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Distributed Immersive Participation as Crowd-Sensing in Culture Events

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Abstract

This article investigates new forms for creating and enabling massive and scalable participatory immersive experiences in live cultural events, characterized by processes, involving pervasive objects, places and people. The multi-disciplinary research outlines a new paradigm for collaborative creation and participation towards technological and social innovation, tapping into crowd-sensing. The approach promotes user-driven content-creation and offsets economic models thereby rewarding creators and performers. In response to these challenges, we propose a framework for bringing about massive and real-time presence and awareness on the Internet through an Internet-of-Things infrastructure to connect artifacts, performers, participants and places. Equally importantly, we enable the in-situ creation of collaborative experiences building on relevant existing and stored content, based on decisions leveraging multi-criteria clustering and proximity of pervasive information, objects, people and places. Finally, we investigate some new ways for immersive experiences via distributed computing but pointing forward to the necessity to do more with regard to collaborative creation.

1. Introduction

Access to culture and cultural events is limited in technical and other aspects. With the advent of digital participation and its alluring promise of widespread engagement and global interconnectedness, this shift has been apparent in fields such as business, entertainment, and journalism as well as in culture.

On the Internet, audiences are increasingly being involved in massive participatory activities, in which they can play an active role and influence the subsequent chain of events. Different flavors of immersion are found in social media, online gaming environments, virtual classrooms, and 3D-TV. The latter, for instance, is capable of providing us with views in real-time without any possibility of a return channel except for on-line chat, etc. Augmented reality applications are stored abstractions of objects without immediacy or relevance to the current state which is observed.

There is a challenge to the creative industry on how to realize new forms of more participatory performing arts. Most of today's performing arts attract citizens wanting to be more active in creating, performing and enjoying events, while at the same time being flexible in terms of time and physical location. There is consequently a large potential in understanding the implications of including sensors and visualization rendering of the participant in a feedback loop of engagement and cognition.

The rapid advancement of ICT technology is confronted with opportunities and needs in the artistic and humanistic sector of society. This particular task challenges Computer Science to modify systems and find sustainable technical support solutions for artistic man-machine interactions. These advances can potentially expand the artistic range of production as well as the societal effects of participation in cultural events. As a side effect, many techniques become visualized and accessible for non-specialists in terms of understanding and applying the artistic and social capacity of new technologies. Despite its timeliness and culture significance, the phenomenon of crowd-sensing in cultural applications has received little attention from researchers and art historians. Indeed, a comprehensive literature review indicates that research in this area is critically absent. This lacuna is particularly striking in comparison to the wealth of literature on the commercial applications of crowd-sensing across a wide variety of domains. At the same time, there is an urgent need to situate this practice within the larger literature of participatory culture, and to engage the features of crowd-sensing art in relation to similar artistic tropes primarily, relational aesthetics and social practice-as a way to better define and understand its socio-cultural position.

This article therefore aims to fill these critical gaps by analyzing the practice of online crowd-sensing culture within a framework of collective creativity and participation theories. The article also provides a framework for creating massive and scalable participatory immersive experiences in performing arts events. This framework addresses participatory mechanisms; crowd-sensing, citizen-driven content creation, reputation mechanisms, data ownership, and economic models for rewarding creators and performers, quality of experience as well as behavioral and societal changes. We suggest an extension of an Internet-of-Things infrastructure for specific mechanisms corresponding to new concepts of building relations and awareness, such as to promote societal changes. This multidisciplinary approach highlights the possibilities with new multimodal technologies applied on participatory arts. This article is structured in the following way: Section 2 defines the background and motivation; Section 3 describes the conceptual model of the framework; Section 4 describes an approach to participation design; Section 5 portrays the designing of the interaction and communication; Section 6 presents the choice of a design and development methodology; Section 7 describes the performance evaluation, and the conclusions are provided in Section 8.

2. Background and Motivation

2.1 Distributed Immersive Participation

Social media via mobile devices has moved participatory events and processes, such as mobile theatre or public decision-making, to urban areas. This highlights new possibilities and challenges due to a profound shift in reversing and transforming the roles of agents and beholders. It is an important statement of the paradigm shift brought about by providing access to an augmented experience on the Internet via mobile devices. Mobile devices such as smartphones have a range of sensors, such as GPS, which can transform the experience according to the physical and emotional states of all objects (be it artifacts, individuals or places). Hence, participants are essentially moved to the Internet and incorporated into a feedback loop of augmented experiences. This is influenced and fed with the emotional and physical states of all objects included in the participatory process, be it local or not. Moreover, advances in mobile technologies enable the seamless synchronized sharing in massive participatory events, sharing and storing of vast amounts of information from local and non-local objects and processes. Hence, we are in the position to discover patterns, and bring these to the attention of agents and observers alike. Thus, in participatory events, we may experience an 'augmented' reality or immersively experience virtuality augmented with real-world sensing. The experience can include not only time-specific non-presence but also emergent relations in other or multiple dimensions, including the replay of subjective experiences of others.

The importance of connecting the real & virtual is emphasized by service growth in relation to a growing presence and engagement on the Internet. For instance, the increase in Facebook users from 2011 to 2012 was 26 %. Meanwhile, the total number of monthly active Facebook users in June 2013 was 1,110,000,000 with 75% outside the US. Roughly 61% used mobile devices to interact with the service on an average of 20 minutes per day. It gives us a measure of how much of our participation has moved to the Internet, and why we should pay attention to the fact that during this decade 500 billion devices (source: Ericsson, Huawei) will increase the total amount of information available to services by several orders of magnitude. Hence, phenomena such as a social web-of-things are just the beginning. The insight is that an Internet-of-Things is being built extending the number of connected people, places and things, for instance sensing via mobile devices (smartphones and wearable sensing gateways), or wirelessly connecting appliances in homes to the Internet via a home gateway. Moreover, the maturity of technology to interconnect things, people and places challenges us to develop and experiment with service infrastructure (operations support systems) for the automatic and autonomic operation of different systems of our society. Such systems concern utilities (e.g., energy, water, etc.) and may include telecommunications, traffic and transport systems, etc. Our participation plays a critical role as success of such systems increasingly relies on crowd-sensing, the importance of which is emphasized by the following examples:

Certain processes characterize the creation of live cultural events with massive and scalable participatory, immersive experiences. Such live cultural events involve vast numbers of pervasive objects, people and places. Other processes characterize these forms of massive participatory activities, involving pervasive objects, people and places. Needless to say, the continuously broadening view on performance in all its current appearances – from sports events to ever expanding multimedia possibilities – requires various technologies, but also enables *a theoretical re-orientation* of what this variety of productions and events offer for the artist as well as for the visitor/spectator/participant. Theatre and performance studies are rarely in a position in which not only the finished "work" can be analyzed, but also which provides the opportunity to closely follow the production process and further –

not the least important – to measure and evaluate the outcome in terms of reception studies. This offers a unique possibility to develop and test advanced theories of media communication which will be artistically highly relevant for the utilization of new media and advanced media technology.

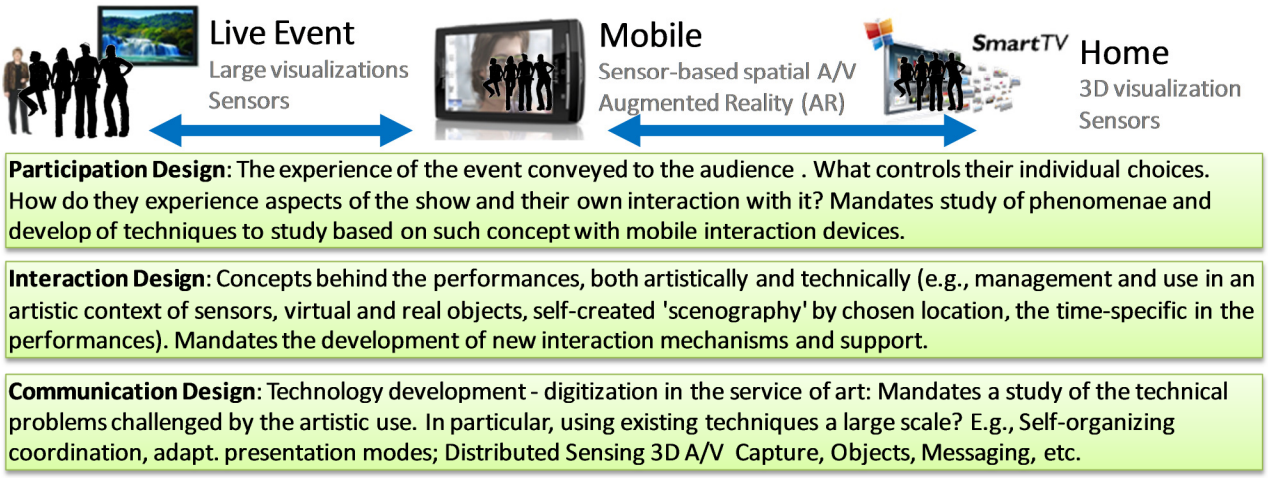

Figure 1: A Possible Framework

2.2 Performing Arts

Regarding traditional theatre, in the broad field of the performing arts (Schechner 2002), Gumbrecht refers to Niklas Luhmann's 'second-order observer' when he notes that this "second-order observer rediscovered the human body and, more specifically, the human senses as an integral part of any world-observation." This phenomenological aspect of the material conditions of watching in the theatre is thoroughly analyzed by Jens Roselt (2008), who describes 'spectating' as an integral aspect of art as phenomenon or even as an art in itself.

All these and many other authors have extended the range and location of various art forms, especially those which are transgressing the traditional distinctions between genres. Site-specific, mobile, interventionist, situationist or disruptive art practices are dealt with in the context of established or emerging artists. In a publication from a working group within the International Federation for Theatre Research, the intermediality in theatre and performance is investigated both from the perspective of performing and reception. The terms *immediality and hypermediality* were developed by Jay Bolter and Richard Grusin (2000) and expanded by others. These terms have opened the possibilities for the inclusion of multiple performance experiments into the empirical basis of theoretical considerations. However, the mixture of performance and participation, digital interaction and live events still require innovative theoretical development. Other current research deals with *Multimedia Performance*, as the recent book by Rosemary Klich and Edward Scheer (2012) is entitled.

2.3 New Concepts in Artistic Technologies

The concepts supported by new technologies in this context are covering at least three main categories: Participation Design, Interaction Design and Communication Design as shown in Figure 1. A framework for this should both advance and combine innovative systems in a multi-disciplinary approach to mediate and enhance presence and participation in societal activities thereby promoting new forms of individual or collective human skills (e.g. mass demonstrations or events) as well as

experiences (e.g., a dramaturgical play). Such a framework can accommodate a synthesis of positioning methods & technologies, advanced audio and rendering as well as elastic computing methods & techniques, in the pervasive and ubiquitous application / service domain. Figure 1 shows how a framework can be structured as domains that interwork in order to enable and support new participatory mixed-reality and immersive 3D experiences. These range from small public events with to vast distributed communities.

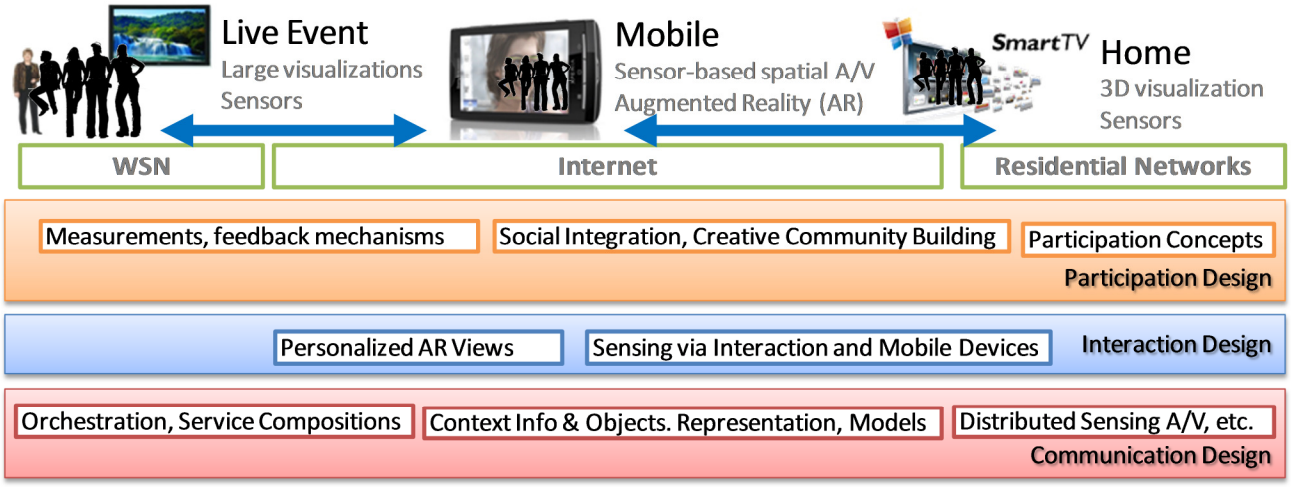

Figure 2: Key Issues within the Framework Strata

Furthermore, the strata here involve concepts fusing together immersive computing and communication concepts related to transmedia productions. This includes the integration with social media, with concepts in the area of interaction and participation related to the development of sociological concepts as a result of the development of new theatrical concepts. Massive and scalable distributed sensing, audio and video can be integrated with Internet-of-Things service infrastructure. Figure 2 shows a further possible detailed layering.

2.4 Socio-Cultural Factors

In the light of the above observations we propose a framework and associated methodology. The purpose is to maximize the social and cultural impact of its technologies adopting an empirical approach, involving open experimental facilities in key multi-disciplinary research areas. We then combine these efforts with engineering systems that merge and exploit cyber-physical systems (sensors, actuators, multimodal interaction devices) and audience's ergonomic-cognitive capabilities and limitations. The objectives of research framework include the following elements:

- Developing a distributed sensing architecture to facilitate the, connecting sources and sink nodes in real-time.
- A proof-of-concept prototype demonstrating the massive awareness towards new participatory performing arts events (including new forms of theatre, dance and opera).
- Conducting experimentation with new forms of performing arts events in order to understand the implications and requirements for participation with distributed awareness in a blended reality.

- Investigating techno-social aspects of this type of event, including privacy by design, “cloudification” (cloud computing for the masses), crowd-sensing, reputation mechanisms, data ownership, citizen involvement, perceived quality of experience, and social impact.

3. Conceptual Framework

3.1 Participatory Design

A central theme here seems to be how to engage users and how to bring about the participatory awareness by utilizing the context, the available technologies and the involved participants. Today we can see many results of media convergence. This is illustrated through our interacting with live TV shows as well as with other spectators via SMS, or through social media, as in transmedia productions such as The Truth About Marika” and ”The Spiral” (Denward, 2011).

In order to give the audience / users a higher degree of engagement and a more convincing feeling of presence, the framework employs the ”Internet of Things” in order to transform interaction theatre and performing art events.

3.2 Interaction Design

When developing and refining a number of methods through which the artists and the audience can interact with tomorrow's media productions, these have to be attractive in order to draw the users into the experience. This concerns support for authoring and producing content, capture & visualization technologies, as well as other sensor & actuator technologies, such as spatial orientation.

We have given priority to models where the experience is not only based on one single user interacting with the production but the user should also be aware of the other participants. The shared experience serves as amplifiers of emotions and reactions, but also provides opportunities for communication and collaboration. One of the greatest challenges, from a technological viewpoint, is to maintain this type of user feedback, but at the same time keep aiming towards large scalability. Preferably, both the content and the interaction model should be automatically adapted to different types of terminals and connections simultaneously. The vision of participation anywhere requires an infrastructure adapted to the asymmetric and heterogeneous conditions, and software that adapts content to them.

In the envisioned scenarios, new challenges arise in the domain of Mixed and Augmented Reality (MR or AR), i.e., in the integration of real-world video and virtual content. In particular, the heterogeneous setting of real-world stage performance on the one hand and distributed, mobile users on the other provide a unique setting for MR.

3.3 Communication Design

The end-user of a communication system should be able to interact via a wide variety of interaction devices with various services included. This could for instance be provided by an open service orchestration in conjunction to cloud service brokerage and adaptive cloud service composition. The proposed framework achieves this through applying contextualization in conjunction to real-time capturing and rendering of audio and visual information. This allows for context-dependent reconfiguration of applications consisting of multiple services during runtime.

Another aspect of this layer is Self-Management, in terms of automatic configuration of distributed sensing components, discovery and correction of errors and resource optimization. We propose to use Open-Flow to decouple physical infrastructure from applications, network-wide virtualization and optimization of network segments, for a particular application. It enables the provision of the entire network to seamlessly handle any application anywhere on the network

4. An Approach to Participation Design

Experimentations with mobile audiences, interactive spectators and split locations have been carried out by the RATS (Research in Arts and Technology for Society) theatre, which is a theatrical scene directly, associated with the Department of Computer and System Sciences within Stockholm University. Since 2008, Stockholm University has collaborated with local communities in a number of artistic productions. The repertoire aims at actively involving groups of spectators who stand outside the traditional theatre and art events. In concrete terms this means that groups of young people are invited to contribute to the creative process of productions. Through these joint activities the inhabitants of various suburban areas are involved in and gain access to both artistic and scholarly developments towards the future environment. The aim is to create long term projects in order to support democracy and social development in less privileged areas. Through these artistic activities within new technologies, a method is explored to break negative structures of social engagement. Through the current research work we seek to broaden this model, encouraging young citizens' participation in societal progress.

In short, these experimentations have shown that it is possible to move audiences through suburban environments with smartphones, directed through sensors (Forsberg, 2011) and to connect stages in different locations through fibre optic cables as well as allowing spectators to communicate with real-time performances from various locations outside the performance venue. In the next step, the various devices of interactive engagement were tested in combinations. The experiments manifest the participatory concepts and allowed a further analysis of the pervasive and ubiquitous applications / services domains towards an approach to Interaction and Communication Design as elaborated below.

4.1 Time-specificity implications

Site-specific performance interacts with the place where it is performed– and could not possibly be moved to just another place – and in the same way, a time-specific presentation is based on the simultaneity of actions taking place in different places. In time-specific performance, time is the cohesive power of playing. It is a real-time experience similar to live-television and Massively Multiplayer Online Games. The unity of theatrical space seems broken. Time-specificity should be explored (Sauter, 2012).

4.2 Co-presence extended meaning to include absence

In any case there is a need for theoretical innovation to capture the field that expands towards various interactions with media. Our discipline requires us to continuously keep abreast of the changing objects we are studying. After an era of post-dramatic theatre we swiftly encounter a period characterized by the innovative use of new digital techniques. Although these experiments have so far mostly been of a limited scope, the Met-disseminations point into the direction of large-scale applications of on-going technical advances.

5. Application Scenarios

In cultural events as well as networks of socio-technical systems, citizens or actors will need to continuously and perhaps invisibly cooperate in highly decentralized activities. The real-time participation in such activities at a national or regional scale made possible by the framework, enable the sharing and fostering of engagement as well as the enhancing and diversifying of user skills and experiences. This in turn will make it possible to offer many types of societal and cultural resources over different interaction devices with direct feedback used to improve the perceived quality of application-services. In application scenarios looking to the deployed mobile audiences, interactive spectators and split locations have been carried out at allowing spectators to communicate with real-time performances from various locations outside the performance venue (the series Women in Science, including ADA (Forsberg, 2012). The scenarios will be further described in sections 6.1-6.3.

6. An Approach to Interaction and Communication Design

The system model of the proposed framework provides the live actors on-stage as well as the audience with an integral visualization or rendering of the performance. This requires the extension of existing methods for rendering and an investigation into which method is most suitable for the live actors, live audience, and remote audience.

The integration of remote users on mobile devices requires us to address rendering challenges with respect to limitations in performance and bandwidth (Paravati, 2011). Here, one needs to investigate how the process of MR video generation can be distributed between powerful, centralized rendering servers and the various mobile devices. Depending on the capabilities of the mobile device, one could either send a fully augmented video, have the client perform simple animation and augmentation on the live video stream, or have the full scene be rendered on the device. To provide a robust and resource-efficient solution, novel rendering systems need to be designed. Here, we investigated adaptive content that serves as a basis for various platforms. Scalability is one important aspect and terminal information (e.g. device display resolution, type of access network, available bandwidth, etc.) helps the platform to process and optimize the contents.

6.1 Content Authoring Tools

The goal and main target of framework content authoring tools was the “ease of use”, to describe and author in easy but flexible ways even for non-technical persons. This as the main target groups are the producers and directors of such an event. The framework enables the group to view (and manipulate) the real and virtual scenes, in the same way that the audience would see it, in real-time using a simple interface.

We also wanted to open up the possibility of different degrees of co-creation from the audience / users enabled by the Internet, such that future culture and entertainment will, to a higher degree, involve the audience to be either co-produced or entirely produced by the users themselves.

6.2 Context-Based Social Community Management

Contextual personalization, or user profiling, has been extensively addressed in the past for mobile applications and services (Coutand, 2009). However, most of the underlying management frameworks employ context models that are centered on location as the overarching indicator of context and context proximity. Additionally user profiles are maintained with respect to needs and interest of an application end-user.

Our framework extends the notion of personalized context delivery to collaborative location independent communities. Consequently, location is subsumed by a heterogeneous multi-criteria relational proximity allowing us, when necessary, to bridge the geographical divide. In addition it allows us to support real-time dramaturgical applications for communities of end-users across multiple locations, with a diverse array of devices and interfaces at their disposal. These experiences include being subjected to dynamic situational and environmental contexts during the performance or the event.

The management of social communities is achieved through self-organization based on clustering using relational proximity algorithms. Here we identify and establish ad-hoc relationships and community channels in dramaturgical settings with the salient points in the performance injected into self-organizing community channels through clustering. The notion of proximity for clustering is defined over the situational and environmental context as well as the shared interest with respect to the plays and their engagement of the end-users. This extends the work of Walters & Kanter in (Walters & Kanter 2011) in order to derive the salient points in the event through RT data processing and contextualization.

Finally, the framework included support for social community and interaction principles focusing on developing mechanisms and technology for social interaction and social community usage. The scenarios and the field trials will provide new opportunities for social interaction and use of the "crowd". For example, a recent innovation in the area of cultural event financing is the concept of "crowd funding", a concept that will be explored, developed and evaluated further within the task since it contains a number of elements engaging the community around particular goals. "Crowdsourcing" can also be used as one or many "modulating forces" and influence the artistic content in different ways.

Crowd-sensing centred application — This application is based on MediaSense (http://www.mediasense.se/), an open-source platform offering scalable, seamless and real-time access among a global collection of entities (artifacts, people, places, information objects) via a heterogeneous network infrastructure as described in (Kanter & Walters, 2009). This constitutes an Internet of Things services infrastructure negotiating a heterogeneous infrastructure of local gateways, mobile and fixed access networks. Operating at the semantic level, MediaSense interfaces with wireless-sensor networks as well as with either web-services or presence services.

This application allows for inter-connecting objects/ mobile phones/ cars and other moving actors to share information in real time thereby enabling dramaturgical advancements through distributed decision making.

Adaptive Cloud Service Composition

The end-users of the framework would use a wide variety of devices for interaction. The set of possible interactions ranges from choosing from a pre-selected list of options to controlling a virtual avatar through a touch-screen. All these devices feature extremely varying characteristics. They are heterogeneous, whatever the point of view: devices have a screen or not, large or small, have input capabilities or not, have computing power or not, and with Google Glass, a novel class of consumer devices has already been announced. The user should be able to reconfigure the execution context of an application to his current needs, at home or in transit, or even should not be bothered by this. Thereto, the framework defines a model for the representation and dynamic management of complex advanced artistic system services on all kinds of devices. Reconfiguration of the enabling cloud service composition should happen on user request or automatically depending on the context parameters acquired for the performance. This enables the structured execution of the dynamic cloud services and

their adaption to the situational context changes and continuously changing physical environments in a self-contained manner.

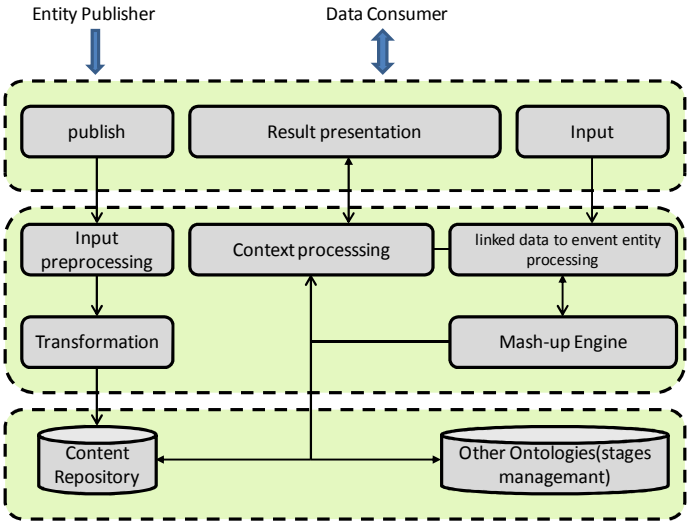

Figure 3: Main component in the Framework for architecture methodology

6.3 Context Information, Objects and Models

Multi-criteria approaches to context centric relationships better support the dynamic nature of context information as well as the heterogeneous array of applications and service requirements. Users interact or even immerse themselves in virtual reality plays if such plays stirred their experiences intensely and broadly. In achieving this, multiple sources of information must be considered when observing the interaction between users with their environment. This provides the information required to build relational context models that can identify and establish relationships between actors. These relationships in turn are the springboard for creating situations where an actor's perceived relationships are elevated and through a diverse set of (un-) intended actions to immerse himself in enriched and novel creative experiences. In this respect context data is the key for the creative systems bringing about such communication patterns and experiences. The proximity approach in (Walters & Kanter, (2011) enables the in-situ creation of collaborative experiences building on relevant existing and stored content.

7. Design and Development Methodology

The choice of design and development methodology can be understood in two ways: first a methodology of ontology for framework development and second, a methodology for generating specific architectures. See in figure 3 concerning how to derive all aspects of the model as well as how to drive the best practices. Simply dissecting them into design steps and processes is not enough - one needs to know how to achieve each step.

In the table below we summarize how architecture methodology for framework on the higher abstract level.

Table 1: Usage of architecture methodologies for the development of the framework

Methodology	Aspect adopted in framework.
Aspect oriented programming	Delineation of functionalities by aspects. This is embodied in the concept of functionality groups.
Model-Driven Engineering	General concept of transformation from a generic to a more specific model. We use this concept for describing and developing our best practice.
Pattern-Based Design	We will test the efficacy of this method upon deriving a concrete architecture as the best practice's test case.
View and perspectives	We adopt the concept of view and perspectives for the derivation of the crowd-sensing platform reference architecture; we arrange all aspects of our reference architecture according to views and perspectives. The same is done for the unified requirements.

8. Results and Evaluation

To evaluate the effectiveness of framework in terms of creating massive, scalable participatory and immersive experiences in live cultural events, we developed a prototype implementation of the components and performed experiments using this prototype. All data recorded from the runs of the application scenarios described in section 4.3 and in all experimentations scenarios by using audiences in the pervasive and ubiquitous service domain, directed through sensors and connected stages in different locations. The results demonstrate that we are capable of realizing collaborative experiences that are built on relevant existing and stored content. These experiences are enhanced through decisions that leverage multi-criteria proximity. The decisions are based on clustering of objects, people and places engaged in performing art productions in suburban environments.

To validate the framework, we defined an ontology shown in Figure 4. Each white ellipse is a sub context domain, while each arrow shows the entity properties for each entity. Entity property is the way to mark the relations among entities, where each entity can be regarded as a property for its peers. The blue ellipse describes the constructions for the message in each context domain. According to a case scenario abstracted from the system, Position, Artist Status, Geo-information, Stage-information and Actions are extracted out as the context domains, where each message can be marked with category under the construction format. A proof-of-concept prototype is written with Jess as shown in (Chen et al., 2004) which helps establish the entity properties. An OWL/XML file is generated by a short Jess code, as illustrated in Figure 5.

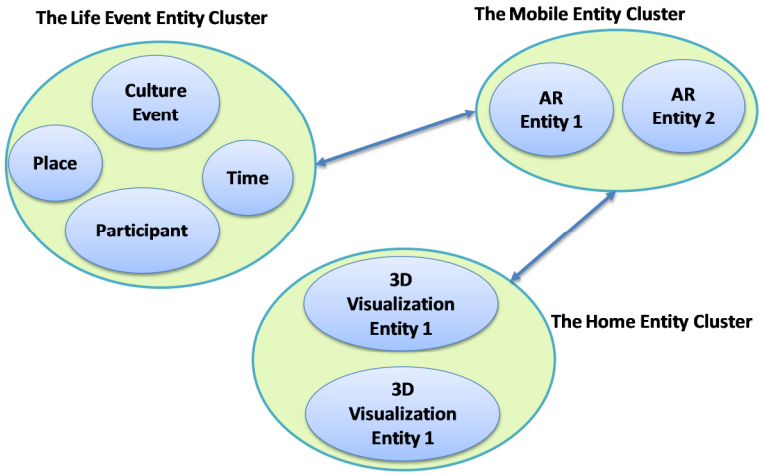

Figure 4: The Ontology based Prototype as an example

```
<?xml version="1.0"?>
<!DOCTYPE rdf:RDF [
   <!ENTITY owl "http://www.w3.org/2002/07/owl#" >
   <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
   <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
   <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" >
]>
<rdf:RDF xmlns="http://www.owl-ontologies.com/Ontology1398776626.owl#"
    xml:base="http://www.owl-ontologies.com/Ontology1398776626.owl"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">
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   </action_inf>
   <action_inf rdf:ID="action_inf_2">
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   </action_inf>
```

Figure 5: Figure 5 The OWL/XML file generated depicting the context

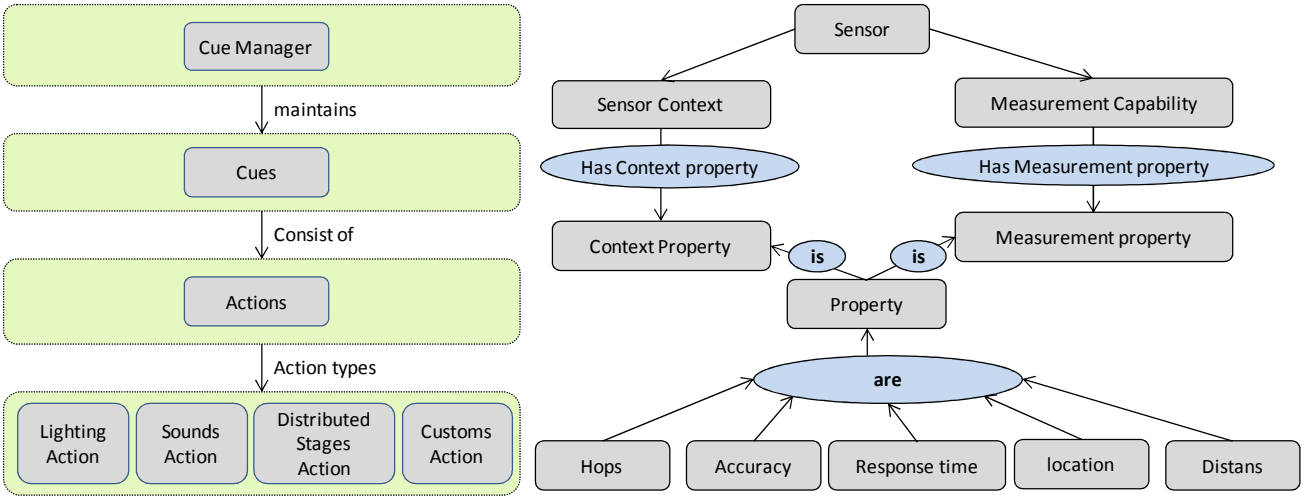

Figure 6: Left: Stages management in the framework Right: Semantic Sensor based ontology

As shown in figure 6 Left the stage manager is responsible for controlling lighting, sounds and stages effects. This control is achieved via sequence of cues the manager triggers at appropriate times during a performance via crowd-sensing platform such as MediaSense (Walters 2012; Kanter 2009)

A semantic context model based on the W3C (http://www.w3.org/2005/Incubator/ssn) Semantic Sensor Network (SSN) is used. The SSN ontology as shown in Figure 6 Right allows for the

representation of information concerning sensor instances. Sensor instances arise each time a new sensor registers a sensor type that is subsequently filled with the information from sensor itself. The SSN ontology allows giving more information to a measurement capability of a sensor node and an entity "Sensor context" was used to describe the sensors context with the same properties used to represent a measurement capability.

The summarized results for all experiments are described below.

8.1 Experiment 1: Antigone's Diary

This experiment concerns the evaluation of a set-up of the prototype in order to meet the needs of computing in pervasive and ubiquitous environments. This engages a performing arts application /service domain which is characterized as being autonomous, cooperative, situational and evolvable through the involving of places and localization. Antigone's Diary is a distributed drama that interacts with the young people around the Kista/Rinkeby City district in Stockholm. This experiment demonstrates the distributed streaming of a new play drama where the content creation of collaborative experiences building on relevant information existing in distributed stages. Here the prototype assumes a constant context state at normal, collecting information regardless of the usefulness of the data to the prototype in order to enable distributed drama productions. This experiment was a context-aware in that demonstrated that context changes can be fed back into the sensor such that redundant data can be omitted to save network resources.

The salient points here are the correlation between our presence in the real world and that of the world of belief and stories, as well as between the experiences of participants.

8.2 Experiment 2: ADA

This play is about Ada Byron, who developed a language for computer programming long before there were any computers. Her amazing life as well as her scientific achievements were the theme of the real-time web drama, which could have been seen on large screens in certain locations, or alternatively, on one's own computer or mobile telephone. During the presentation of the drama, spectators are encouraged to participate through texting (SMS), Twitter and the web. In this experiment, utilizing a context-aware framework, one action is implemented with context changes during an interval of time. This is achieved by sampling data for sensor nodes in that time interval. The measured data in term of packets have been written out to sensor nodes to change their sampling corresponding to the context states changes over that time interval. This experiment is a control experiment and the results of measurement show by correct sampling of data which reduced total messages sent from sink to sources.

The salient points here are the coexistence of spectator and actors in a virtual scene, hence a distributed world between belief and stories, as well as between the experiences of participants.

8.3 Experiment 3: MARYAM

In this experiment we focused on transitioning to multipurpose interactive public environment. Moving from both single-application and known environment to multipurpose interactive public environment creates new possibilities for design of distributed virtual stage in the pervasive and ubiquitous service domain. The transition to multipurpose interactive public environment raises a host of new questions such as:

- What is the best way to interact with multiple applications (cf. transmedia)?

- How can we exploit the competition among applications to user attention?

We anticipate answering these questions in our future work. An important research direction is to develop design of interaction patterns that both suggest and entice interaction with interactive public virtual stages.

The salient points here are the correlation between our presence and awareness 1) in the real world and that of the world of belief and stories, as well as 2) between participants, places, artefacts; thereby adding new elements in comparison with 8.2.

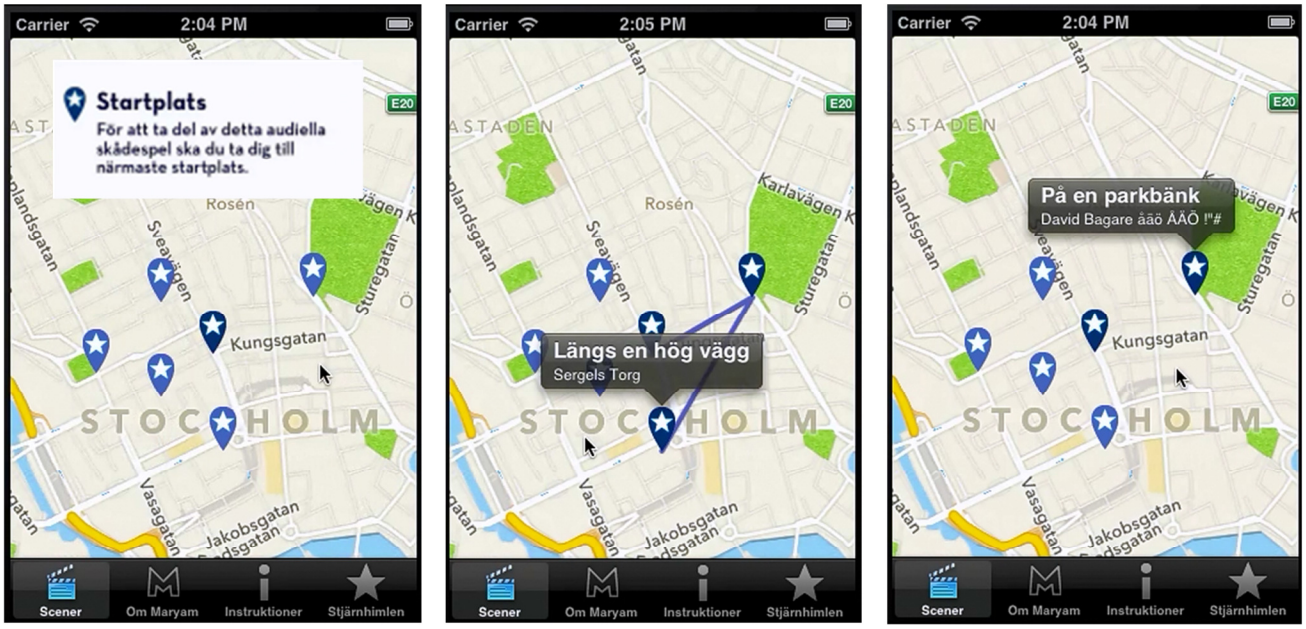

Figure 7: Screenshot from different distributed stages in MARYAM

9. Conclusions

This paper investigated new forms for creating massive and scalable participatory immersive experiences in live cultural events, characterized by processes, involving pervasive objects, people and places. The forms were either non-existent or lacked adequate support. In response to these challenges, we propose novel techniques for bringing about massive and real-time presence and awareness on the Internet, through an Internet-of-Things infrastructure, to connect artifacts, performers, participants and places. This offers (and necessitates) the possibility of the development of theories that exceed the limitations of established frames within the disciplines of theatre, dance and film studies. Mimetic dimensions of performance, definitions of fiction and the whole area of representation have to be re-evaluated in order to bring theoretical coherence into the new field of multimedia performance. The field of digital performances requires more theoretical insights into the nature of new communicational modalities, presence and absence as well as the mobility of participants in space and time.

The framework offers the possibility to combine theoretical investigations with the empirical tests that no theoretical development can do without. The key terms for such a theoretical development can be summarized as follows:

- Time-specificity as paradigm of theatrical events;

- *Immediality and hypermediality* as continuum rather than oppositions;
- Mobility of the beholder in theatrical events;
- Social responsibility of young audiences;
- Mimesis as a mode of spectating;
- Presence redefined beyond corporeal situations in time and space

This multi-disciplinary research entails a novel paradigm for collaborative creation and participation towards technological and social innovation, tapping into crowd-sensing, citizen-driven content creation, and economic models, rewarding creators and performers. The significance of this new model is that it enables collaborative creation, circumvents road blocks, shortens and reduces production lead times. Finally the model brings new values in user experience in combination with flows of compensation for the creative efforts back to artists, etc. Then, finally, there is the identification of research questions to be answered in a future work and put in relation to each other in our framework. Research has so far focused on optimizations in massive participatory activities, such as online games or social media, which do not work for simultaneous, massive, and interaction in mixed-reality. In response to these challenges, we propose novel techniques for bringing massive and real-time presence and awareness on the inter-net through an internet-of-things infrastructure to connect artifacts, performers, participants and places. The contributions here are threefold:

First, the identification of challenges that enabling-technology has to overcome in combination with some that have already been overcome and described in this paper, including the identification of issues mandating further research.

Second and equally important, we enable the in-situ creation of collaborative experiences building on relevant existing and stored content, based on decisions, leveraging multi-criteria clustering and proximity of pervasive information, objects, people and places. The salient points here are the correlation of the real and digital world, enabled by a seamless overlay, comprising an internet of things service infrastructure in addition the correlation of our present (possibly joint) and past (possibly joint) experiences.

Finally, we describe some performing art productions which demonstrate these new concepts. The results and evaluation section described how we investigated and demonstrated some of the basic concepts alluded to, regarding new ways for immersive experiences via distributed computing but pointing forward to the necessity of doing more with regard to collaborative creation.

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