings (両備ホールディングス). According to their own estimations, the test reached a total of 20.000 users. The signage was branded as Mayuse Channel (まゆせチャンネル) and the content offered consisted of images and text, incorporating a graphic character called Mayuse.

This experiment consisted in mounting 13 inch digital signage terminals inside 31 different bus units, while each bus could contains up to five screens, displaying the current route and an estimation of time until arriving to the next station. The

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[10] Available at http://wirelesswire.jp/Todays_Next/201310302138.html

[11] Available at http://k-tai.impress.co.jp/docs/news/20131030_621491.html

[12] Available at http://www.digital-signage.jp/case/detail_31.html

screens were updated once every 15 seconds, and would show recommendations and coupon offers of different stores that were part of the experiment. Aside from this, the screens presents information of the Okayama Municipality and the Okayama Police Department. The whole network was connected using WiMAX. To obtain position information, the system uses the 3G/LTE network. Advertisers can upload their own content using an iPad application and filling in a text field and an image field. The submission is taken by the system with a delay of 10 minutes and displayed on the screen inside the bus at a non-specified time.

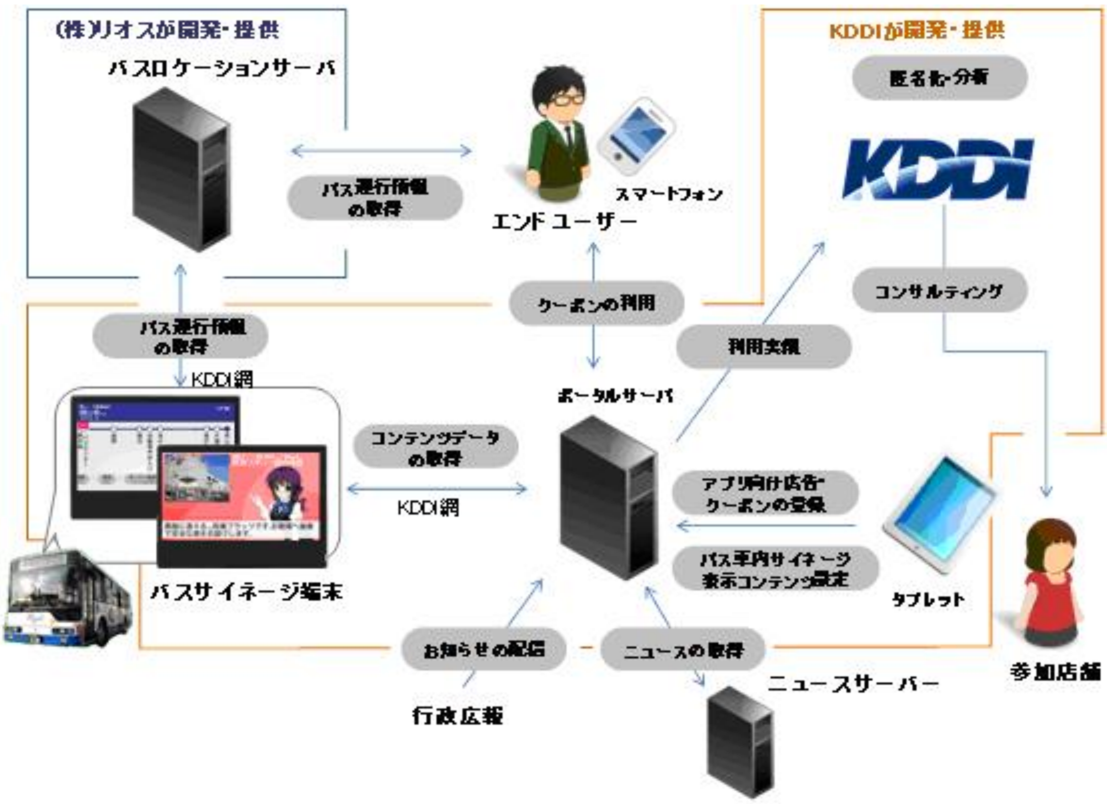

Figure 2: O2O Experiment Architecture

The design and implementation of this system have several similarities with CITIUS. Nevertheless, there are two essential differences:

1) No relation between bus position and advertising: While navigation information such as next station or last station is presented, the display

of advertising is not related to the current position of the bus. Instead, promotions and other advertisings are introduced based on time. With CITIUS, it is proposed to connect promotions and advertisings to the current location of the bus.

2) No real time animation: Instead of video or real time motion graphics, the O2O Experiment present the content either as still images or as simple typographic animations (similar to a slideshow presentation). Content presentation in advertising is key, and one of the challenges of CITIUS is to offer high quality presentation in a digital signage system while keeping content updates simple.

It should be mentioned that the O2O experiment made a very interesting use of smartphone technology, which allows to collect coupons inside the bus and use them at shop counters. At the moment of writing this thesis, there is no function similar implemented in CITIUS. For that reason, it becomes interesting to consider implementing a similar function in near-future implementations.

2.3. Microad: bus signage experiment in Tsukuba[13][14]

Another very recent experiment that comes close to CITIUS is the so called "Microad: Experiment advertising in digital signage oriented to bus cars and bus stops" (or マイクロアド、バス車内およびバス停へのデジタルサイネージ広告の配信実験). This project had its first experiment in the Ibaraki prefecture in January 22, 2014 and was carried out by the Japanese company Microad (株式会社マイクロアド), a subsidiary of Cyber Agent (株式会社サイバーエージェント) based in Tokyo. The experiment consisted in installing signage terminals inside one bus unit and in bus stops, adding up to 24 terminals.

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[13] Available at https://www.microad.co.jp/news/release/detail.php?newid=News-0254

[14] Available at http://news.mynavi.jp/news/2014/01/23/286/

According to the company that carried out the experiment, they developed the system with the idea of offering “a new source of income both for bus companies and local shops” although at the time there is “no plans of real implementation soon”[15]. The signage terminals provide advertising according to the bus position, such as nearby rooms for rent or clothing for students when running near a university.

While the project by Microad has similarities with the system introduced by this thesis related to offering promotions and coupons according to the bus position, its presentation aspect remains too simple. The system is limited to present simple still images and not rich content as CITIUS does, providing high quality animations in real time. Also, the system does not provide detailed navigation information such as humps on the road, crossings, which CITIUS does. It should also be noted that this experiment also took place 7 months after the first experiment of CITIUS.

2.4. MBDSS based on Service Delivery Platform

Another work that comes close to this research is "Mobile digital signage system based on service delivery platform location based targeted advertisement service" [12] which explore the introduction of a location based digital signage system using a Delivery Service Platform (DSP). Although this work provides an option for location based digital signage, it proposes broadcasting pre-recorded multimedia, and overlaying a text banner with sales information on top.

The proposal of CITIUS is to reduce the cost of production by generating animation in real time, providing an aesthetically pleasing and engaging solution while requiring little input from the content designer. Furthermore, in the system mentioned the mobile user connects to a mobile application using the Internet through an access point, thus the method to check user location is Wi-Fi and not global positioning system [12] which might be a good solution for it, but the

[15] Available at
http://www.nikkei.com/article/DGXNASFK30034_R30C14A1000000/?df=3

environment in which CITIUS needs to run is not only mobile, but needs to be even more precise. Because of this it is proposed to use a GNSS/CN system instead.
The following scheme presents the characteristics and differences the systems that come closer to CITIUS and were analyzed in this review:

Table 2: CITIUS vs. other digital signage systems

	Fukuoka Experiment	O2O Experiment	Microad	CITIUS
Connectivity	IP Cast (data)	WiMAX (data), Cellular Data (position)	3G (data), Wifi Network ID (position)	3G (data), GNSS / CN (position)
Location Awareness	Different content according to the route	Navigation Information	Navigation, location-based advertising	Navigation, Driving Information, Location-based Advertising
Precise Location Information	X	X	X	> 1 meter
Web Based	X	X	HTML5	HTML5
Real Time Animation	X	X	X	CSS3, WebGL
Time from remote update to presentation	Hourly (news) Daily (rest of the content)	> 10 Minutes	> 10 Seconds	> 1 Second

3. Design

3.1. Methodology

To develop, implement and evaluate CITIUS, a one year plan was conceived. The plan consisted in develop and implement the totality of the system functionalities gradually over four successive real field experiments spanning a year. From the second experiment, the system remained installed, working and in use in real buses while data was collected. Collected information consisted in a position log provided by the OBU device and information of uptime provided by the terminals. In order to evaluate the performance of real time 3d events versus pre-rendered events, the network was monitored and analyzed and then compared with similar pre-rendered videos.

The software environment for all experiments was Windows 8 SP1 as per the original configuration of the terminals from the second experiment. To log the network traffic, the software NetBalancer[16] by Seriousbit was utilized, which allows to isolate a process (in this case Google Chrome) and monitor its activity with detail during a specified period of time.

Table 3: Research Activities Schedule

[16] Available for download at http://seriousbit.com/netbalancer/

2013-04～2013-05	Development of the first prototype
2013-05	First field experiment in NUS Kent Ridge Campus, Singapore, with a reduced demonstration scenario Installation and evaluation of the first prototype in a rental car Collection of initial location data
2013-05～2013-09	Evaluation of initial results Extend to real world events (150+) Sponsor feedback Sound Implementation
2013-09	Second real field experiment Installation of the system in two bus units Start of location and uptime data collection
2013-09～2013-11	Development of CSS Events Changes in the routes
2013-11-17	Third real field experiment
2013-11～2014-03	Development of 3d animated events Optimization of the system
2014-03-12	Fourth real field experiment in NUS Kent Ridge Campus, Singapore, with a reduced demonstration scenario Presentation and real life demonstration with possible adopters of the system. Network Data Collection

3.3. System Architecture

The development and design of CITIUS is based on a Service-oriented architecture (SOA). In line with the objectives of this research, it was decided that the best solution to was to develop the front end as a web application. As such, the structure in CITIUS is constituted by a server, the display terminals and the

GNSS/CN devices, which should be installed physically inside the bus to be evaluated. The server should run both a web service and a database service.

Each terminal would run a web client, and would be connected to a GNSS/CN device which provides event information that update speed of 1 Hz. Messages from would be read and written into an XML file by the OBU parser. In the case of an event, the client request the corresponding multimedia data to the server (text, images, sound) and can regenerate an animation in real time when necessary. What follows is a detailed list of the elements necessary to make CITIUS work:

- Media Server and Database Server: The signage server should store all the information that will be displayed on the signage displays. The solution is to set up a server comprising of an http server and a database server. Both the web server and the database server are running on Apache and MySQL respectively. The environment chosen for the server was Debian Linux while the web interface was executed in Chrome, installed in a computer running Windows 8.
- Front End (web application): Each signage terminal has installed a web browser that supports HTML5 and WebGL which should be connected to the Internet. The Web interface of CITIUS is developed in HTML5 while the interface between the web application and the database is developed in PHP. Because of its support of WebGL technology, the software chosen to evaluate the system and therefore installed in every terminal was Google Chrome.
- OBU (GNSS/CN): The OBU provides extremely precise location information as well as other useful data[17] with an update frequency of 1 Hz.
- OBU parser: Messages from the OBU should be parsed so that the web application can interpret it. This application picks up the information received from the OBU and writes out an XML file periodically that will be read by the web application. This part is programmed in C# and runs on a Debian Linux virtual machine installed in the terminal.

[17] For details regarding the functions of the OBU see 3.3.2

- Vehicle (bus): Every terminal along with an OBU should be installed inside a moving bus which should travel along a designated route which is specified in each demo scenario.
- Wireless network: The DSS terminal should be able to connect to the internet to retrieve information from the server. Being a mobile system the most suitable solution is to use a 3G internet connection.
- Event administrator: Every time the event list has to be updated, an event administrator should remotely access the server to update the event list. This way, every time an event is updated on the server it will automatically be updated for all the terminals. The event administrator will also update the content of the advertisings utilizing design templates.
- Content designer: A content designer creates templates for advertising in HTML5/CSS3 so that the event administrator can utilize them to create new advertising events.

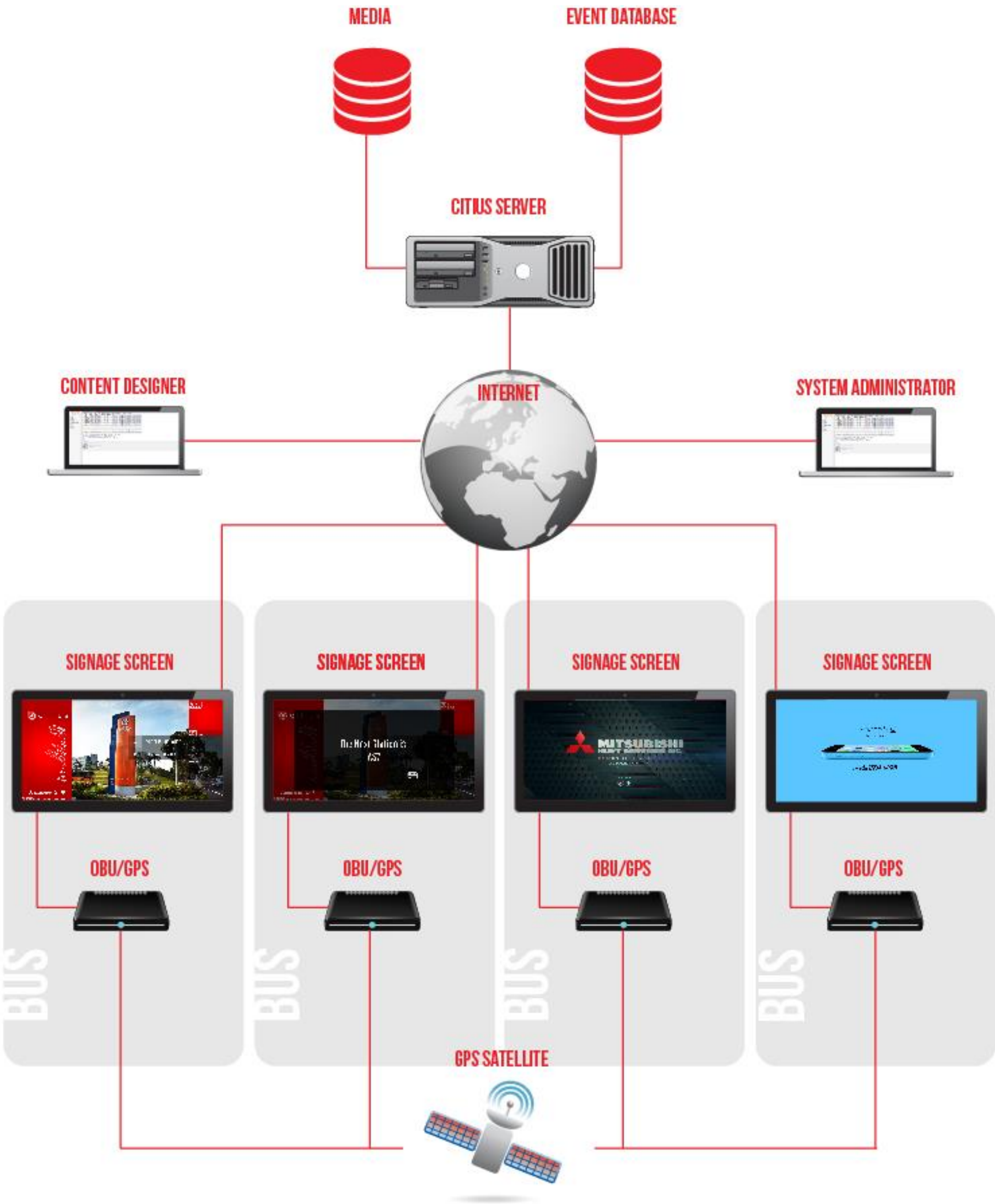

Figure 3 System architecture

3.3.1. EVENTS

The web application was designed as an event-based system. Each event is associated to a specific geographic location and is triggered when the bus approaches to it. This allows the possibility of predicting upcoming events based on geographical distance. It is necessary to emphasize once again that differently to most mobile digital signage infrastructures available, the event system developed in CITIUS does not work as a playlist, and instead it depends mainly on location. Each type of event has a specific duration pre-determined, and will be triggered only when the location is matched it. The system currently handles a total of 9 different categories of events, which is multiplied for the amount of individual events inside these.

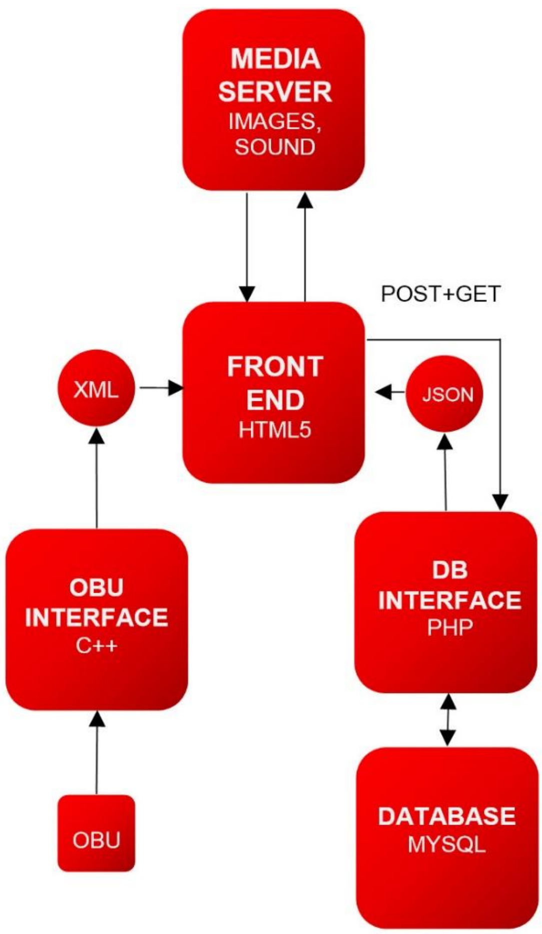

Figure 4: Data flow

Events are determined by a specific set of coordinates (latitude and longitude) and an event category among the described in the table Standard Events (below). Every time a new event is determined, is loaded both to the event database of the server and to the OBU. When the current coordinates of the OBU installed in the bus match an event, it will send a message to the signage screen containing the position and the event type. Then the application will request new content to the server when needed and will display it according to the characteristics of the event.

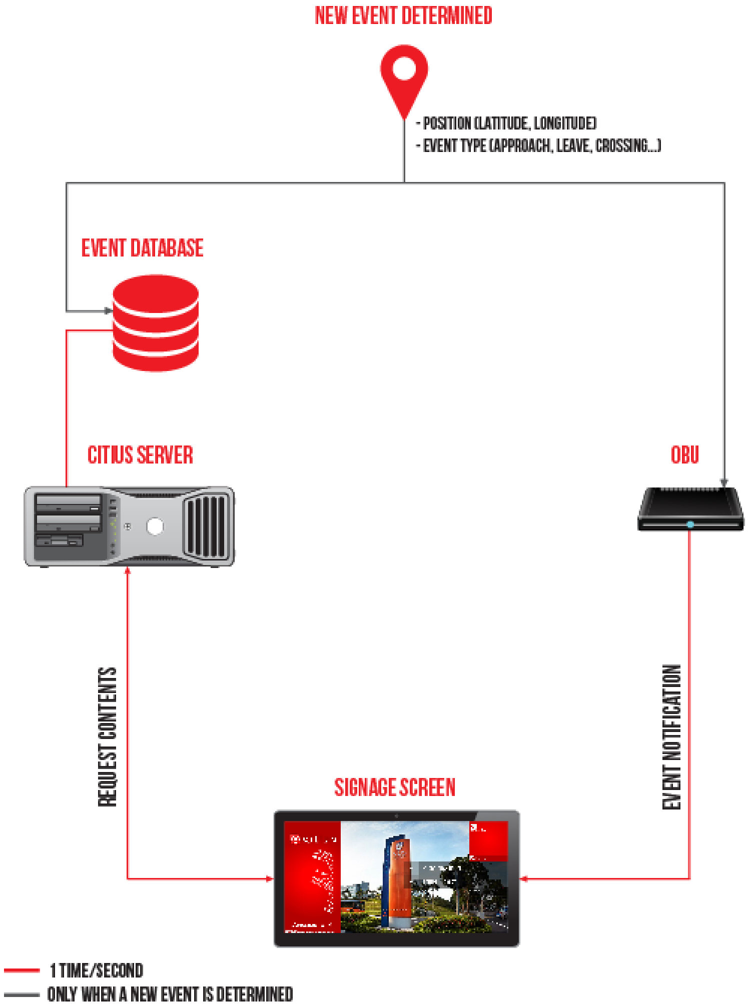

Figure 5: Event determination scheme

Table 4: Standard Events

Event	Action
APPROACH [station_name]	60 meters before arriving to a station, it triggers an animation that informs that we are arriving to that specific station.
LEAVE [station_name]	After 10 meters of leaving a station, it triggers an animation that informs the next station.
HUMP	Triggers a small alert letting the users know there is a hump ahead.
TURN_RIGHT	Triggers a small alert letting the users know the bus will turn right abruptly.
TURN_LEFT	Triggers a small alert letting the users know the bus will turn left abruptly.
XING	Triggers a small alert letting the users know the bus there's a crossing ahead.
ROADIN	Updates the current road.
ROADOUT	Updates the current road.
EMERGENCY	It triggers a full screen graphic alert on the system, displaying relevant instructions to the users in case of an emergency.

3.3.2. THE 2nd GENERATION ELECTRONIC ROAD PRICING (ERP2)

In order to develop a location aware advertising system is necessary to have the ability to 1) provide correct positioning information, 2) define or pick up specific regions exactly, 3) identify in short time that the device has entered into one specific region. For this development it was decided that the best option was to adopt the OBU system developed by Mitsubishi Heavy Industries. The OBU (On-Board Unit) was developed as a core component of the ERP2 Trial system which is the new generation of Electronic Road Pricing in Singapore, and it is meant to be connected to an external display device to provide a wide range of information. Because of this, when the ERP2 system is fully adopted every bus and taxi in Singapore will be required to install an OBU system by law, preparing the necessary conditions to install CITIUS.

The first version of the ERP system consists of a set of physical gantries located in strategic entry/exit points to the Singapore's central business district and also in expressways and arterial roads with heavy traffic with the main objective of discouraging the usage during peak hours. Currently, the ERP2 or GNSS / CN based electric toll collection system is being considered for implementation. In contrast with ERP1, in a GNSS/CN based system the vehicle's position is calculated by a GNSS positioning technique and records of the vehicle transactions are sent to a Central System by the cellular networks [13]. This system enables a more flexible and therefore fairer road pricing without gantries. The GNSS/CN OBU provides precise positioning information in real time, which enables CITIUS to trigger messages "at the right place" without delay.

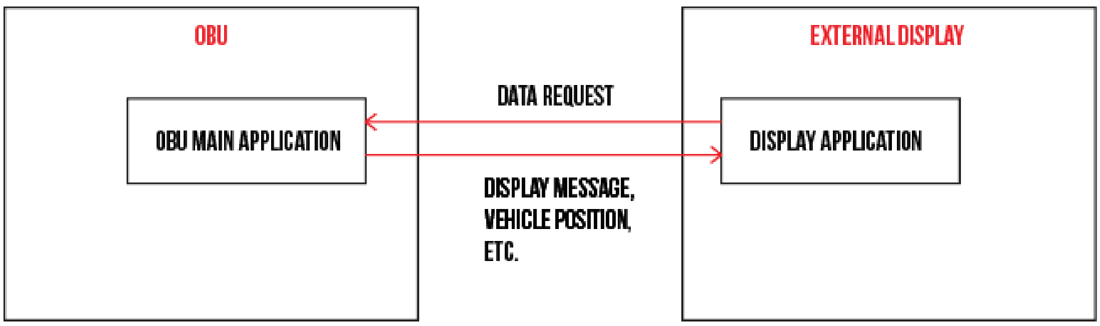

Figure 6: OBU Connection

The OBU system can provide location information within a 1 meter radius, while updating the data every second. In its most basic application it can display only characters (20 characters x 2 lines) but it can also be connected to devices with higher performance. By connecting the OBU to a high performance external display, a wide list of functions can be performed. Because of NDA limitations, those functions that were not used by CITIUS were removed.

Table 5 OBU Functions (those utilized in CITIUS are highlighted)

S/N	Function
1	Confirmation of Device Information
2	Display of Charging Result
3	Display of Traffic Information
4	Display of Vehicle Position
5	Display of Event
6	Display of Accident Information
7	Detection of Accident
8	Display of Charging Record
9	Icon on the map
10	Display of ERP 'virtual' entry/exit points and ERP charges.
11	Routing
12	Re Routing

3.3.3. PRESENTATION

To create both the interface and the motion graphics presented by the DSS the system, it was necessary to establish guidelines in terms of aesthetics and style. Particularly when talking about motion graphics, much attention should be paid to the way television and particularly broadcast design works. Being CITIUS a real life implementation that meant to be utilized by real consumers, the concept of branding was considered important from the beginning. The brand "CITIUS" along with a logotype and its animated version were created. A basic color palette was introduced basically consisting of the following colors: Red (#fd0000), Grey (#b1b1b1) and Black (#fd0000).

Figure 7: Example of interface and DOM update

The screen is segmented into regions, so that it becomes easier for the user to find what he's looking for. The segmentation considers a region for the route, next and last station, street, and warnings (hump, turn left, turn right and crossing). Also, the interface makes use of transparency to simulate glass for specific containers like Next Station or Last Station.

Transitions between events are dynamic, therefore the DOM are updated autonomously and independently. This also applies to relevant events which appear with a subtle "lights off" effect of the interface and takes up 90% of the screen, while still leaving a reference of the logo visible in the background. This follows the concept of channel packaging, which helps establishing ownership of the content.

4. Feasibility Study

In order to evaluate the postulates of the models, four field experiments were planned and executed between May 2013 and March 2014. During the field experiments, the general operation of the system was evaluated while collecting location information. During the first field experiment, the first prototype was installed in a private vehicle which ran on a route different to that of the real bus. Starting on the second experiment, the system was installed in two real bus units which running with normal people every day. At this stage location information and uptime information was collected at all times. During the third and the fourth field experiments, real time animation events were introduced, evaluating the response of the system and collecting network information to evaluate the merit of this option versus pre-rendered videos.

4.1 First Real Field Experiment

The first real field experiment of a working system took place during the week of May 5, 2013 and May 17, 2013 was mainly oriented to internal presentations of the system. A specially designed circuit inside the NUS Kent Ridge campus was decided and a private vehicle was used to install the terminal. This time, CITIUS was installed on a VAIO tap 20 with an Intel Core i5 i5-3337U CPU and 6GB of ram. The device also counted with a 20 inch, 1600x900 pixels LCD screen. For this scenario the interface design was fixed, which means that it was created specially to match the resolution of the device. An ad-hoc route for the demo scenario was designed with a total of 20 events. A private vehicle with a driver was hired and the system was installed in the back, accommodating a total of 8 passengers (MHI's engineer monitoring the OBU, two researchers from Keio-NUS monitoring CITIUS and five guests) plus the driver.

Figure 8: Private van utilized during the first field experiment

Starting on this experiment, APPROACH events were triggered 60 meters before arriving to the station while LEAVE events are triggered 10 meters after leaving the station. As a first implementation in terms of contents, it was decided to display relevant information regarding the bus route as well as a graphical representation of the bus on a map. For this reason, it was decided that the best would be to divide the screen vertically and make use of the Google Maps API.

Figure 9: Mount and setup of the system[18]

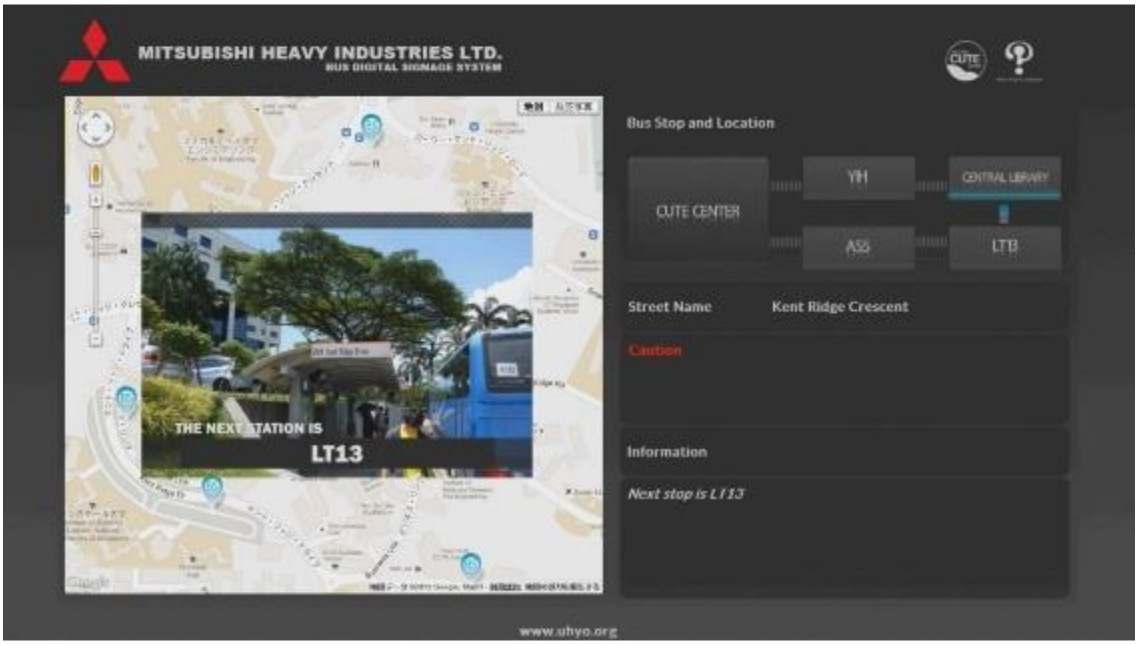

Figure 10 Screen of the first experiment

All the stations of the first scenario were presented using beacons on the map, and an icon representing the bus current position updating once per second. The

[18] Screen running CITIUS mounted inside the van (left)
and system preparation before the first field experiment (right) at NUS, Singapore

right side of the screen was divided vertically on its own displaying the bus route on the upper side and textual information on the bottom. The left side displayed the map, where overlay messages were displayed. In this scenario, there was only one advertising event that triggered when passing by the store, overlaying an image without animation on the map.

The designated route was limited to the NUS Kent Ridge campus and it was as follows:

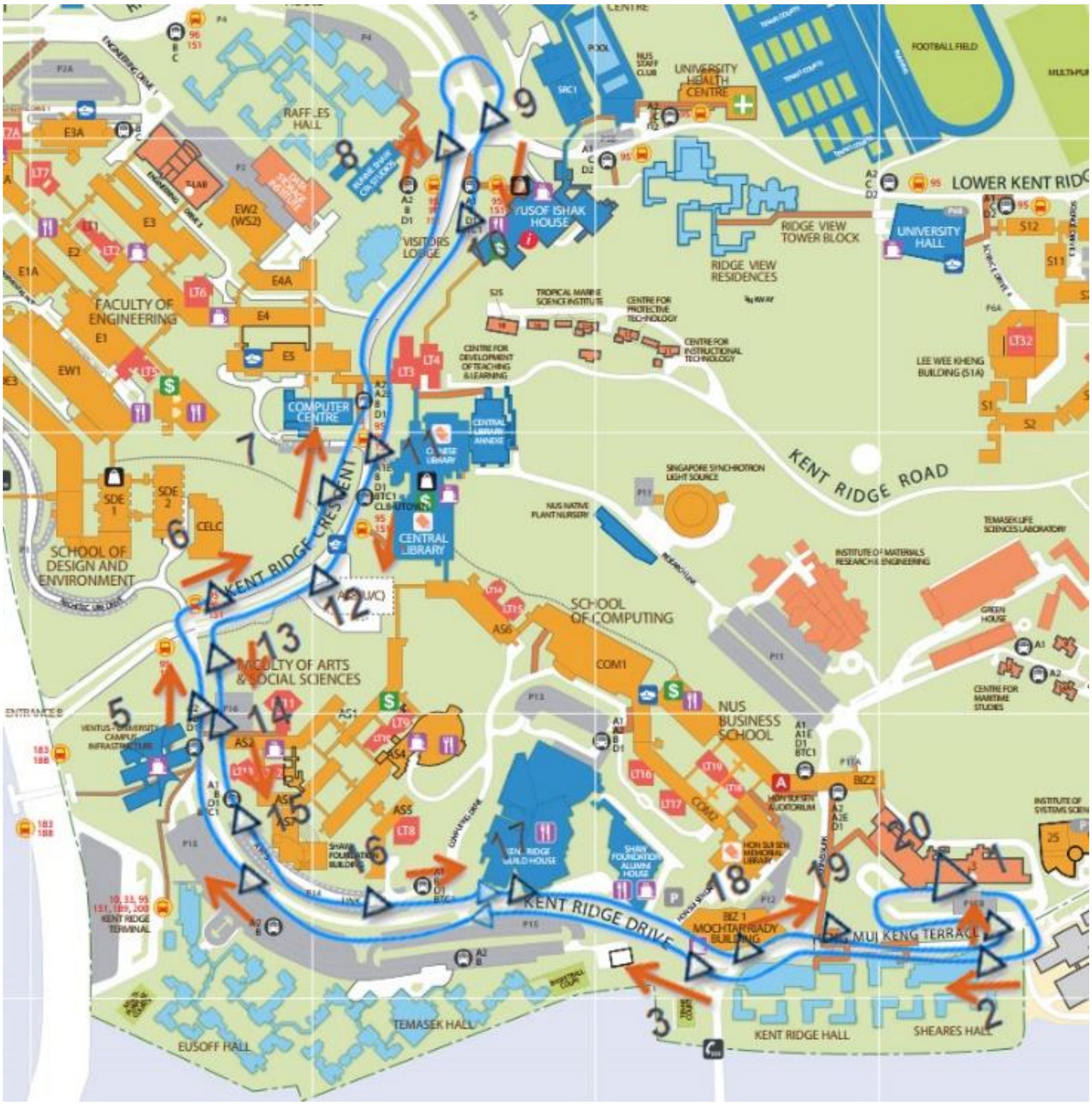

Figure 11: Reduced Route (first experiment)

Table 6: First Real Field Experiment: List of Events

No.	Event	OBU Message	ASCII
1	Start Point	No Messages from the OBU	—
2	Opening Animation	PUBLICINFO:Opening	50 55 42 4C 49 43 49 4E 46 4F 3A 4F 70 65 6E 69 6E 67
3	Road Information	ROADIN:KentRidgeDr_CW	52 4F 41 44 49 4E 3A 4B 65 6E 74 52 69 64 67 65 44 72 5F 43 57
4	Hump	PUBLICINFO:HUMP	50 55 42 4C 49 43 49 4E 46 4F 3A 48 55 4D 50
5	Turn Right	PUBLICINFO:TurnRight	50 55 42 4C 49 43 49 4E 46 4F 3A 54 75 72 6E 52 69 67 68 74
6	Road Information	ROADIN:KentRidgeCrescent_CW	52 4F 41 44 49 4E 3A 4B 65 6E 74 52 69 64 67 65 43 72 65 73 63 65 6E 74 5F 43 57
7	Crossing	PUBLICINFO:X-ing	50 55 42 4C 49 43 49 4E 46 4F 3A 58 2D 69 6E 67
8	U Turn	PUBLICINFO:U-Turn	50 55 42 4C 49 43 49 4E 46 4F 3A 55 2D 54 75 72 6E
9	Station Information	APPROACH:YIH	41 50 50 52 4F 41 43 48 3A 59 49 48
10	Station Information	LEAVE:YIH	4C 45 41 56 45 3A 59 49 48
11	Station Information	APPROACH:CentralLibrary	41 50 50 52 4F 41 43 48 3A 43 65 6E 74 72 61 6C 4C 69 62 72 61 72 79
12	Station Information	LEAVE:CentralLibrary	4C 45 41 56 45 3A 43 65 6E 74 72 61 6C 4C 69 62 72 61 72 79
13	Road Information	ROADIN:KentRidgeDr_CCW	52 4F 41 44 49 4E 3A 4B 65 6E 74 52 69 64 67 65 44 72 5F 43 43 57

14	Station Information	APPROACH:LT13	41 50 50 52 4F 41 43 48 3A 4C 54 31 33
15	Station Information	LEAVE:LT13	4C 45 41 56 45 3A 4C 54 31 33
16	Station Information	APPROACH:AS5	41 50 50 52 4F 41 43 48 3A 41 53 35
17	Station Information	LEAVE:AS5	4C 45 41 56 45 3A 41 53 35
18	Road Information	ROADOUT:KentRidgeDr_CCW	52 4F 41 44 4F 55 54 3A 4B 65 6E 74 52 69 64 67 65 44 72 5F 43 43 57
19	Road Information	ROADIN:HengMuiKengTerrace_CCW	52 4F 41 44 49 4E 3A 48 65 6E 67 4D 75 69 4B 65 6E 67 54 65 72 72 61 63 65 5F 43 43 57
20	Ending Animation	PUBLICINFO:Ending	50 55 42 4C 49 43 49 4E 46 4F 3A 45 6E 64 69 6E 67

4.2. Second Real Field Experiment

The second Real Field Experiment took place in September 7, 2013 and it marked the first implementation of the system in two currently active buses of the public transport network of Singapore. Naturally, since the system had to be installed in currently active buses, it was unavoidable to restructure the demo circuit and therefore expand the events, which totaled over 150 at the time of the implementation. This version counted with several major modifications, one of which that the contents that were hardcoded in the first demo event were moved to an external MySQL database, allowing remote updates of the contents triggered on each event. After considering the size of the screen, the hardware was upgraded from the VAIO Tap 20 to an ONKYO TW21A-B36 using an Intel Core i5 i5-3210M CPU and 8GB of ram. In this occasion, the screen was 21.5 inch with 1920x1080 resolution.

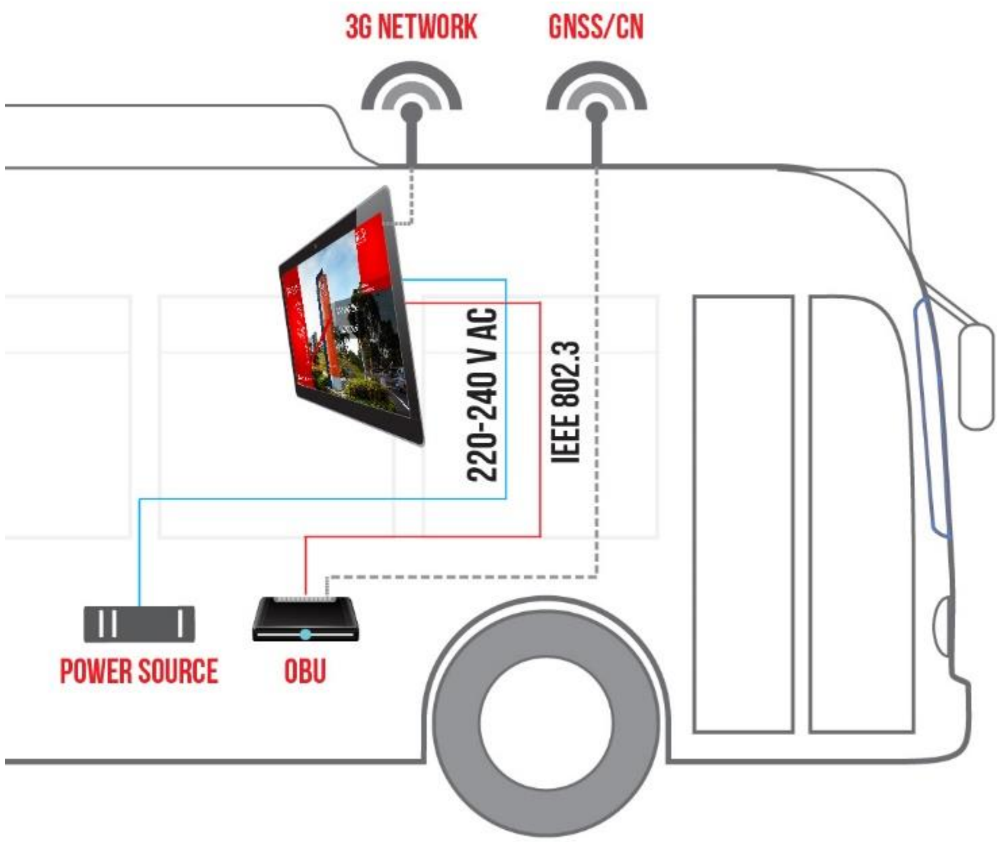

Figure 12: Bus installation scheme

Figure 13: Buses utilized from the 2nd real field experiment

Figure 14: Installing CITIUS in one of the two bus units

The design of the interface was rebuilt from scratch for this version, making it fluid and adaptable both to portable and full HD screens. In terms of content, after the key elements of the first demo's interface were selected, all the non-essential elements were discarded. In terms of optimization, and in line with one of the secondary objectives of this research which is to optimize bandwidth usage, it was decided to bring the number of rasterized graphics down to a minimum, replacing backgrounds and icons for dynamic graphics created using CCS3.

Another major modification during this stage was removing the map in favor of a more prominent graphical representation of the bus stops. This was because of two reasons. The first came from the feedback of the first demo where it was pointed out that implementation of the map on the screen was not essential. The second, and most important, it was decided to emphasize the independent factor on the development of the system and therefore it was best to avoid depending on third party APIs such as Google Maps. Event alerts such as APPROACH and LEAVE as well as advertising events were displayed on a full screen overlay which appeared and disappeared according to the events. Less important events such as HUMP, TURN RIGHT and TURN LEFT were displayed on a designated area of the screen (bottom right) and included simple animation. Finally, this was the first demo that included sound alerts on specific events.

Besides expanding the original route and incrementing the amount of events, an additional route was implemented. In order to save space, only APPROACH and LEAVE events will be described in the second and third real field experiments although all events from former experiments (hump, turn right, turn left, etc.) were implemented as well.

Table 7: A1 Route (2^{nd} real field experiment)

No.	OBU Message	Notation
A1_1	A1_APPROACH_PGPTERMINAL	APPROACH PGP TERMINAL
A1_2	A1_LEAVE_PGPTERMINAL	LEAVE PGP TERMINAL
A1_3	A1_APPROACH_AFTERSCIENCEPARKDRIVE	APPROACH AFTER SCIENCE PARK DRIVE
A1_4	A1_LEAVE_AFTERSCIENCEPARKDRIVE	LEAVE AFTER SCIENCE PARK DRIVE
A1_5	A1_APPROACH_KENTRIDGEMRTSTATION	APPROACH KENT RIDGE MRT STATION
::	::	::
A1_29	A1_APPROACH_HOUSE7	APPROACH HOUSE7

Table 8: A2 Route (2^{nd} real field experiment)

No.	OBU Message	Notation
A2_1	A2_APPROACH_PGPTERMINAL	APPROACH PGP TERMINAL
A2_2	A2_LEAVE_PGPTERMINAL	LEAVE PGP TERMINAL
A2_3	A2_APPROACH_BETWEENHOUSE14AND15	APPROACH BETWEEN HOUSE 14 AND 15
A2_4	A2_LEAVE_BETWEENHOUSE14AND15	LEAVE BETWEEN HOUSE 14 AND 15
A2_5	A2_APPROACH_HOUSE12	APPROACH HOUSE 12
::	::	::
A2_29	A2_APPROACH_NUH	APPROACH NUH

Additionally, it was necessary to implement modifications to comply with the bus running the circuit reversed, which implied facing new obstacles. Problems occur when two different buses, one driving straight (route A1) and one driving in reverse (route A2) and find the same spot. Since no additional information of the circuit is given, both buses identify the event as being part of the same route. Particularly, this is an issue when taking into consideration that the order of the circuit is displayed at all times on the screen. The solution to this problem consisted in evaluating the last stop when the event in question was triggered, deciding then if the relevant content that should be displayed is either A1_APPROACH_COM2 of route A1 or A2_APPROACH_COM2 of route A2.

4.3. Third Real Field Experiment

The third experiment took place in November 17, 2013, and introduced several improvements the structure of the system as well as the interface, but most importantly this demo was marked by the implementation of real time regeneration of animated advertising in CITIUS.

Table 9: 3rd Real Field Experiment: List of Events

No.	OBU Message	Notation	Action
::	::	::	::
2	A1_LEAVE_PGPTERMINAL	LEAVE PGP TERMINAL	Upcoming: MRT station
::	::	::	::
4	A1_LEAVE_AFTERSCIENCEPARKDRIVE	LEAVE BETWEEN HOUSE 14 AND 15	Animation: MRT station
::	::	::	::
12	A1_LEAVE_UNIVERSITYHALL	LEAVE TEMASEK HALL	Upcoming: Starbucks
::	::	::	::
14	A1_LEAVE_STAFFCLUB	LEAVE EUSOFF HALL	Animation: Starbucks
::	::	::	::
16	A1_LEAVE_YUSOFISHAKHOUSE	LEAVE LT13	Upcoming: Bookstore
17	A1_APPROACH_CENTRALLIBRARY	APPROACH COMPUTER CENTER	Animation: Apple
::	::	::	::
19	A1_APPROACH_LT13	APPROACH YUSOF ISHAK HOUSE	Animation: NUS News
::	::	::	::
23	AA_APPROACH_COM2	APPROACH STAFF CLUB	Animation: NUS News 2
::	::	::	::

26	A1_LEAVE_BIZ2	LEAVE UNIVERSITY HALL	Animation: Opening
::	::	::	::
31	ALERT_EMERGENCY	LEAVE PGP TERMINAL	Animation: Emergency

Figure 15: Bus route A1 (from 3nd real field experiment)

Acknowledging the conditions of a real life implementation, some APPROACH and LEAVE event names had to be changed according to the changes that the bus company implemented on the real circuit. At this stage a new type of event called EMERGENCY was introduced. When triggering this event at any time, a full screen emergency message is displayed giving information and instructions to the passengers.

In terms of the interface, five full screen animated events were created. Each event had an arbitrary runtime which was estimated in 20 seconds following the results of the second real field experiment. The animated advertising templates are designed using CSS3 and each animate differently. Each template has different customizable fields that can be updated remotely by the event administrator. What follows is an example of two different animated events, the editable content in the database and a representation of the resulting animation:

Figure 16 Progression of CSS animated event 01 (Apple Commercial)

Figure 17: Progression of CSS animated (NUS Public Information)

After the making a simple request to the database to generate the animated advertising, different simple CSS3 effects such as scale and blur are combined with 3d translation and graphical enhancements such as vignettes. As can be seen in the figure below, it is possible to present an animated advertising spanning 20 seconds using minimal network load (totalizing 333kb), while sustaining high resolution and adaptability.

Table 10: Editable content for CSS3 Advertising Event

Name
textLine01 [text]
textLine02 [text]
image01 [jpg file]
image02 [jpg file]

Table 11: Data requested by CSS animated event 01 (Apple Commercial)

Name	Type	Initiator	Size	Time
cm01.html	text/html	main.js:255	9.0 KB	9ms
cm01-promo01.jpg	image/jpeg	cm01.html:236	191KB	9ms
cm01-close01.jpg	image/jpeg	cm01.html:237	133KB	7ms
obuData.xml	application/xml	main.js:45	481 B	2ms

4.4. Fourth Real Field Experiment

Taking place in March 12th and 13th of 2014, the fourth real field experiment introduced events that make use of WebGL technology for real time 3d rendering in CITIUS making use of the three.js library. Two different templates were created consisting of 3d meshes, textures, dynamic lighting and shadows and full screen antialiasing. These events also included audio to improve the experience. What follows is a full table of the real bus running on the A1 route (only APPROACH and

LEAVE events are considered, since others less important events would add up to over 150). In the table it is possible to appreciate the transferred data per event.

Table 12: A1 road at the 4th Real field experiment[19]

Time	Data	OBU Event	Notes
3:18:00 PM	2 KB	A1_APPROACH_HOUSE7	CSS Animation "Approach"
3:17:00 PM	3 KB	A1_LEAVE_HOUSE12	CSS Animation "Leave"
3:16:00 PM	2 KB	A1_APPROACH_HOUSE12	CSS Animation "Approach"
3:15:00 PM	8 KB	A1_LEAVE_HOUSE7	CSS Animation "Leave"
3:14:00 PM	4 KB	A1_LEAVE_BIZ2	CSS Animation
3:13:00 PM	315 KB	A1_APPROACH_BIZ2	CSS Animation "Ending"
3:12:00 PM	823 KB	AA_APPROACH_COM2	CSS Animation "NUS Info 3"
3:11:00 PM	1474 KB	A1_APPROACH_CENTRALLIBRARY	CSS Animation "Apple Store"
3:10:00 PM	13 KB	A1_LEAVE_LT13	CSS Animation "Leave"
3:09:00 PM	185 KB	A1_APPROACH_LT13	CSS Animation "NUS Info 2"
3:07:00 PM	639 KB	A1_LEAVE_YUSOFISHAKHOUSE	CSS Animation "NUS Library"

19 Events of high bandwidth usage are highlighted.

3:06:00 PM	12 KB	A1_APPROACH_YUSOFISHAKHOUSE	CSS Animation "Approach"
3:05:00 PM	785	A1_LEAVE_STAFFCLUB	CSS Animation "Starbucks"
3:04:00 PM	77 KB	A1_APPROACH_STAFFCLUB	CSS Animation "Approach"
3:03:00 PM	11 KB	A1_LEAVE_LT29	CSS Animation "Leave"
3:02:00 PM	10 KB	A1_APPROACH_LT29	CSS Animation "Approach"
3:01:00 PM	6 KB	A1_LEAVE_NUH	CSS Animation "Leave"
3:00:00 PM	6 KB	A1_APPROACH_NUH	CSS Animation "Approach"
2:59:00 PM	7 KB	A1_LEAVE_KENTRIDGEMRTSTATION	CSS Animation "Leave"
2:58:00 PM	10 KB	A1_APPROACH_KENTRIDGEMRTSTATION	CSS Animation "Approach"
2:57:00 PM	2799 KB	A1_LEAVE_AFTERSCIENCEPARKDRIVE	WebGL "Mitsubishi"
2:56:00 PM	234 KB	A1_LEAVE_PGPTERMINAL	CSS Animation "Leave"
2:53:00 PM	1023	A1_APPROACH_PGPTERMINAL	Initial Load

In the following graphic (fig. 17) the highest peaks of transferred data are coincident with WebGL events in A1_LEAVE_AFTERSCIENCEPARKDRIVE (2799 Kb) and CSS3 events in A1_LEAVE_STAFFCLUB (786 Kb) and AA_APPROACH_COM2 (823 Kb) among others.

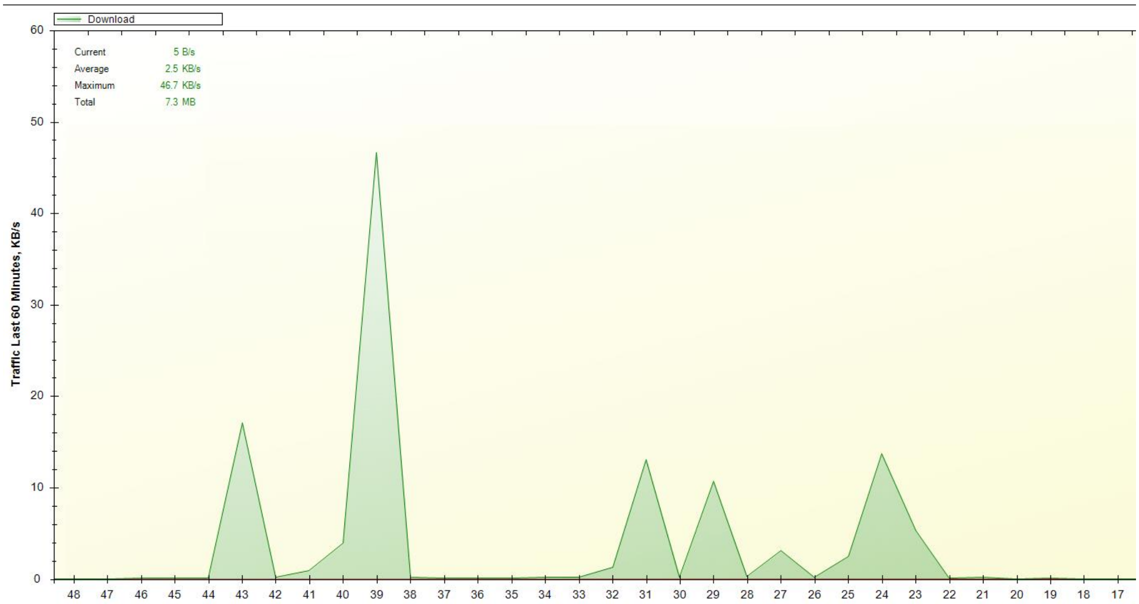

Figure 18: A1 road network traffic[20]

To be able to compare, video animations with similar quality and same length has been designed and pre-rendered. After that, the data loaded for each real time event was compared with is pre-render counterpart. As an example, here's the analysis based on the event A1_LEAVE_AFTERSCIENCEPARKDRIVE:

Table 13: Composition of WebGL Event "Mitsubishi"

Name	Type	Initiator	Size	Time
cm04.html	text/html	main.js:255	12.8 KB	12ms
three.min.js	application/javascript	cm04.html:43	403KB	7ms
Detector.js	application/javascript	cm04.html:45	2.2KB	6ms

[20] One pass, fourth demonstration.

OBJloader.js	application/javascript	cm04.html:44	2.2KB	6ms
tween.min.js	application/javascript	cm03.html:46	2.2KB	6ms
concrete.jpg	image/jpeg	three.min.js:221	97.1KB	7ms
concrete_bump.jpg	image/jpeg	three.min.js:221	97.3KB	5ms
pyramids.jpg	image/jpeg	three.min.js:221	97.4KB	5ms
logo.obj	image/jpeg	three.min.js:221	2.1MB	833ms
MHI_open.mp3	audio/mpeg	cm04.html:44	209 KB	6ms

The table above shows all the different elements required to reconstruct a 3d animation in real time using WebGL. It should be noticed that the TweenJS[21] library was also used, which allows easier handling of key frames in WebGL. The compositing parts are libraries (three.min.js, detector.js, OBJloader.js, tween.min.js), 3d models (logo.obj) textures (concrete.jpg, concrete_bump.jpg, pyramids.jpg) and sound (MHI_open.mp3). Particularly for this WebGL event, the total network load for a runtime of 27 seconds was 3032 kilobytes including the audio. A video with equal resolution although unavoidably lower quality because of the video compression (H264 codec) added up to over 25000 kilobytes, demonstrating for this particular case a reduction in a ratio of 8:1 in the network load.

[21] Available at http://www.createjs.com/#!/TweenJS

5. Conclusions and Future Development

5.1. Conclusions

A total of four real field experiments were carried out between May 2013 and March 2014, three of which involved installing the system in actual bus units working in the bus network of Singapore and monitor its behavior over prolonged periods of time. Based on the results of the implementation, it is possible to conclude that CITIUS becomes an interesting option as a web based autonomous digital signage system for the public transport.

Based on the first model of this research, it is possible to affirm that it is possible to develop an autonomous and efficient location aware digital signage architecture utilizing current web technology. CITIUS has demonstrated being able to provide information as well as advertising autonomously at the right time and the right place by combining location information with high quality content. While in operation, the time required to update the signage system stood among the range of 1-2 seconds. Just by changing a few options remotely to the server, it was possible to update all the terminals with new information or advertising. Also, because CITIUS was developed as a web application, it can operate in different platforms that support a web browser and in different resolutions which makes it easily portable regardless of the hardware or operating system. Consistency in the operation was other important factor when evaluating the system, and CITIUS has demonstrated it can sustain very high uptime during the feasibility tests, which involved installing the system in two bus units simultaneously and monitor it's uptime over 6 months. Furthermore, in cases of sudden loss of energy or of scheduled suspension of the system, the system turns on and becomes functional again automatically.

Based on the third model, it has been demonstrated that rendering the content in real time can greatly reduce the network load in a digital signage system. For WebGL events, it has been demonstrated that it is possible to optimize the required data for presenting a full motion commercial by an 88.75% when compared to pre-render video compressed with state of the art codecs. Nevertheless, when deploying the system with WebGL events, it becomes necessary to consider that requirements might be higher. These requirements and limitations will be specified in the next section.

Also, making use of the OBU, enabled the system to obtain position information very quickly and accurately, and in the likely case that the ERP2 system is adopted by the Singaporean government, it would mean a big step to expand the system. It is projected that the OBU device will be installed in every bus and taxi in Singapore as a part of the ERP2 program if it becomes adopted as the successor of the ERP.

Finally, this thesis describes the design and implementation of the system and the effectiveness and utility of the model; however, the experiments provided us with other interesting experiences like usability, human aspects, and user modeling. We intend to present these experiences in the future.

5.2. Merits

5.2.1. FOR THE USERS

The main users of this system has been identified as students, professors, workers and visitors of the National University of Singapore Kent Ridge Campus. Users can get precise navigation information in real time according to the current bus location. Among the different information they receive using CITIUS:

- Localization information. Arriving to/leaving X station, current street: (without localization it is difficult to get off at the right destination)
- Estimated time to arrival (without CITIUS, it is not clear when the bus can arrive at the destination)
- Points of interest (university buildings, libraries, restaurants, etc.)
- Where to change with another bus line or the metro
- Public information (information about events, new courses and others related to NUS)
- Sudden turns, humps on the road, crossings
- Emergency information (in case of accidents, natural disasters, etc.)

5.2.2. FOR THE STAKEHOLDERS

Several stakeholders have been identified for CITIUS: Advertising companies, Mitsubishi Heavy Industries and bus company owners.

- Advertising companies: For advertising companies, CITIUS represents a new tool for advertising inside buses in Singapore. Current signage, where available, is analog (traditional signage). CITIUS allows advertisers to deliver targeted content to users very precisely.
    - Add/Remove/Modify advertising content in real time (up to 1 second delay since updating)
    - Remote administration
    - Reduce costs of replacing the advertisings
    - When updating the content, all terminals connected to the network will automatically pick up the new content (no need to update every single terminal)
    - Can provide content in different formats and resolutions (landscape, portrait, big or small screens)
- Mitsubishi Heavy Industries (sponsor of this research): The position information that the infrastructure utilizes is provided by the On Board Unit (OBU) which is developed and produced by Mitsubishi Heavy Industries. As an essential part

of the system, every bus with the current version of CITIUS will require the installation of the OBU device.

- Bus company owners: By adopting this system, bus companies will see themselves be benefited by:
    - Monetizing. New source of income selling the space to advertisers. Optimized use of the available space for advertising inside the bus.
    - Improve the service quality (better navigation for their users)
    - Since the system works autonomously, it requires minimum maintenance

5.3. Limitations

While rendering 3d content in real time has great advantages that were described before, the content for real time rendering must be prepared in a particular way, differently to the workflow of pre-rendered content.

- Vertices: Differently from video content, real time content must consider that the 3d objects will be processed in real time. The limitation by the library utilized to display real time 3d (Three.js) is currently 65.536 vertices. There is also a limitation in the amounts of objects to be displayed on the screen at the same time, although this varies greatly according to the hardware capabilities of the terminal.
- Live Action footage: For artistic reasons, some commercial pieces might require the inclusion of real footage. It is possible to display live action footage in CITIUS and mix it with content regenerated in real time, although it will be necessary to include and treat the footage as a texture that can be then rendered in the 3d environment.
- Hardware limitations: In order to display real time 3d content, CITIUS requires a GPU capable of processing shaders.

- Software Limitations: Currently WebGL can run in Chrome (all platforms) and Firefox (Windows, MacOSX, X11 and Firefox Mobile). Other platforms are not supported at the moment.

Another limitation of the system that must be considered, is that while it is possible to reproduce motion graphics in real time, the audio is not being rendered in real time, making use of compressed files such as mp3 for the dummy events. It should be mentioned though, that while compressed video files can be quite large, compressed audio files can become small enough, having no delay issues when testing the system.

5.4. Future Development

One of the most likely future implementations being discussed at the moment, is taking advantage of the system portability to expand its context awareness to the user side. For example, functions such as accessing the system using a smartphone and being able to select the language are being considered. This can be useful particularly in countries such as Singapore with four official languages or when big international events are carried. At the moment there are these and other discussions to expand the system functionalities and reach the commercial stage. At the same time, it is under consideration the implementation of CITIUS in other mobile transport systems such as the boat taxi in Singapore which might happen during 2015.

5.4.1. CONSIDER THE BUS FARE

After being pointed out at the midterm presentation, the bus fare when displaying promotions will be consider for future implementations. Currently, when a promotion is presented, it is necessary to get off the bus and go to the shop in order to make use of it. The problem comes when the ticket has already been paid, so the promotion might become useless if the cost of a second ticket is higher than the savings offered by the promotion. This was not a problem in particular for the real field experiments, since the bus lines that run inside the Kent Ridge Campus are free, but it might become an obstacle when expanding the system outside NUS. For this reason, it might be interesting to think of a way that the fare can be connected in the system too. For example, connect the signage with the charging system and get a free pass when using the promotion.

5.4.2. COUPONS THROUGH SMARTPHONES

Making use of the capabilities allowed by developing the system under HTML5, it is possible to run CITIUS in smartphones as well. As revealed by the review of similar systems, it can be useful to use the smartphone to "catch" the promotions while riding the bus, and use them at a different moment. This might not be possible for all time sales (since many times these are released for reasons of stock or weather conditions that does not prolong in time) but for others it can be a good solution.

5.4.3. INCORPORATE THE BUS USER'S PERSPECTIVE

Due mainly to time and economic constraints, the development and implementation of this system was focused predominantly on the provider's perspective.

Nevertheless, there is a whole new dimension that should be added by evaluating the response of the bus users. At this stage a profile of the users and stakeholders was built, but in order to reach the commercial stage new content should be introduced. Because content is directed specifically to the bus users, it is proposed to continue the development of the system and in particular that of the new content by getting user's feedback during the next evaluation phase of the system.

An interesting possible approach to evaluate user reaction would be utilize the camera already installed inside the CITIUS terminals to determine when passangers are paying attention to the content and for how long. This can be complemented with surveys when they get off the bus. By combining the two methods we can improve the design of the content that is provided to the users inside the bus and adjust the system to better accomodate such content.

5.4.4. CONSIDER EXTENDING THE SYSTEM TO OTHER TRANSPORTATION SERVICES OR EVEN PEDESTRIANS

Currently the system was developed specifically to work on the bus network, but with modifications it is possible that this same system can be applied to a variety of transportation services. But what sort of modifications are necessary to expand CITIUS to other transportation services?

In the case of buses, having the route predefined helps solving issues such as when two different buses (running in different lines) pass through the same geographical point therefore triggering the same event. To solve this issue line identification was used[22]. But in the case of taxis for example, this is not possible. The quickest solution to this issue is to receive and use extra information from the OBU, therefore combining location and terminal ID, providing different content in different taxi units when necessary.

Going further into the future, another interesting possibility is to extend the system to pedestrians, either by accessing the system through a cellphone or through a new wearable devices. For that particular case, it is impossible to keep utilizing the OBU device, but it is possible to use location information provided by smartphones. This opens very interesting possibilities to provide location aware content to individuals anywhere, at any time.

5.5. Steps to reach the commercial stage

There are some aspects of the system that needs further work before successfully reaching the commercial stage. First of all, a more user-friendly interface for the back end (content management system) needs to be designed and in particular a user system must be implemented. At the moment, new events are added to directly to the database using a single user (or administrator) which might leave space for problems in the hypothetical case than events are added by more than one user. The solution would be creating a hierarchy based access to the administration system.

[22] See page 42 for real example observed during the experimentation phase

It must also be noted that the current implementation CITIUS depends on the OBU device, which is currently working only in Singapore. In order to be able to expand the system out of Singapore there are two possible solutions: The first is to ask the MHI to make the OBU device available in other regions. The second option to expand outside Singapore, is to find an alternative device that provides accurate location information. While CITIUS has been designed to work exclusively with the OBU device for the real field experiments, it is possible to adapt its code to work with different devices that provide location information and might already be available in other regions. It must be noted that one of the great advantages of the OBU device is its combination of speed when updating the position (1hz.) and its accuracy, on which CITIUS relies. To get similar results with CITIUS, any other device that provide positioning information should be up to par.

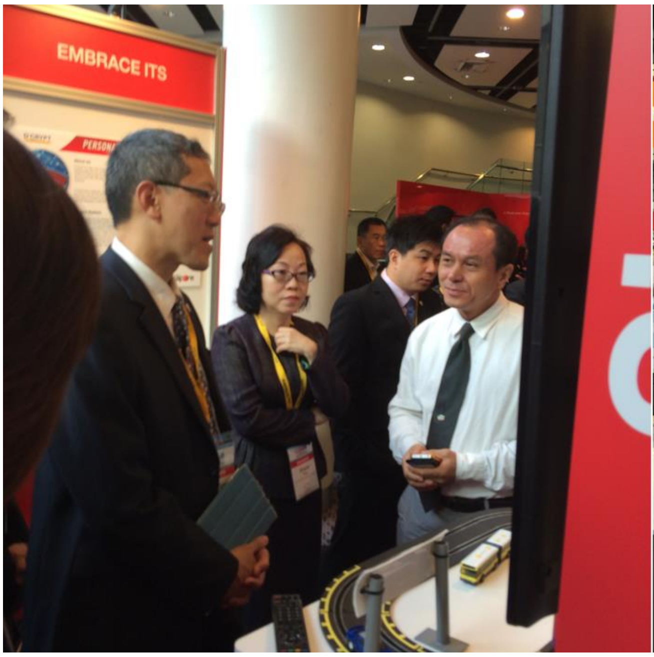

Figure 19: CITIUS presentation from MHI[23]

Until the moment of writing this thesis, the system was presented to potential early adopters in April 2014 in Singapore. The system was introduced by Professor Sugiura, Professor Sato and myself, together with Mitsubishi Heavy Industries engineers and executives. MHI, on its side, is also introducing the system to different possible adopters in order to reach the commercial stage.

Table 14: Demonstrations to possible adopters of CITIUS

Date	Description	Details
13/3/2014	CITIUS demonstration at NUS Campus to OCA-NUS	OCA: office of campus amenity, a division of NUS
23/4/2014	CITIUS demonstration at NUS Campus to URA CITIUS demonstration at NUS Campus to NCS	URA: Urban Redevelopment Authority, Singapore government[24] NCS: Singapore IT constructor[25]
25/4/2014	CITIUS demonstration at NUS Campus to DNP	DNP: Dai Nippon Printing[26]

[23] Mr. Masayuki Yamamoto, Senior General Manager of MHIES-A (white shirt, left picture) introducing CITIUS to the CEO of the Land Transport Authority of Singapore Mr. Chew Hock Yong (at ITS AP in Auckland)

[24] http://www.ura.gov.sg/uol/

[25] http://www.ncs.com.sg

[26] http://www.dnp.co.jp/eng/

20/5/2014	CITIUS demonstration at NUS Campus to SMRT	SMRT: Singapore's BUS/Train/TAXI company[27]
20/5/2014	CITIUS demonstration at NUS Campus to LTA	LTA: Land Transport Authority[28]

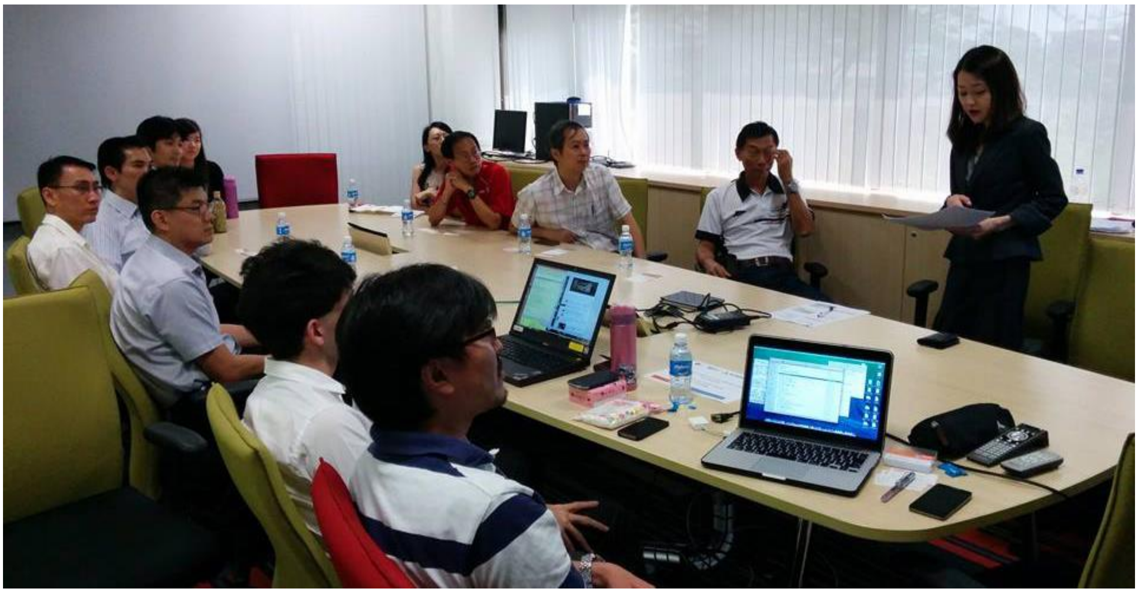

Figure 20: Meeting before demonstration of CITIUS to potential adopters[29]

[27] http://www.smrt.com.sg

[28] http://www.lta.gov.sg/content/ltaweb/en.html

[29] Demonstration to NCS in charge of Kyoko Oshima (MHI), Professor Sato, Professor Sugiura and Nahuel Salcedo at NUS Campus, Singapore

5.6. Media Coverage

After the first press release[30] from Mitsubishi Heavy Industries in June 11, 2014, CITIUS has been introduced in a variety of major newspapers and digital media in Japan.

Japanese Newspapers:

- 日本経済新聞　2014.6.12　「バスに情報提供システム」
- 日経産業新聞　2014.6.12　「バスに運行情報提供」
- 日刊工業新聞　2014.6.11　「情報提供システムＧＮＳＳ利用」
- 化学工業日報　2014.6.12　「バス車内用情報提供システム開発」

Japanese Digital media:

- Asahi Shimbun Digital 2014.6.12　三菱重工業など、シンガポールのバス車内向け情報提供システム「CITIUS」を開発[31]
- 日経新聞　2014.6.11　「三菱重工、バスに情報提供システム　シンガポールで実証運用」[32]
- Yahoo Japan 2014.6.11「三菱重工、バスの位置情報に基づく情報提供システムを開発…シンガポールで実証」[33]
- MSN 2014.6.11「三菱重工、バスの位置情報に基づく情報提供システムを開発…シンガポールで実証」[34]

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[30] See Appendix “A”

[31] http://www.asahi.com/and_M/information/pressrelease/Cjcn1406122341.html

[32] http://www.nikkei.com/article/DGXNASDZ110EE_R10C14A6TJ2000/

[33] http://headlines.yahoo.co.jp/hl?a=20140611-00000045-rps-bus_all

[34] http://topics.jp.msn.com/economy/photo-article.aspx?mediaid=8591865

6. Acknowledgements

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8. Appendix

A. CITIUS Press Release (English version)

"CITIUS" Location-aware Information System for Buses

- Collaboration with Keio-NUS CUTE Center, Research Institute Jointly Founded by Keio University and National University of Singapore –

Tokyo, June 11, 2014 - Mitsubishi Heavy Industries, Ltd. (MHI), has partnered Keio-NUS CUTE Center at the National University of Singapore (NUS) to develop a location-aware information system for buses. Called CITIUS (Communication Infrastructure of Transport Information for Universal Service), the system aims to provide bus operators and commuters with useful area information based on the precise location and condition of the bus, in real-time.

CITIUS incorporates the elements of transportation, location, and Point-of-Interest (POI) information into its design. The precise location of a bus is tracked and identified using the highly-precise global navigation satellite system (GNSS). Based on this collected data, the CITIUS system is "aware" of the real-time location of the bus and will suitably retrieve and display related area information onto the digital signage onboard the bus. Besides providing the name of the next bus stop, information on nearby public facilities and notifications of ongoing events around the area, the system can also warn drivers of potential road hazards ahead (such as humps, speed limit, sharp turns, etc.).

Using cellular network, the CITIUS can function as a remote monitoring system as well. By making use of sensors mounted on On-Board Unit to gather vehicular activity and traffic conditions, the data from the bus journey is recorded and can then be analyzed further to study how safer and more sustainable bus operations can be maintained.

With its helpful automatic notifications and smart monitoring capabilities, the CITIUS system can help prevent passengers from missing their stops and enable bus operators to find out about the operating conditions of their buses in real-time. The CITIUS system may also be a form of additional revenue as it can be extended to retail advertising use.

MHI, together with the team of researchers led by Dr. Masaaki Sato, Visiting Senior Research Fellow at the Keio-NUS CUTE Center, plans to continue making efforts in developing technologies that can make public transportation much more convenient and smarter in the future.

The development of CITIUS has benefited from MHI's experience in producing highly reliable technologies in Intelligent Transportation Systems (ITS). MHI's precise positioning technology has been accumulated through its smart community demonstration projects in Malaga, Spain; Kansai Science City ("Keihanna"); and through the development of its GNSS-based Electronic Fee Collection (EFC). These technologies, coupled with Keio-NUS CUTE Center's continuous quest for developing media technologies and deep knowledge of the probe data management, have led to the reinvention of a simple and convenient system for transport infrastructure.

Traffic congestion is a significant problem in urban areas, particularly in Asia's cities which are undergoing sustained rapid economic development. CITIUS may be a possible technology that could address some of these urban transportation challenges and benefit not only the local population, but also the working and holidaying visitors.

MHI and Keio-NUS CUTE Center will continue to develop intelligent systems that could potentially serve as optimal solutions for today's transportation problems and inspire re-inventions for future city transportation infrastructure.

Notes:

1. Established in 2009, Keio-NUS CUTE (Connective Ubiquitous Technology for Embodiments) Center is a joint collaboration between the National University of Singapore (NUS) and Keio University, Japan, and is funded by a grant from the

National Research Foundation administered through the Media Development Authority of Singapore. It has a center located at NUS in Singapore and a center at Keio in Tokyo to collaborate on fundamental research in the area of interactive digital media for the creative and digital media industries.

2. Probe data: sensor information transmitted to a server from a vehicle for processing to create a good understanding of the driving environment

B. CITIUS Main JS Code (4^{th} demonstration)

```
//onload
window.onload = function(){
        var layout;
        layout = new Layout();

        //add initial data
        layout.update(layout);

        //update the content every 1 second
        setInterval(
                function(){
                        layout.update(layout);
                        },
                1000);
};

//Create main layout object
var Layout = function(){
        this.lastScenario;
        this.lastStation;
        this.nextStation;
        this.stationList;
        this.display;
        this.streetContent;
        this.src;
        this.circuitCode;
        this.upcomingSrc = "img/spacer.png";
        this.soundFX = document.createElement('audio');
        this.soundFX.setAttribute('src', 'audio/ding.mp3');
        this.soundFXcrossing = document.createElement('audio');
        this.soundFXcrossing.setAttribute('src', 'audio/crossing.mp3');
```

```
        this.soundFXturnRight = document.createElement('audio');
        this.soundFXturnRight.setAttribute('src', 'audio/turnRight.mp3');
        this.soundFXturnLeft = document.createElement('audio');
        this.soundFXturnLeft.setAttribute('src', 'audio/turnLeft.mp3');
        this.soundFXhump = document.createElement('audio');
        this.soundFXhump.setAttribute('src', 'audio/hump.mp3');
};

//Update Content
Layout.prototype.update = function(layout){
        //xml request
        var httpobj = layout.httpObj();
        httpobj.open('GET', 'xml/lords.xml', false);
        httpobj.send(null);

        //parse xml
        var lastState;
        var txt;
        var lords = httpobj.responseXML.getElementsByTagName('LORDS');
        var eventobj = lords[0].getElementsByTagName('Event');
        var originalTxt;

        // Define Behavior Events
        var humpString = "A1_BEHAVIOR_HUMP";
        var xingString = "A1_BEHAVIOR_XING";
        var turnRightString = "A1_BEHAVIOR_TURNRIGHT";
        var turnLeftString = "A1_BEHAVIOR_TURNLEFT";



        //Scenarios
        if(eventobj[0].childNodes.length > 0){
                txt = eventobj[0].childNodes[0].nodeValue;
                originalTxt = txt;
```

```
if (this.lastScenario != txt){
        //Behavior Event Selector
        var stringB = txt.substr(3);
        if ( stringB.search( humpString.substr(3) ) > -1 ) {
                txt = humpString;
                this.soundFXhump.play();
        } else {
                this.soundFX.play();
        }
        if ( stringB.search( xingString.substr(3) ) > -1 ) {
                txt = xingString;
                this.soundFXcrossing.play();
        }
        if ( stringB.search( turnRightString.substr(3) ) > -1 ) {
                txt = turnRightString;
                this.soundFXturnRight.play();
        }
        if ( stringB.search( turnLeftString.substr(3) ) > -1 ) {
                txt = turnLeftString;
                this.soundFXturnLeft.play();
        }

        //Circuit Identifier
        if ( txt ===
"A2_LEAVE_HONSUISENMEMORIALLIBRARY" ) {
                this.circuitCode = "A2";
        }
        if ( txt === "A1_LEAVE_AS7" ) {
                this.circuitCode = "A1";
        }
        if ( txt === "AA_APPROACH_COM2" ) {
                if (this.circuitCode === "A1" ){
```

```
                txt     =     "A1_APPROACH_COM2";

        }
        if (this.circuitCode === "A2" ){
                txt     =     "A2_APPROACH_COM2";

        }
}
if ( txt === "AA_LEAVE_COM2" ) {
        if (this.circuitCode === "A1" ){
                txt = "A1_LEAVE_COM2";

        }
        if (this.circuitCode === "A2" ){
                txt = "A2_LEAVE_COM2";

        }
}

// Retrieve Information from the Database
$.ajax({
        async: false,
        type: 'POST',
        url: 'data.php',
        data: { 'txt': txt},
        dataType: 'json',
        success: function (data) {
        $.each(data, function(entryIndex, entry){
                if(entry.event == txt){
                        this.src  =  information  =
entry['src'];
                        var     streetContent     =
entry['streetContent'];
```

```
});
}

var infoContent = entry['infoContent'];
var cautionContent = entry['cautionContent'];
var cautionSrc = entry['cautionSrc'];
var upcomingSrc = entry['upcomingSrc'];
var lastScenario = originalTxt;
var displayFS = entry['displayFS'];
var fullScreenID = entry['fullScreenID'];
var lastStation = entry['lastStation'];
var nextStation = entry['nextStation'];
var fsMSG = entry['fsMSG'];
var stationList = entry['stationList'];
if(displayFS === "yes"){
    var fsContent = entry['fsContent'];
}

layout.changeInfo(this.src, infoContent, streetContent, cautionContent, cautionSrc, upcomingSrc, lastScenario, lastStation, nextStation, fsContent, displayFS, stationList, fsMSG, fullScreenID);
};
});
}
```

```
                    });
                }
            }
                else {
                    if (this.lastScenario != "none"){
                        this.src = information = "";
                        var streetContent = "";
                        var infoContent = "";
                        var cautionContent = "";
                        var cautionSrc = "";
                        var upcomingSrc = "";
                        var lastScenario = "";
                        var displayFS = "";
                        var fullScreenID   = "";
                        var lastStation   = "";
                        var nextStation   = "";
                        var stationList   = "";
                        var fsMSG   = "";
                        layout.changeInfo(this.src,     infoContent,
streetContent, cautionContent, cautionSrc, upcomingSrc, lastScenario, lastStation,
nextStation, stationList, fsMSG, fullScreenID);
                    }
                }
    }


    //XMLHttpRequest
    Layout.prototype.httpObj = function(){
        if(window.ActiveXObject){
            try{
                return new ActiveXObject("MSXML2.XMLHTTP6.0");
            }
            catch(e){
```

```
                try{
                        //old msxml
                        return new ActiveXObject("MSXML2.XMLHTTP3.0");
                }
              catch(e){
                        try{
                                return new
ActiveXObject("MSXML2.XMLHTTP");
                        }
                        catch(e){
                                alert("error");
                        }
                }
          }
      }
      else if(window.XMLHttpRequest){
                //other than IE
          return new XMLHttpRequest();
      }
      else{
          return null;
       }
  }

  //Update DOM
  Layout.prototype.changeInfo = function(src, infoContent, streetContent,
cautionContent, cautionSrc, upcomingSrc, lastScenario, lastStation, nextStation,
fsContent, displayFS, stationList, fsMSG, fullScreenID){
        this.lastScenario = lastScenario;

        //Update Caution Image
        if(cautionSrc.length == 0){
                document.getElementById("cautionImg").src="img/spacer.png";
```

```
	}
	else{
		document.getElementById("cautionImg").src=cautionSrc;
	}

	// Update Upcoming Image
	if(upcomingSrc.length != 0){
		if(upcomingSrc == "remove"){
			this.upcomingSrc = "img/spacer.png";
		} else {
			this.upcomingSrc = upcomingSrc;
		}
	}
	document.getElementById("upcomingImg").src=this.upcomingSrc;

	//Update Information Box
	document.getElementById("infoContent").innerHTML=cautionContent;
	if (streetContent != 0) {
		this.streetContent = streetContent;
	};
	document.getElementById("streetContent").innerHTML=this.streetConte
nt;

	//Update Last Station
	if (lastStation != 0) {
		this.lastStation = lastStation;
	};
	document.getElementById("lastStation").innerHTML=this.lastStation;

	//Update Next Station
	if (lastStation != 0) {
		this.nextStation = nextStation;
	};
```

```
            document.getElementById("nextStation").innerHTML=this.nextStation;
            document.getElementById("content07").style.display='inline';
            document.getElementById("alertFrameContent").innerHTML=nextStatio
n;

            //Update Station List
            if(typeof stationList === 'undefined' || stationList === ""){
            } else{
            this.stationList = stationList;
            };
            document.getElementById("stationList").innerHTML=this.stationList;

            //Update Full Screen Content
            if (displayFS == "yes") {
                        document.getElementById("content07").style.display='none';
                        document.getElementById("content07-
cm01").style.display='none';
                        if (fullScreenID == "0") {

            document.getElementById("content07").style.display='inline';

            document.getElementById("alertFrameContent").innerHTML=fsContent;

            document.getElementById("fsMSG").innerHTML=fsMSG;
                        }
                        if (fullScreenID == "1" || fullScreenID == "2" || fullScreenID ==
"3" || fullScreenID == "4" || fullScreenID == "6" || fullScreenID == "7" ||
fullScreenID == "8") {
                                    document.getElementById("cm01-iframe").src            =
"cm/cm0" + fullScreenID + ".html";
                                    document.getElementById("content07-
cm01").style.display='inline';
                        }
```

```
                    if (fullScreenID == "5") {
                              document.getElementById("content07-
cm05").style.display='inline';

          document.getElementById("emergencyFrameContent").innerHTML=fsCo
ntent;

          document.getElementById("emergencyFsMSG").innerHTML=fsMSG;
                    }
          } else {
                    document.getElementById("content07").style.display='none';
                    document.getElementById("content07-
cm01").style.display='none';
          };
     }
```

B. CITIUS Style Layout (4th demonstration)

```
html {
   height:100%;
}
body {
   color:#F4F4F4;
   font-family:Pathway Gothic One;
   font-size: 150%;
   height:100%;
   background: url(../img/bg01.jpg);
   background-size: 110% auto;
   margin: 0px 0px 0px 0px;
   -webkit-transform: perspective(500px) matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0,
0, 0, 0,1);
}
```

```
/* *************************** */
/* CONTENT BLOCKS STYLE */
/* *************************** */
.content00 {
  position:absolute;
  left:0px;
  width: 25%;
  height: 100%;
  background-color:#F00;
  background-position:bottom;
  background: -webkit-gradient(radial, 50% 50%, 400, 50% 50%, 100,
from(#B30000), to(#F00));
  -webkit-box-shadow: 1px 2px 3px rgba(0,0,0,.5);
  -webkit-animation-name: content00Slide;
  -webkit-animation-timing-function: ease-in;
  -webkit-animation-duration: 0.5s;
  display:-webkit-box;
  -webkit-box-align:stretch;
}

.logo{
    position:absolute;
    background-repeat:no-repeat;
    background-image:url(../img/logo.png);
    background-size:100% auto;
    width: 90%;
    height: 60%;
      top:10%;
    left:7%;
}
.content01 {
  position: absolute;
```

```
    right: 0px;
    width: 17%;
    height: 30%;
    background-color:#F00;
    background: -webkit-gradient(radial, 50% 50%, 400, 50% 50%, 15, from(#B30000), to(#F00));
    text-align:right;
    -webkit-box-shadow: -1px 2px 3px rgba(0,0,0,.5);
    display:-webkit-box;
    -webkit-box-pack:end;
    -webkit-box-align:end;
  }
  #content02 {
    position: absolute;
    right: 0px;
    width: 17%;
    height: 6%;
    top:30%;
    background-color:#AE0000;
  }
  #content03 {
    position: absolute;
    right: 0px;
    width: 40%;
    height: 12%;
    top:35.9%;
    background-color:rgba(0,0,0,0.5);
    display:-webkit-box;
    -webkit-box-pack:start;
    -webkit-box-align:center;
  }
  .content04 {
    position: absolute;
```

```
    right: 0px;
    width: 40%;
    height: 12%;
    top:48%;
    background-color:rgba(0,0,0,0.5);
    display:-webkit-box;
    -webkit-box-pack:start;
    -webkit-box-align:center;
}
.content09 {
    position: absolute;
    right: 0px;
    width: 13%;
    height: 24%;
    top:36%;
    background-color:rgba(0,0,0,0.5);
    display:-webkit-box;
    -webkit-box-pack:start;
    -webkit-box-align:center;
}
.arrowUp {
    position: absolute;
    font-size: 1em;
    right: 0px;
    width: 7%;
    height: 12%;
    top:35.9%;
    right:40%;
    background-color:rgba(0,0,0,0.3);
    display:-webkit-box;
    -webkit-box-pack:center;
    -webkit-box-align:center;
}
```

```
.arrowDown {
   position: absolute;
   right: 0px;
   width: 7%;
   height: 12%;
   top:48%;
   right:40%;
   background-color:rgba(0,0,0,0.4);
   display:-webkit-box;
   -webkit-box-pack:center;
   -webkit-box-align:center;
}
.content05 {
   position: absolute;
   right: 0px;
   width: 17%;
   height: 6%;
   top:60%;
   background-color:rgba(0,0,0,0.8);
}
#content06 {
   position: absolute;
   right: 0px;
   width: 17%;
   height: 25%;
   top:66%;
   background-color:rgba(0,0,0,0.4);
}
#content07 {
      display:none;
}

#content07-cm01, #content07-cm05 {
```

```
    display:none;
}

/* ****************************** */
/* FULL SCREEN EVENTS STYLE */
/* ****************************** */
.alertLightsOff {
  position:absolute;
  background-color:rgba(0,0,0,0.5);
  width: 100%;
  height: 100%;
  display:-webkit-box;
  -webkit-box-pack:center;
  -webkit-box-align:center;
  -webkit-transform-style: preserve-3d;
}
#alertFrame {
  position:relative;
  font-size:500%;
  background-color:rgba(0,0,0,0.8);
  width: 80%;
  height: 80%;
  display:-webkit-box;
  text-align:center;
  -webkit-box-pack:center;
  -webkit-box-align:center;
  -webkit-animation:fade 1s 0 linear 1;
  overflow:hidden;
}
#alertFrame2 {
  position:relative;
  font-size:500%;
  background-color:#FFF;
```

```
  width: 81%;
  height: 78%;
  display:-webkit-box;
  text-align:center;
  -webkit-box-pack:center;
  -webkit-box-align:center;
  -webkit-animation:fade 1s 0 linear 1;
  overflow:hidden;
}
#fs01 {
  position:relative;
  font-size:500%;
  background-color:rgba(0,0,0,0.8);
  width: 80%;
  height: 80%;
  display:-webkit-box;
  text-align:center;
  -webkit-box-pack:center;
  -webkit-box-align:center;
  -webkit-animation:fade 1s 0 linear 1;
  overflow:hidden;
}
#fsMSG {
  position:absolute;
  text-align:center;
  right: 10%;
  font-size:40%;
  width: 80%;
  height: 80%;
  top: 29%;
  display:-webkit-box;
  -webkit-box-pack:center;
  -webkit-box-align:center;
```

```
    -webkit-animation:fade 1s 0 linear 1;
    overflow:hidden;
}

#cm01-iframe {
    width: 100%;
    height: 100%;
    display:-webkit-box;
    -webkit-box-pack:center;
    -webkit-box-align:center;
    -webkit-animation:fade 1s 0 linear 1;
    -webkit-box-shadow: inset 0 0 10em #333;
    z-index: 2;
    overflow:hidden;
}

/* ************************ */
/* TEXT CONTENT STYLE */
/* ************************ */
.disclaimer {
    font-family:Tahoma, Geneva, sans-serif;
    font-size: 40%;
    display:-webkit-box;
    margin-bottom: 5px;
    margin-left: 5px;
    -webkit-box-pack:end;
    -webkit-box-align:end;
}
.clock {
    position:absolute;
    font-size: 300%;
    top: 1%;
    left: 2%;
```

```
}
#Date {
   position:absolute;
   font-size: 80%;
   top: 75px;
   left: 2%;
}
#stationList{
   font-size: 150%;
   position: absolute;
   right: 0px;
   top: 23%;
   text-align:right;
   margin-right: 10%;
   display:-webkit-box;
   -webkit-box-pack:end;
   -webkit-box-align:end;
}
#notThisStation {
   position: absolute;
   display:-webkit-box;
   width:300px;
   right: 0px;
   -webkit-box-pack:end;
   -webkit-box-align:end;
   -webkit-transform: rotate(25deg);
}
#thisStation {
   font-size: 120%;
   position: absolute;
   display:-webkit-box;
   width:300px;
   right: 0px;
```

```
    margin-top: -5px;
    font-weight: bold;
    -webkit-box-pack:end;
    -webkit-box-align:end;
    -webkit-transform: rotate(25deg);
    -webkit-animation:fade 1.5s 0 ease 15;
}

#sponsorsCont{
    position: absolute;
    left: 8%;
    top: 90%;
    width:85%;
    text-align:left;
    display:-webkit-box;
    -webkit-box-pack:end;
    -webkit-box-align:end;
}
#sponsors{
    width: 100%;
    height:90px;
    margin-left:5%;
    background-image:url(../img/sponsors.png);
    background-repeat:no-repeat;
    background-size:90% auto;
    display:-webkit-box;
    -webkit-box-pack:end;
    -webkit-box-align:end;
}
#lastStation {
    font-size:250%;
    position:relative;
    margin-left: 5%;
```

```
}
#nextStation {
   font-size:250%;
   position:relative;
   margin-left: 5%;
}

.arrows {
   font-size: 100%;
}

#busImg{
       position:absolute;
       -webkit-animation:busJump .2s 0 linear infinite;
       -webkit-animation:bus 3s 0 linear infinite;
}

#cautionImg {
       height:50%;
       width:auto;
      -webkit-animation:fade 1s 0 linear infinite;
}

#upcomingImg {
       height:90%;
       width:auto;
/*      -webkit-animation:fade 1s 0 linear infinite; */
}
#alertFrameContent{
   display:-webkit-box;
   text-align:center;
   -webkit-box-pack:center;
   -webkit-box-align:center;
```

```
}

/* ************************************* */
/***** A N I M A T I O N *****/
/* ************************************* */
/* ************************************* */

/* *************************** */
/* LOGO ORBIT ANIMATION */
/* *************************** */
#atom {         position:absolute;
        top: -2%;
        left:12%;
        opacity:1;
         -webkit-perspective: 1000; }

.orbit {top:0; left:0; width:400px; height:400px; border-radius:400px; -webkit-border-radius:300px; -moz-border-radius:400px; border: 0px solid #C0C0C0; -webkit-transform-style: preserve-3d; -webkit-transform: rotateX(-85deg) rotateY(20deg);}

.path { width:400px; height:400px; position:relative; -webkit-transform-style: preserve-3d; -webkit-animation-name: pathRotate; -webkit-animation-duration: 3s; -webkit-animation-iteration-count: infinite; -webkit-animation-timing-function: linear; }

.electron { position: absolute; top:-5px; left:50%; margin-left:-5px; width:10px; height:10px; border-radius:10px; background:#FFF; -webkit-animation-name: electronFix; -webkit-animation-duration: 3s; -webkit-animation-iteration-count: infinite; -webkit-animation-timing-function: linear;   }

/* ********************** */
/* SIMPLE ANIMATIONS */
```

```
/* ********************** */
@-webkit-keyframes jump {
	0%	{-webkit-transform: rotate(25deg) translateX(0%) translateY(0%);}
	20%	{-webkit-transform: rotate(25deg) translateX(-20%) translateY(0%);}
	60%	{-webkit-transform: rotate(25deg) translateX(0%) translateY(0%);}
	80%	{-webkit-transform: rotate(25deg) translateX(-3%) translateY(0%);}
	100% {-webkit-transform: rotate(25deg) translateX(0%) translateY(0%);}
}
@-webkit-keyframes fade {
	0%	{opacity:0}
	1%	{opacity:0}
	100% {opacity:1;}
}
@-webkit-keyframes bus {
	0%	{-webkit-transform: translateX(-600%) translateY(800%);}
	50%	{-webkit-transform: translateX(0%) translateY(800%);}
	100% {-webkit-transform: translateX(900%) translateY(800%);}
}
@-webkit-keyframes busJump {
	0%	{-webkit-transform: scaleY(1);}
	50%	{-webkit-transform: scaleY(1.2);}
	100% {-webkit-transform: scaleY(1);}
}
@-webkit-keyframes fadeOut {
	0%	{opacity:1}
	1%	{opacity:0}
	100% {opacity:0;}
}

@-webkit-keyframes content00Slide {
  0% {
     left: -25%;
	}
```

```
    100% {
            left: 0;
       }
}

@-webkit-keyframes pathRotate {
        from {
                    -webkit-transform: rotateZ(0deg);
                    }
        to {
                    -webkit-transform: rotateZ(360deg);
                    }
}

@-webkit-keyframes electronFix {
        from {
                    -webkit-transform: rotateX(90deg) rotateY(0deg);
                    }
        to {
                    -webkit-transform: rotateX(90deg) rotateY(-360deg);
                    }
}


/* ********************************** */
/* FULL SCREEN ANIMATION CM 01 */
/* ********************************** */

.cm01-div-text {
   position: absolute;
   font-family: 'Arial Black';
   font-size: 120px;
   z-index:999;
```

```
}

.cm01-text01-content {
    text-align: center;
}

.cm01-text02-content {
    text-align: center;
}

.cm01-div-text-animation {
    -webkit-animation: element01-keyframes 2s linear .5s 1 forwards;
}

.cm01-div-text-animation02 {
    -webkit-animation: element02-keyframes 1.8s linear 2.2s 1 forwards;
}

.cm01-div-text-animation-keyframe {
    top: 302px;
    left: 419px;
    width: 1000px;
    height: 216px;
    -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -5000, 1);
    opacity: 0;
}

@-webkit-keyframes element02-keyframes {
    0% { top: 302px; left: 419px; width: 1000px; height: 216px; -webkit-transform:
matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -5000, 1); opacity: 0; -webkit-animation-
timing-function: linear; }
```

```
    16.6667% { top: 302px; left: 419px; width: 1000px; height: 216px; -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -400, 1); opacity: 1; -webkit-animation-timing-function: linear; }
    83.3333% { top: 302px; left: 419px; width: 1000px; height: 216px; -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -200, 1); opacity: 1; -webkit-animation-timing-function: linear; }
    100% { top: 302px; left: 419px; width: 1000px; height: 216px; -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 500, 1); opacity: 1; -webkit-animation-timing-function: linear; }
  }
  @-webkit-keyframes element01-keyframes {
    0% { top: 302px; left: 419px; width: 1000px; height: 216px; -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -5000, 1); opacity: 0; -webkit-animation-timing-function: linear; }
    16.6667% { top: 302px; left: 419px; width: 1000px; height: 216px; -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -400, 1); opacity: 1; -webkit-animation-timing-function: linear; }
    83.3333% { top: 302px; left: 419px; width: 1000px; height: 216px; -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -200, 1); opacity: 1; -webkit-animation-timing-function: linear; }
    100% { top: 302px; left: 419px; width: 1000px; height: 216px; -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, 500, 1); opacity: 1; -webkit-animation-timing-function: linear; }
  }
  .cm01-div-text-animation-keyframe {
    top: 302px;
    left: 419px;
    width: 1000px;
    height: 216px;
    -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -5000, 1);
    opacity: 0;
  }
```

```
.cm01-div-text-animation02-keyframe {
   top: 302px;
   left: 419px;
   width: 1000px;
   height: 216px;
   -webkit-transform: matrix3d(1, 0, 0, 0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 0, -5000, 1);
   opacity: 0;
}

/* ***** */
/* OTHER */
/* ***** */
ul {
      margin: 0 auto;
      padding: 0px;
      list-style: none;
      text-align: center;
}
ul li {
      display: inline;
      text-align: center;
}
```

C. WebGL Event MHI (4th demonstration)

```
if ( ! Detector.webgl ) Detector.addGetWebGLMessage();

                    var camera, scene, renderer, controls,
                    particle1, particle2, particle4, particle4, particle5,
particle6,
```

```
light1, light2, light3, light4, light5, light6, light7;

var FAR = 300;

var clock = new THREE.Clock();

var object;

init();
animate();
var audio = new Audio('audio/MHI_open.mp3');
audio.play();

function init() {

    var container = document.getElementById( 'container' );

    // CAMERA

    camera = new THREE.PerspectiveCamera( 50, window.innerWidth / window.innerHeight, 1, FAR );
    //camera.position.set( 0, 15, 150 );
    camera.position.set( -30, 0, 60 );
    //camera.position.set( 0, 20, 0 );
    camera.lookAt( new THREE.Vector3(0,10,0) );

    // SCENE

    scene = new THREE.Scene();
    scene.fog = new THREE.Fog( 0x040306, 10, FAR );
```

```
// KEYFRAMES
var position = { x : 200, y:   0 , z: 100 };
var rotation = { x : 0, y:   0 , z: 0 };

var tweenCam00 = new
TWEEN.Tween(position)
        .to({x: 50, y: 0, z: 100}, 4000)
        .delay(0)

.easing(TWEEN.Easing.Linear.None)
        .onUpdate(function(){
        camera.position.x = position.x;
        camera.position.y = position.y;
        camera.position.z = position.z;
        });

var tweenCam01 = new
TWEEN.Tween(position)
        .to({x: 0, y: 60, z: 40}, 0)
        .delay(0)

.easing(TWEEN.Easing.Linear.None)
        .onUpdate(function(){
        camera.position.x = position.x;
        camera.position.y = position.y;
        camera.position.z = position.z;
        camera.lookAt( new
THREE.Vector3(0,10,0) );
        });

var tweenCam02 = new
TWEEN.Tween(position)
        .to({x: 0, y: 30, z: 40}, 1500)
```

```
.delay(0)

.easing(TWEEN.Easing.Linear.None)
.onUpdate(function(){
camera.position.x = position.x;
camera.position.y = position.y;
camera.position.z = position.z;
camera.lookAt(                    new
THREE.Vector3(0,10,0) );
});

var    tweenCam03    =    new
TWEEN.Tween(position)
.to({x: -10, y: 7, z: 20}, 0)
.delay(0)

.easing(TWEEN.Easing.Linear.None)
.onUpdate(function(){
camera.position.x = position.x;
camera.position.y = position.y;
camera.position.z = position.z;
camera.lookAt(                    new
THREE.Vector3(0,10,0) );
});
var    tweenCam04    =    new
TWEEN.Tween(position)
.to({x: 15, y: 7, z: 20}, 3000)
.delay(0)

.easing(TWEEN.Easing.Linear.None)
.onUpdate(function(){
camera.position.x = position.x;
camera.position.y = position.y;
```

```
camera.position.z = position.z;
});
var tweenCam05 = new
TWEEN.Tween(position)
.to({x: 0, y:0, z: 50}, 0)
.delay(0)

.easing(TWEEN.Easing.Linear.None)
.onUpdate(function(){
camera.position.x = position.x;
camera.position.y = position.y;
camera.position.z = position.z;
camera.lookAt( new
THREE.Vector3(0,10,0) );
});
var tweenCam06 = new
TWEEN.Tween(position)
.to({x: 0, y:20, z: 50}, 3000)
.delay(0)

.easing(TWEEN.Easing.Linear.None)
.onUpdate(function(){
camera.position.x = position.x;
camera.position.y = position.y;
camera.position.z = position.z;
camera.lookAt( new
THREE.Vector3(0,10,0) );
});
var tweenCam06_2 = new
TWEEN.Tween(rotation)
.to({x: 0, y:0, z:  Math.PI / 4}, 6000)
.delay(0)
```

```
.easing(TWEEN.Easing.Linear.None)
.onUpdate(function(){
camera.rotation.x = rotation.x;
camera.rotation.y = rotation.y;
camera.rotation.z = rotation.z;
camera.lookAt( new THREE.Vector3(0,10,0) );
});

var tweenCam07 = new TWEEN.Tween(position)
.to({x: 0, y:10, z: 40}, 0)
.delay(0)

.easing(TWEEN.Easing.Linear.None)
.onUpdate(function(){
camera.position.x = position.x;
camera.position.y = position.y;
camera.position.z = position.z;
camera.lookAt( new THREE.Vector3(0,10,0) );
});
var tweenCam08 = new TWEEN.Tween(position)
.to({x: 0, y:8, z: 70}, 5000)
.delay(0)

.easing(TWEEN.Easing.Quadratic.Out)
.onUpdate(function(){
camera.position.x = position.x;
camera.position.y = position.y;
camera.position.z = position.z;
```

```
camera.lookAt( new THREE.Vector3(0,10,0) );
});

tweenCam00.chain(tweenCam01);
tweenCam01.chain(tweenCam02);
tweenCam02.chain(tweenCam03);
tweenCam03.chain(tweenCam04);
tweenCam03.chain(tweenCam04);
tweenCam04.chain(tweenCam05);

tweenCam05.chain(tweenCam06, tweenCam06_2);
tweenCam06.chain(tweenCam07);
tweenCam07.chain(tweenCam08);


//                    tweenCam03.chain(tweenCam00);

tweenCam00.start();


// TEXTURES

var texture = THREE.ImageUtils.loadTexture( "textures/concrete.jpg" );
texture.repeat.set( 40, 20 );
texture.wrapS = texture.wrapT = THREE.RepeatWrapping;
texture.format = THREE.RGBFormat;

var bumpMap = THREE.ImageUtils.loadTexture( "textures/concrete_bump.jpg" );
```

```
texture.repeat.set( 20, 10 );
texture.wrapS = texture.wrapT = THREE.RepeatWrapping;
texture.format = THREE.RGBFormat;

var texture2 = THREE.ImageUtils.loadTexture( "textures/pyramids.jpg" );
texture2.repeat.set( 2, 1 );
texture2.wrapS = texture2.wrapT = THREE.RepeatWrapping;
texture2.format = THREE.RGBFormat;

// MATERIALS

var groundMaterial = new THREE.MeshPhongMaterial( { color: 0xffffff, ambient: 0x444444, map: texture, bumpMap: bumpMap, metal: true} );
var objectMaterial = new THREE.MeshPhongMaterial( { color: 0x000000, ambient: 0x111111, specular: 0xffffff, metal: true, map: texture2, shading: THREE.FlatShading } );
var logoMaterial = new THREE.MeshPhongMaterial( { color: 0x00000F, ambient: 0x111111, specular: 0xffffff, metal: true, shading: THREE.FlatShading } );
var grLogoMaterial = new THREE.MeshPhongMaterial( { color: 0xFF0000 , ambient: 0x111111, specular: 0xffffff, metal: true, shading: THREE.FlatShading } );

// GROUND

var mesh = new THREE.Mesh( new THREE.PlaneGeometry( 1200, 600, 2, 2 ), groundMaterial );
mesh.position.y = -5;
mesh.rotation.x = - Math.PI / 2;
```

```
scene.add( mesh );

// OBJECTS

var objectGeometry = new THREE.CylinderGeometry(0,2,3,4,false);

for ( var i = 0; i < 500; i ++ ) {

    var mesh = new THREE.Mesh( objectGeometry, objectMaterial );

    mesh.position.x = 400 * ( 0.5 - Math.random() ) +230;
    mesh.position.y = 50 * ( 0.5 - Math.random() ) + 25;
    mesh.position.z = 200 * ( 0.5 - Math.random() );

    mesh.rotation.y = 3.14 * ( 0.5 - Math.random() );
    mesh.rotation.x = 3.14 * ( 0.5 - Math.random() );

    mesh.matrixAutoUpdate = false;
    mesh.updateMatrix();
    scene.add( mesh );

}

for ( var i = 0; i < 500; i ++ ) {
```

```
var mesh = new THREE.Mesh( objectGeometry, objectMaterial );

mesh.position.x = 400 * ( 0.5 - Math.random() ) -230;
mesh.position.y = 50 * ( 0.5 - Math.random() ) + 25;
mesh.position.z = 200 * ( 0.5 - Math.random() );

mesh.rotation.y = 3.14 * ( 0.5 - Math.random() );
mesh.rotation.x = 3.14 * ( 0.5 - Math.random() );

mesh.matrixAutoUpdate = false;
mesh.updateMatrix();
scene.add( mesh );

}

var manager = new THREE.LoadingManager();
manager.onProgress = function ( item, loaded, total ) {

console.log( item, loaded, total );

};
```

```
var loader = new THREE.OBJLoader( manager );
loader.load( 'obj/logo.obj', function ( object ) {

    object.traverse( function ( child ) {

        if ( child instanceof THREE.Mesh ) {

            child.material = logoMaterial;

        }

    } );

    object.position.y = 10;
    object.position.z = 10;
    object.scale.y = 0.02;
    object.scale.x = 0.02;
    object.scale.z = 0.02;
    scene.add( object );


} );

// LIGHTS

scene.add( new THREE.AmbientLight( 0x111111 ) );


var intensity = 2.5;
var distance = 100;
```

```
var c1 = 0xff0040, c2 = 0x0040ff, c3 = 0x80ff80,
c4 = 0xffaa00, c5 = 0x00ffaa, c6 = 0xff1100;
//var c1 = 0xffffff, c2 = 0xffffff, c3 = 0xffffff, c4
= 0xffffff, c5 = 0xffffff, c6 = 0xffffff;

light1 = new THREE.PointLight( c2, intensity,
distance );
scene.add( light1 );

light2 = new THREE.PointLight( c2, intensity,
distance );
scene.add( light2 );

light3 = new THREE.PointLight( c2, intensity,
distance );
scene.add( light3 );

light4 = new THREE.PointLight( c2, intensity,
distance );
scene.add( light4 );

light5 = new THREE.PointLight( c2, intensity,
distance );
scene.add( light5 );

light6 = new THREE.PointLight( c2, intensity,
distance );
scene.add( light6 );

light7 = new THREE.PointLight( c1, intensity,
distance );
scene.add( light7 );
```

```
var dlight = new THREE.DirectionalLight( 0xffffff, 0.1 );
dlight.position.set( 0.5, -1, 0 ).normalize();
scene.add( dlight );

var sphere = new THREE.SphereGeometry( 0.25, 16, 8 );

var l1 = new THREE.Mesh( sphere, new THREE.MeshBasicMaterial( { color: c1 } ) );
l1.position = light1.position;
scene.add( l1 );

var l2 = new THREE.Mesh( sphere, new THREE.MeshBasicMaterial( { color: c2 } ) );
l2.position = light2.position;
scene.add( l2 );

var l3 = new THREE.Mesh( sphere, new THREE.MeshBasicMaterial( { color: c3 } ) );
l3.position = light3.position;
scene.add( l3 );

var l4 = new THREE.Mesh( sphere, new THREE.MeshBasicMaterial( { color: c4 } ) );
l4.position = light4.position;
scene.add( l4 );

var l5 = new THREE.Mesh( sphere, new THREE.MeshBasicMaterial( { color: c5 } ) );
l5.position = light5.position;
scene.add( l5 );
```

```
var l6 = new THREE.Mesh( sphere, new
THREE.MeshBasicMaterial( { color: c6 } ) );
l6.position = light6.position;
scene.add( l6 );

// RENDERER

renderer = new
THREE.WebGLRenderer( { antialias: true } );
renderer.setClearColor( scene.fog.color, 1 );
renderer.setSize( window.innerWidth,
window.innerHeight );


container.appendChild( renderer.domElement );

renderer.gammaInput = true;
renderer.gammaOutput = true;

//

window.addEventListener( 'resize',
onWindowResize, false );

}

function onWindowResize() {

camera.aspect = window.innerWidth /
window.innerHeight;
camera.updateProjectionMatrix();
```

```
        renderer.setSize( window.innerWidth, window.innerHeight );

}

//

function animate() {

        requestAnimationFrame( animate );

        render();
}

function render() {

        TWEEN.update();

        var time = Date.now() * 0.00025;
        var z = 20, d = 150;

        light1.position.x = Math.sin( time * 0.7 ) * d;
        light1.position.z = Math.cos( time * 0.3 ) * d;

        light2.position.x = Math.cos( time * 0.3 ) * d;
        light2.position.z = Math.sin( time * 0.7 ) * d;

        light3.position.x = Math.sin( time * 0.7 ) * d;
        light3.position.z = Math.sin( time * 0.5 ) * d;

        light4.position.x = Math.sin( time * 0.3 ) * d;
        light4.position.z = Math.sin( time * 0.5 ) * d;
```

```
        light5.position.x = Math.cos( time * 0.3 ) * d;
        light5.position.z = Math.sin( time * 0.5 ) * d;

        light6.position.x = Math.cos( time * 0.7 ) * d;
        light6.position.z = Math.cos( time * 0.5 ) * d;

        light7.position.y = 20;
        light7.position.z = 70;

        renderer.render( scene, camera );

}
```