STEER: Exploring the dynamic relationship between social information and networked media through experimentation

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***Abstract* — With the growing popularity of social networks, online video services and smart phones, the traditional content consumers are becoming the editors and broadcasters of their own stories. Within the EU FP7 project STEER, project partners have developed a novel system of new algorithms and toolsets that extract and analyse social informatics generated by social networks. Combined with advanced networking technologies, the platform creates services that offer more personalized and accurate content discovery and retrieval services. The STEER system has been deployed in multiple geographical locations during live social events such as the 2014 Winter Olympics. Our use case experiments demonstrate the feasibility and efficiency of the underlying technologies.**

***Keywords* —Social Media, Networked Media, Innovative experiments, Live Social Events.**

I. Introduction

Technological advancements are transforming the environments we are surrounded by, as they introduce new interactions between humans and objects. Social media is at the centre of this transformation, since they already influence social relationships, thus changing social structure. It is therefore becoming natural for users within this emerging social cyberspace to demand the kind of experiences they are accustomed to in their daily lives with the community type of communications being at the central stage. To this end, there is a compelling need to address this community-centric digitally-based ecosystem which we refer to as "Social Telemedia", defined as a cross-breeding of social networks and networked media, as shown in Figure 1. Social Telemedia further intensify current societal practices and habits and they flourish on a new network middleware framework that efficiently combine social informatics and content delivery. Social informatics loosely refer to any digitized information that is generated or exchanged in the context of social networking, whereas content delivery

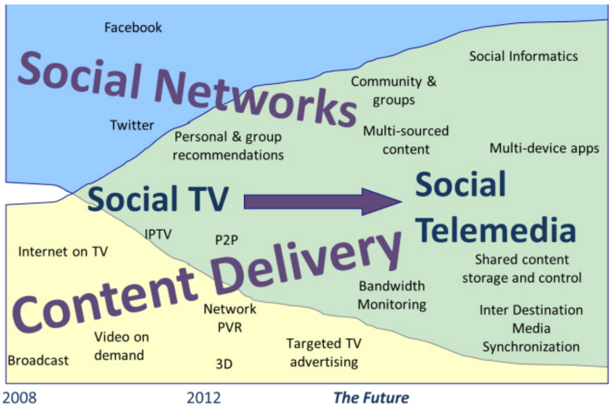

Figure 1: "Social Telemedia" is a community-centric digitally-based ecosystem, defined as a cross-breeding of social networks and networked media.

represents the communication medium through which social informatics are exchanged. In Social Telemedia, content could be delivered through a bundle of synchronized and heterogeneous flows to a community of users.

The STEER [1] (Social Telemedia Environment for Experimental Research) project aims to explore the dynamic relationship between social information and networked media through experimentation. Several projects have been investigating similar concepts as the STEER project. CrowdRec [2] project pursues three recommendation related objectives: stream recommendations, crowd engagement and creation of a benchmarking and validation framework for large scale testing. STEER is an orthogonal project able to exploit these technologies. ENGINE [3] (European research centre of Network intelliGence for INnovation Enhancement) focuses on social network and social media analysis methods. STEER enhances the recent advances

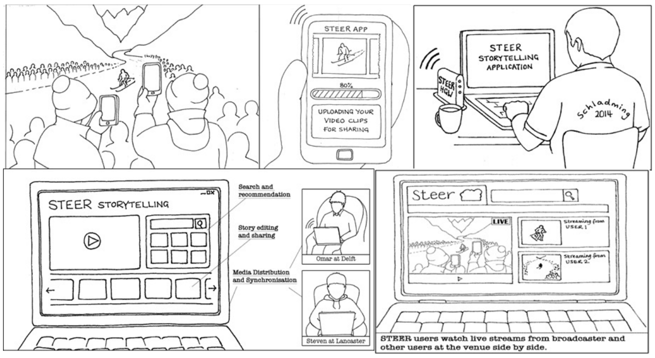

Figure 2: Graphical depiction of the two STEER use cases.

towards these goals. SOCIALSENSOR [4] develops a set of software applications that collect data from social media and automatically transforms it into interesting, relevant, and entertaining content for the purposes of both news and infotainment. Again STEER could exploit these modules and their applications.

The overall objective of the STEER project was to make significant advances in Social Telemedia research and practices, and engineer an operational Social Telemedia environment customized to support various innovative experiments. This paper reports on these advances. In section II, we describe the use cases that drove the technological developments within STEER. Section III discusses the underlying technologies of the STEER system. In section IV, we report on several experiments that were undertaken with the STEER system. Finally, in section V we draw conclusions and outline future work.

II. Use Cases and Systems

Within the Social Telemedia ecosystem, user communities contribute and consume media objects related to the interests and experiences they are happy to share in various circumstances of their lives. We believe that examples of this behaviour which are of particular relevance in real life, involve people contributing to produce, share and circulate narrations of live events which they are part of as actors or witnesses. In such cases, media contents that are autonomously produced or gathered from various sources by one or more persons who participate in an event are assembled in real-time, distributed and cached for efficient access in key network nodes, with the help of dedicated smart tools and network infrastructures. These contents, ranging from video clips taken from personal cameras (with audio and superimposed comments) to segments of live TV broadcast programs, can be organized by their producers or any third-party amateur storytellers to form multi-faceted stories or commentaries for an immediate or delayed enjoyment by groups of people, or communities. The communities can be the ones who have previously expressed an interest to, or have been notified in real-time of, that event, either directly or through the mediation of a recommendation system.

We identified two use cases that give distinctive and yet associated favours of this general description, that is i) Collaborative Storytelling, and ii) Live Augmented Broadcast. as depicted in Figure 2. For each of the use cases, we developed specific system-level implementations, where the system incorporates subsets of inter-connected STEER technologies.

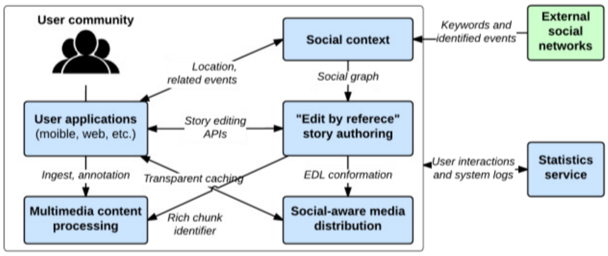

Figure 3: Online multimedia storytelling system.

A. An online multimedia storytelling system

The Collaborative Storytelling use case [5] revolves around enabling communities to collaboratively author and edit video narratives of a live social event. Figure 3 gives an overview of our social-aware online multimedia storytelling system for Collaborative Storytelling. Two user applications, a web portal and a mobile application provide the user-facing elements including video capture, sharing, searching and story authoring. The user applications also capture live metadata such as location information, which is exploited to provide personalized media experiences. The multimedia processing function encompasses operations such as transcoding, chunking, content analysis, and indexing so that user-generated content can be better shared and discovered for story authoring. The story-authoring engine uses a unique and lightweight "edit by reference" design to enable collaborative online story editing. It uses edit-decision lists to define time-addressable references of user-generated content so that user stories can be made by manipulating hierarchical references to static video objects without any complex video rendering. The social-context integration function monitors related events and trends in social networks in order to i) improve the user experience in tagging user creations and ii) discover shared stories related to trending topics nearby.

The social-aware media distribution function is introduced to improve the network efficiency and user experience of media distribution during story editing and sharing. As a research and experimentation platform, the storytelling system is also equipped with a bespoke statistics service, which captures time-coded user activities as well as service status.

B. A live augmented broadcast system

Figure 4 shows a system for a Live Augmented Broadcast (LAB) use case [6], that revolves around combining professional broadcast of live events with live user generated-content from mobile devices. Event visitors make live recordings with mobile devices, and this video footage can be watched in sync with live broadcast by viewers at home. An analysis of Twitter messages is

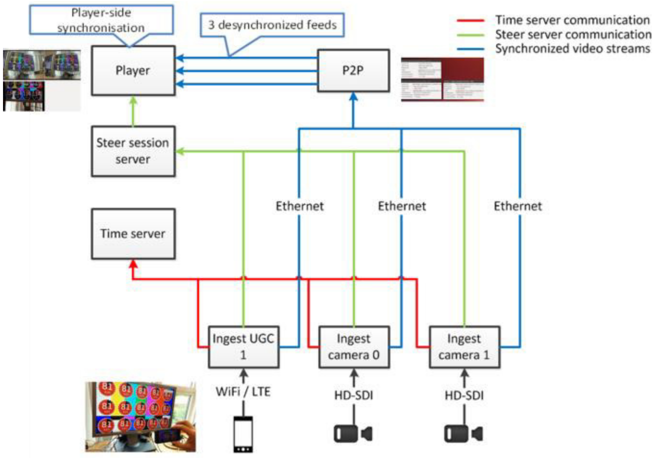

Figure 4: Live Augmented Broadcast system.

performed to retrieve and show most relevant posts in sync with video. By providing additional content, the live broadcast is enriched and viewers can enjoy an augmented view on live events. The live augmented broadcast use case and system are vehicles to integrate existing and new components and to perform experiments on them. The main components used in this use case are described in the technologies presented in the following sections. There were two experiments around Storytelling that have been carried out presented afterwards.

III. TECHNOLOGIES

The STEER systems leverage social media, and advanced networking technologies to enable new applications based on technologies derived directly from research and experiments. Combining such advanced technologies enables a new range of social tele-media applications.

A. *Adaptive Event Profiler*

With the adaptive event profiler (AEP) [7], one can follow news socially connected an event. It allows for emerging event detection through event tracking on social media, and for personalization through ranking and clustering social media posts. Use cases range from suggesting related terms to an event for tagging videos, to following social media messages around an event in real-time, to the creation of a dataset of social media data around a topic. The adaptive event profiler allows the retrieval of social media data in a significant higher volume and degree of accuracy than simply following a single keyword as was demonstrated during three large-scale experiments on 2014 Winter Olympics, the 2014 Silverstone F1 race and the World Rowing Championship 2014. As shown in Figure 5, this technology incorporates the following features:

- Retrieve Likeable Tweets: the adaptive event profiler retrieves significantly more likeable tweets than following a single keyword, without introducing too much noise in the dataset.

- Simple and easy Interfacing through Web Services Implementation: the adaptive event profiler runs as a web

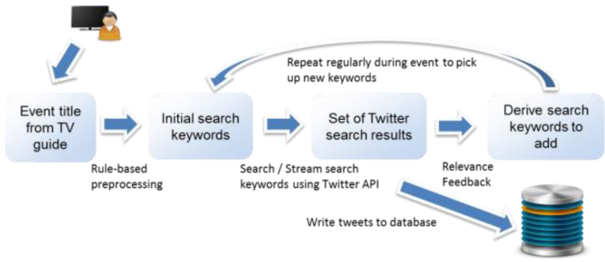

Figure 5: Adaptive Event Profiling: An innovative state-of-the-art social media analysis platform.

service on any cloud environment. The API allows users to list all events, create and stop events, check event details and to open specific Twitter streams.

- Simple and easy Interfacing through Web Services Implementation: the adaptive event profiler runs as a web service on any cloud environment. The API allows users to list all events, create and stop events, check event details and to open specific Twitter streams.

- Works with Twitter and Facebook: Twitter is used as a source of textual content to find related keywords. During public events, tweets are continually posted with information on the current events, such as news about the participants and match outcomes. Facebook event pages can be tracked, and images can be resolved.

B. *Media Asset Referencing System*

One unique feature of the online storytelling system, designed to facilitate community online co-authoring, is the “edit by reference” design. Instead of physically editing and rendering a video object, which consumes computational and network resources for every edit, we allow a user story to be composed by creating a list of references to existing video objects. The idea is similar to creating a playlist where each line of the list refers to a section of a song stored externally in the cloud. Editing a story simply maps to editing a small “playlist”.

The Media Asset Referencing System (MARS) is a media management system that recognizes time-addressable media assets within chunked media objects, and generates new media objects on-the-fly by combining just the segments that represent time periods that fall within or overlap with those assets. The core of MARS is the management of edit-decision lists (EDLs). An EDL is a script-based expression of composition of a media object. It creates a time-addressable descriptive view on the internal structure of media objects using frame-accurate presentation and navigation of time-codes, so that virtual operations visually assisted by key-frames such as cut and fast-forward can be carried out without physically examining the corresponding media objects.

When a chunk is created from a media object, an EDL generator defines a rich chunk identifier (RCI) to index the chunk and uses it to generate a rushes EDL for the media object. Parameters within the RCI describe the media encoded in the chunk. Using the story composer on a storytelling application, a video story can then be expressed as a story EDL that references defined segments in one or more rushes EDLs, or even the EDLs of other derived content; story editing then boils down to the editing of text-based scripts. At the time of playback, the story EDLs are converted into a directly playable media manifest on-the-fly. An EDL can be converted to MPEG-4 first by resolving all segments so that only segments referring to chunks remain. An MPEG-4 track is created for each EDL channel. Each chunk is allocated a non-overlapping time period within the track, and a description is derived from its RCI parameters, and encoded as part of the track description. An MPEG-4 edit list is included in the track to indicate which parts of the track are actually to be played and when. The URIs of the chunks are also derived from their RCIs, and listed in the track for the player to fetch. The resultant manifest file is an MPEG-4 header that describes the audio-visual file structure and includes URIs to locate the corresponding chunks in the network. The process requires no transcoding, and a virtual layer in the EDL hierarchy allows all profiles of a rush to be referenced together, one being chosen only during resolution; the results of editing are directly available, and at all quality levels.

C. *Live streaming for User Generated Content*

Current commercial live video streaming systems are based either on a typical client-server (cloud) or on a peer-to-peer (P2P) architecture. The former is preferred for stability and QoS while the latter is scalable with small bandwidth and management cost. In STEER, a scalable and stable service management architecture for a cloud assisted P2P live streaming system was developed, one that is suitable for streaming user generated content.

The P2NER [8] architecture consists of a media server in a cloud and a set of peers. A server divides the stream into video blocks and is responsible for: i) the initial diffusion of blocks to a small subset of nodes among participating peers, ii) the bootstrap of the P2P overlay, iii) the dynamic and scalable monitor of the resources of participating peers, iv) the dynamic control of auxiliary bandwidth and playback rate. In order to allow peers to exchange video blocks, each peer maintains network connections with a small subset of other peers which will be noted as neighbours. The sets of these connections change dynamically and form a dynamic graph called the P2P overlay which is a graph topology and P2P overlay management algorithms that each peer periodically executes. In [9] we use distributed optimization theory in order to dynamically ensure in a distributed (scalable) and dynamic fashion that: i) peers have connections proportional with their upload bandwidth, ii) peers have connections with other peers close to the underlying network, iii) our P2P overlay is adaptable to underlying network changes and peer arrivals and departures. Furthermore Distributed Block Transmission Scheduler (DBTS) [9] coordinates video block exchanges in a distributed fashion. In order to achieve this every peer through the dynamic communication with its neighbors in the P2P overlay executes a set of algorithms that we developed. The major objective of DBTS is to ensure the

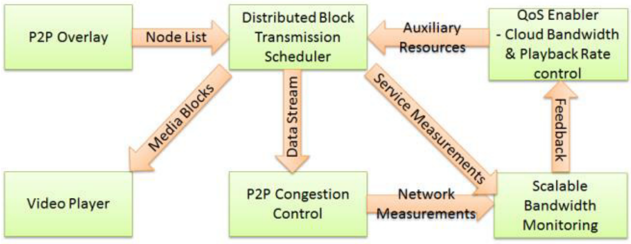

Figure 6: STEER live streaming architecture and major interactions.

timely delivery of every block to every peer by exploiting the upload bandwidth of participating peers and the additional bandwidth resources that media servers may contribute through the dynamic communication with its neighbors in the P2P overlay executes a set of algorithms that we developed. The major objective of DBTS is to ensure the timely delivery of every block to every peer by exploiting the upload bandwidth of participating peers and the additional bandwidth resources that media servers may contribute.

DBTS propagates the video blocks that have to be sent in the P2P congestion control component. P2P congestion control [10] is able to manage sequential transmissions of video blocks to multiple locations in contrast with traditional congestion control architectures which are designed for bulk point to point transfers. P2P congestion control provides to the Scalable Bandwidth Monitoring the dynamic estimation of: i) the upload bandwidth capacity, ii) the idle bandwidth resources of each participating peer. Finally, QoS enabler adapts dynamically the playback rate [8] or allocates dynamically auxiliary upload bandwidth [11] towards a stable live streaming service in a way that it offers an attractive trade-off between efficiency and stability.

D. *Hybrid Media Synchronisation*

The STEER media synchronization technology for live event coverage enables to seamlessly combine professional broadcast with amateur videos shot by the crowd, as well as with social media feeds such as Twitter and Facebook streams. In the STEER player, all media is shown synchronised in time, faithfully recreating an immersive user experience. The technology is also distribution agnostic, independent of media codecs and transport mechanisms, which were validated with a large-scale experiment during the World Rowing Championship 2014.

The features of this technology include:

- Distributed and scalable content ingest platform: content can be ingested by a local node and/or in the cloud. Ingest nodes work together to achieve frame accurate media time-stamping.
- Frame-accurate synchronization and playback of media: all media sources can insert timestamps in the captured media streams, all using synchronised clocks. Frame-accurate playback uses these timestamps.

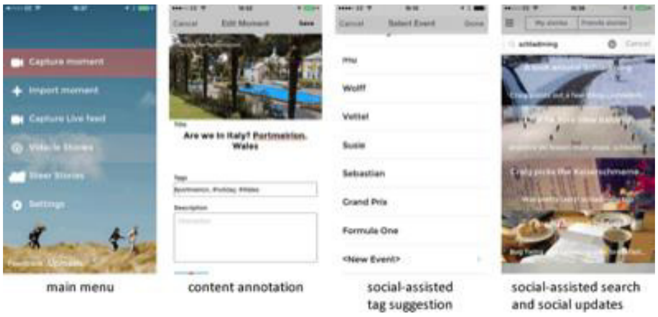

Figure 7: User-generated content capturing, sharing, annotation, and retrieval on Vidacle mobile application.

- Multi-device support: the solution supports multiple devices, both on the capture side (professional, iOS phones and tablets) and playback side (Linux systems).
- Various media streams can be played back on a primary TV screen and secondary companion screen.
- Distribution-agnostic technology: the platform supports a variety of codecs and transport protocols, and can thus enhance any existing media production facility.

E. Vidacle

The Vidacle mobile application is designed with an intuitive user interface and content-management system to streamline capturing, tagging, sharing and exploring of community stories on the same mobile device during the live event. Once a capture is made, users are given the opportunity to type in a title, description, and tags. Vidacle also manages the user videos, their associated annotations and other metadata such as geo-location in the background without further intervention.

User feedback from our previous experiments suggests that typing in a text annotation (i.e., title, description, tags, etc.) to accompany a video can be “annoying especially when you are standing on a ski slope with many other things happening around you”. This illustrates the need for automatically gathering as much relevant information as possible and presenting the user with suggestions, making their life easier. Vidacle exploits the trending events derived by AEP in conjunction with the current location of the device to offer a number of suggested tags for users to select (Figure 7). This feature greatly reduces the overhead of video annotation between video captures, allowing users to focus on content creation during a live event and enabling quick social sharing. Stories made by a user’s friends are also “pushed” to Vidacle in the “Friends’ stories” tab, so storytelling users are always up-to-date with stories in their ego networks.

IV. Experiments

The STEER system provides users with novel and exciting opportunities to share and enjoy media experiences. As shown previously, we have captured the features of the system through two use cases that share most of the functionality. These use cases enable real users to broadcast or edit footage directly from an event and share it within

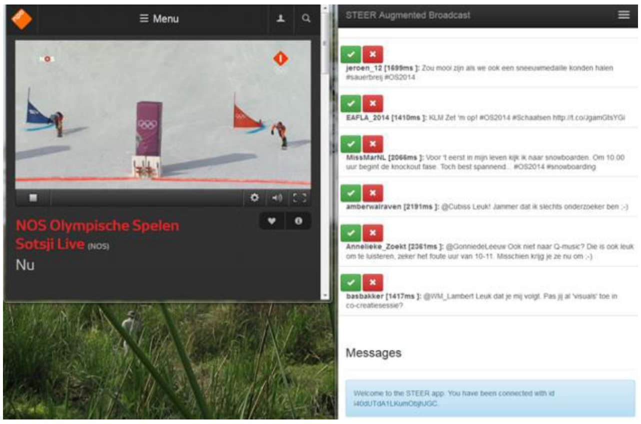

Figure 8: Interface for 2014 Winter Olympics experiment.

communities of users in a scalable and on demand manner. More specifically, the STEER innovations allows to capture live events on mobile devices and tell a specific side of the story either through live broadcast or through storytelling; to share a story through P2P and social networks with friends at home; and to deliver shared and synchronized multiscreen experiences to real and virtual communities.

The STEER system has been deployed in a series of venues with experiments that demonstrate the feasibility of the bespoke technologies. This section presents experiments that have already successfully taken place.

A. 2014 Winter Olympics

During the 2014 Winter Olympics (Sochi, Russia), a STEER experiment took place in collaboration with Delft University of Technology. The goal of the experiment was to assess the interestingness and relevancy of social media posts during a live TV broadcast (see Figure 8). The STEER adaptive event profiler was deployed to retrieve and filter selected Tweets during a series of live broadcasts of ice skating games. The experiment considered a number of research questions: i) How can we design an event profiler that generates a set of query terms to retrieve relevant and interesting tweets during an event?, ii) How does the event profiler perform in generating relevant and interesting tweets, compared to a traditional tool based on the simple event hashtag?, iii) What is the relation between relevancy and interestingness of tweets, also depending on the event profiler settings?

During the experiment, two sessions with 10 participants took place at two different locations. All participants watched a live broadcast of men’s 10000 m (session A) and women’s 5000 m (session B) speed skating finals, with approximately 25 minutes of viewing time. Tweets shown were evaluated on *7-point Likert scale* for interestingness and relevancy. Participants gave feedback by clicking a green or red button. The main keyword to start the profiler was “#os2014”, i.e. the hashtag that was promoted by the television broadcaster NOS. A list of keywords generated by the event profiler was updated every 5 minutes. We found that the event profiler retrieved significantly more likeable and interesting tweets comparing with results from following merely a single keyword, without introducing too much noise. Interestingly, relevant tweets are not necessarily interesting, but interesting tweets are usually relevant.

B. 2015 Silverstone Formula 1

An experiment was held at Silverstone, UK during the British Grand Prix Formula 1 racing event (http://www.formula1.com/races/in_detail/great_britain_924) on 6th July 2014. For this experiment, we selected two groups of members of the public as the participants. Group 1 is a family of three (plus one friend), who are long-term Formula 1 fans, on their first trip to the Silverstone GP, invited for Vauxhall "VXR Power Events" which allows exclusive access to certain areas of the Silverstone circuit during the event. Group 2 is a family of two (plus one friend), who are frequent Formula 1 visitors. The two user groups do not know each other.

Both groups used the storytelling applications extensively to capture the highlights of their Silverstone experience. Group 1 shared 33 rushes (900MB) from one iPhone and 47 rushes (2GB) from a second iPhone. Group 2 returned with 89 rushes (4GB) and 104 rushes (4.6GB) from two iPhones respectively. This suggests that participants of live events are very likely to capture a large amount of audio-visual content (not only still images) for personal archiving or social sharing, especially when a group of friends and family travel together. The rushes cover the entire trip to Silverstone. We noticed that only a small portion of the rushes are about the actual racing, while most others are related to other parts of the Silverstone experience, including travelling, camping, and auxiliary entertainment.

The social context integration proved to be effective in improving video annotation and in enhancing the search function during the experiments. Using AEP to recognize trending events, the integration of social context ideally solves the classical "cold start" problem in content recommendation. Given user location, the storytelling system is able to suggest a number of popular user stories related to socially trending keywords nearby (for example, as shown in Figure 4). The main keyword used as input for the AEP in this case is "Silverstone". Event and participant names (such as *#britishgp* and *Hamilton*) are among the most popular suggestions during the event. For the enhanced search function, AEP provides a list of related keywords and a metric to quantify the relevance to the search request.

Figure 9 shows a heatmap of related terms in a social network generated from data output by AEP on the F1 race day (6th July 2014). The darker the episode of the related keywords is, the higher its relevance to the main keyword "Silverstone". It illustrates how hot topics related to live events in social media evolve over time as influenced by how the event develops. For instance, *#pinkforpapa,* a story

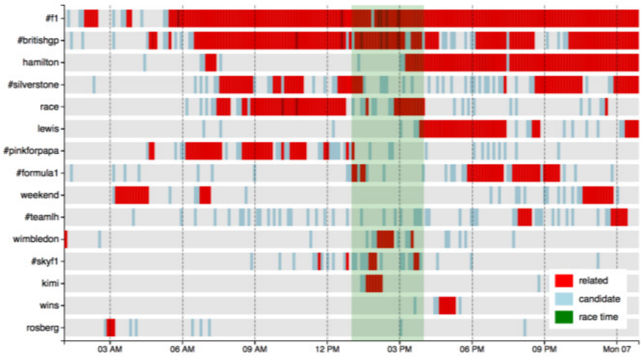

Figure 9: Heatmap of related social terms on the Silverstone F1 race day.

related to the British driver Jenson Button and his father, was a very hot topic of the Silverstone F1 prior to the actual race. This demonstrates how AEP identifies social discussions on background stories of the race. The hotness of the term '*kimi*' in the heatmap reflects our observations keywords and a metric to quantify the relevance to the search request.

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During the course of the experiments, composite stories were created and repeatedly edited by many individuals. One example is the Silverstone F1 story (available on Youtube via http://youtu.be/Zo83I1MPQcI), which demonstrates the experience of a group of participants through their personal and unique perspectives of the trip (Figure 10). The story was made by group 1 using 37 media assets and involved more than 100 revisions. It demonstrates how the storytelling platform assists users in creating a compact and engaging story from a large amount of user shared content. Most of the content used for the story was originally captured by the same user group, though the storyteller did adopt footage shot by user group 2 with a great viewing angle about an evening event, which both user groups attended coincidentally. In the user interviews participants suggested "the true best way of watching the F1 race is to 'sit at home and watch it on

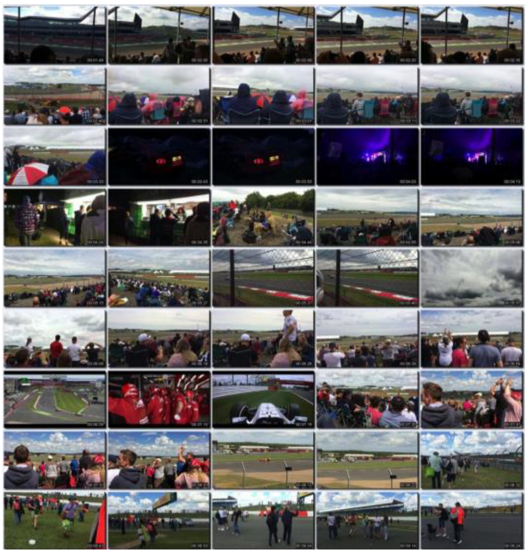

Figure 10: Silverstone F1 Storytelling experiments.

television'". They continued by saying that "the official broadcasters have the best access to all viewing angles so that viewers can keep track of incidents and accidents during the race as well as the background stories from reporters, while people at the Silverstone circuit normally have only the view of the race at a corner". Our participants believe that "the true F1 racing experience lies in the F1 atmosphere which gives you the experience of being with the crowd, enjoying the live sound of the F1 engine, walking on the F1 track, going to the evening events, etc." The user feedback proves right the design principles of our storytelling platform, which is not made to replace or challenge conventional broadcasters but to assist individuals or small communities in recreating their personal experience by assembling pieces of highlights at a live event. Moreover, one consensus among participants of both groups is that storytelling of personal/group experience of an event is "a very natural thing to do". Most found that the storytelling system for capturing and sharing their own creations made them feel that they were "telling a live story to their friends". They were mostly adding the narratives directly while recording. Sometimes a group member spontaneously acted like a reporter, letting other group members talk about what had just happened.

V. CONCLUSIONS AND FUTURE WORK

Through the research and development under the framework of STEER project, we designed innovative algorithms and tools that extract and process social informatics generated by social networks to enhance media services with service personalization, better content distribution and context-aware content discovery..

Moreover, the scalable and efficient socially-aware media distribution architecture optimizes the usage of network/user resources through dynamic monitoring and synchronizing bundles of media flows for community based communication. The rich and geographically dispersed experimental environment of the project recreates real life user environment that facilitates large scale experimentation. Additionally, the propose methods can be incorporated in the next generation home gateway architecture based on accurate predictions and appropriate architectural choices inspired by Social Telemedia applications and services.

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