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On current crowd management practices and the need for increased situation awareness, prediction, and intervention

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ABSTRACT

Recent accidents (News, 2006, 2010, 2013, 2015) show that crowded events can quickly turn into tragedies. The goal of crowd management is to avoid such accidents through careful planning and implementation. Crowd management practices are collaborative efforts between the different actors of the crowd management team and the crowd that depend on effective handling, sharing, and communication of information. Safety and comfort of a crowd depend on the success of such efforts. We have studied current practices and the role of technology through interviews to crowd managers. Our findings show that event planning and monitoring can be complex and sophisticated, but are operated with little support from technology. Crowd managers intend to increase their use of technology, but they have been so far dissatisfied by existing solutions. We provide recommendations for a bigger role of technology in crowd management.

1. Introduction

Crowd management is essentially a set of collaborative practices between a number of different actors, e.g. event planners and managers, emergency services, local authorities, transport authorities, stewards, and the crowd itself (W. Challenger et al., 2009; Wijermans et al., 2016). These practices start months ahead of an event. In fact, as we discuss in this paper, preparations take about 90% of the efforts. Usually a multi-agency approach is followed, incorporating all relevant parties, to enable a wide range of knowledge and expertise to be drawn upon. Preparation activities include detailed risk analyses to identify and prioritize potential risks, use and development of comprehensive "what-if" scenarios to consider management strategies and contingency plans, establishment of a control point to coordinate all activities and personnel. The remaining 10% consists of implementing the plan, comprising monitoring crowd activity to identify potential problems, and intervention, that in extreme conditions can result in crowd control. It must be noted that the focus of crowd management is facilitating crowd activities, hence proactively preventing, or quickly resolving, problems. The correct and effective execution of such practices is crucial to the success of an event, with the most important outcome being the safety and comfort of the crowd (Abbott and Geddie, 2000; Earl et al., 2004).

It has been argued that a more systematic approach to crowd management could have avoided recent accidents in large crowded events (Dickie, 1995; Challenger and Clegg, 2011). We postulate that new developments in technology, including mobile sensors, decision-support systems, and novel communication and interaction paradigms, can support crowd management operations during the planning and implementation of an event. However, as also supported by our results, currently the success of operations is still mainly dependent on the personal experience and skills of the crowd management team, with little or no aid from technology.

Towards a better understanding of the limitations and requirements of current crowd management practices, in particular regarding the role of technology, we present the perspective of crowd managers. We interviewed 10 crowd managers daily involved with managing large crowds, including a stadium hosting tens of thousands of visitors, a large train station, a multi-day music festival, a yearly celebration involving more than a million people. A main result emerging from our interviews is that crowd managers feel the need for instruments offering an increased situation awareness, a more reliable and timely monitoring of the state of the crowd, and the ability to predict and steer the behavior of the crowd without use of force.

In this paper, we make the following contributions. First, we present background and supporting literature, including crowd

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behavior modeling and prediction, mobile sensing, and decision-support systems. Second, we present current crowd management practices, as they emerged during our interviews. In particular, we focus on the role of technology and its limitations. Third, we present crowd managers' requirements for future technology to support their operations. Finally, we discuss opportunities and recommendations within the framework of a techno-social system.

2. Background

A generally accepted definition of a crowd is that it is a large gathering of diverse people at the same physical location, at the same time, not necessarily sharing the same goal or interest (Wijermans, 2011). Understanding the behavior of crowds, and how to manage them effectively, is still a scattered effort that involves different fields including theoretical physics, sociology, psychology, computational science, and artificial intelligence. Recently, studies have been published with overviews of common crowd management practices (W. Challenger et al., 2009; Health and Executive, 2014), but more work is required. The literature about crowds and crowd behavior focuses on theoretical modeling of the psychology of crowd behavior (Sime, 1995; Reicher, 2001), predicting crowd behavior through physics-inspired models, recognizing behavior through various kinds of sensors and analysis.

An approach to studying crowd behavior is by synthesizing it through crowd behavior prediction models. Crowd behavior prediction models are also used for a priori planning of events through simulation (Still, 2000; Zarboutis and Marmaras, 2007; Al Bosta, 2011; Siddiqui and Gwynne, 2012). A popular example of a crowd behavior model is the social-force model (Helbing and Molnar, 1995). The models usually target so-called crowd dynamics, referring to patterns of crowd movement, and more precisely to "the coordinated movement of a large number of individuals to which a semantically relevant meaning can be attributed, depending on the respective application" (Roggen et al., 2011). Examples include a queue of people, the formation of uni-directional "lanes" in bi-directional pedestrian flows, the intersection of these lanes, or a group of people at a specific location. Approaches to crowd modeling and simulation have been extensively surveyed (Venuti et al., 2007; Bellomo and Dogbe, 2011; Duives et al., 2013).

A different approach is to investigate how to detect and recognize crowd behavior. Traditionally, computer-vision techniques have been employed to characterize and automatically detect anomalies in a crowd (Zhan et al., 2008; Yaseen et al., 2013). The diffusion of pervasive and ubiquitous technologies such as smart phones and smart watches, has enabled the monitoring of social behavior through a wide range of sensing modalities, from temperature, to movement, to spatial proximity (Vinciarelli et al., 2009; Atallah and Yang, 2009). For example, smart phones have been used to detect crowd dynamics such as pedestrian flows and bottlenecks, and social groups (Wirz et al., 2009, 2012, 2013b). In particular, crowd dynamics such as pedestrian lanes and clogging have a strong spatio-temporal nature that can be captured as so-called crowd textures using proximity sensors (Martella et al., 2014). Accelerometers can be used to characterize queues, and activities such as running and walking (Kwapisz et al., 2011). Finally, microphones can be used to measure the mood of a crowd (Cinimodstudio, 2011) or recognize locations and places (Lane et al., 2010).[1] Some of these approaches are grouped also under the term Ambient Intelligence (AmI), referring to "electronic systems that are sensitive and responsive to the presence of people" including context and social-aware miniaturized pervasive computing devices and sensors, which can be envisioned to enhance and support, for example, crowd monitoring and evacuation (Mitleton-Kelly et al., 2013).

While synthesizing and recognizing crowd behavior has been addressed in the literature, less attention has been dedicated to how such data can help crowd managers make effective decisions in the control room, for example, during an event. Existing works either tend to focus on managing disasters and emergencies (Bui and Sankaran, 2001; Perry, 2003; Lorincz et al., 2004; Reddy et al., 2009; Asimakopoulou and Bessis, 2011; Illiyas et al., 2013), or on very specific cases such as air traffic control (Bentley et al., 1992; Mackay et al., 1998) and underground stations (Suchman, 1997; Luff and Heath, 2000), overlooking how technology can be used to support decisions *before* accidents happen during an event, or to support planning and debriefs.

Theories on socio-technical systems recommend new systems to be designed and operated with a holistic approach that optimizes both technical and social factors (Cherns, 1976, 1987; Clegg, 2000; Clegg and Shepherd, 2007). This body of work is crucial to the design of system that make use of technology to support the work of crowd managers. While these principles have been applied to the domain of technology and work design over the last decades, a broader and braver approach is necessary to extend their reach, for example, to crowd management (Davis et al., 2014). In this paper, we take a technological stand within this attempt, by studying how technology currently helps (or fails to help) crowd managers in their practices, and how existing and new research can serve the work of crowd managers in organizing and managing safer and more secure crowds.

3. Method

In this section we present our participants and the methods used to conduct the interviews and analyse the collected data.

3.1. Participants

We carried out 10 individual interviews with 10 crowd experts. We selected and approached 10 organizations in The Netherlands known for hosting and managing among the largest crowds in the country. From each organization, we interviewed a senior professional with experience in dealing with large crowds. Type of event, location, visitors profiles, time of year, among others, define different scenarios of crowd behavior and the different strategies to manage them. For this reason, we chose organizations that allowed us to cover the widest range of events and crowds, from those emerging at peak hours in train stations to those in multi-day outdoor music festivals. Note that also within the same type of location, e.g. a train station, experts manage diverse scenarios. For example, train stations must deal with both week-day peak-hours crowds and day-long special celebration events, with hundreds of thousands of people coming in from all over the country. We summarize the participants and their domain of expertise in Table 1. We also included an expert from the Research & Development department of an organization specialized in designing and building barriers for large events, such as music festivals and parades. As such, he presented a different perspective of the requirements and the use cases of the crowd managers. Finally, the organization we dubbed "Security Company" differs from the other organizations due to their consultancy-oriented business model, that includes the delivery of crowd management trainings and workshops, as well as consulting on events organization and man-

[1] Note that these techniques differ from the emerging field of Mobile Crowd Sensing (MCS) (Ganti et al., 2011). MCS uses mobile devices to collect information from individuals dislocated and distributed in wide areas, and defines a crowd as a large number of individuals that may be distributed geographically in *different locations* (and even different countries), or that visit the same location at *different times*.