The Future of Spatial Systems for Disaster Management

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ABSTRACT

Disaster management processes and systems are critically dependent on spatial systems to connect locations, people and activities. Many new developments like mobile telephony, applications and social networking platforms, however, have underpinned the development of spatial systems 'inter-connectedness with *exclusiveness*'[1] due in part, to their commercial and proprietary nature. This paper highlights major themes from the Spatial Futures Forum 2017 to support development of spatial systems 'inter-connectedness with *inclusiveness*'[2]. This is especially important as effective disaster management situational awareness and community resilience requires: connection and integration of the 'islands' of spatial information; a real-time 'data on demand' approach which is also reliant on effective connection of these 'islands'; and curation of an individual's 'virtual identity' from ethical, legal, property ownership and risk perspectives.

Keywords

Spatial information systems, disaster management, situational awareness, community resilience

INTRODUCTION

Disaster management processes and systems are critically dependent on spatial systems i.e. the ability to monitor the "digital connection between location, people and activities"[3] to develop accurate situational awareness and optimal outcomes. We are also now living in a time where basic mobile telephony, applications and social networking platforms have profoundly changed the decision making of, and relationships that individuals have with government, commercial and social organisations and each other. These new technologies also create a barrier to development of effective spatial systems solutions, due in part to their commercial focus and proprietary nature. To this end, the University of Sydney, Interoperability in Extreme Events Research Group (IEERG)[4] and the UNSW, Geoscience and Earth Observing Systems Group (GEOS), invited leading academics and professionals to present their views on these issues at a Spatial Futures Forum[5], held in Sydney during September 2017.

This is a time of growing personal dependence on technological inter-connectedness. Smartphones and embedded computing devices in homes, cars and offices; information, software, networking and communication providers such as Google, Facebook and Twitter; and product and service providers such Amazon and Uber, all contribute to how each of us defines our 'virtual selves' and how we relate to each other in an increasingly informed virtual world. Our smartphones are becoming our window to the world, not only providing us with a huge and diverse amount of information, but also enabling us to know where we are at any given time in relation to the people and things around us i.e. spatially.

Amongst these existing and emerging technologies 'spatial systems' are often a significant 'silent' partner in our progress towards the connection of locations, people and activities. "This information can graphically illustrate

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[1] Locations, people or activities that connect to a proprietary or commercial network of systems

[2] Locations, people or activities that connect to an open network of systems

[3] CRC for Spatial Information http://www.crcsi.com.au/about/what-is-spatial-information/ - last accessed 05/09/2018

[4] Interoperability for Extreme Events Research Group http://sydney.edu.au/business/research/ieerg - last accessed 05/09/2018

[5] Spatial Futures Forum 2017 (event agenda and registration page) - http://sydney.edu.au/business/events/2017/research/2017/spatial-futures-forum-2017 - last accessed 05/09/2018

what is happening (where, how and why) to show the insight and impact of the past, the present and the (likely) future."[6] Such developments in personal information technology platforms have profoundly changed the way we use and view information. They have also directly contributed to consumer, institutional and economic transformation in the form of the sharing economy, and our view of the products and services that we buy, the organisations in which we work and how we estimate our value to the societies in which we live.

We no longer only seek information - we are information which has great value to commercial interests like Google, Facebook, Twitter, Amazon and Uber.

Our digital footprint embodies a 'virtual self' in which commerce and government can profile and share information about us, and increasingly and more accurately, know and share our whereabouts, potentially in real-time. It is predicted that by 2019 more than five billion people will have mobile phones, with roughly 50% of them being smart phones[7]. Potentially, this will have an enormous influence on the ability of government agencies, private organisations, communities, and individuals to work together to achieve the best outcomes and solutions for the social cohesion and inclusiveness that we all seek. Social cohesion and inclusiveness is an important foundation for community resilience during crises and disasters (COAG, 2011, Magis, 2010). Current and future developments in spatial information systems that seek to overcome issues caused by commercial and proprietary spatial system interests, therefore, should be of high level interest to disaster managers.

In disaster management research there have been calls for a conceptual framework for a spatially integrated policy infrastructure for flood risk (Ran and Nedovic-Budic, 2016) and geospatial data management framework for humanitarian response (Cowan, 2011). There are also illustrative examples of systems that have integrated risk analysis, evacuation strategy dissemination to communities, and "real-time detection of environmental risk and evacuation support" for tsunamis (Ai et al., 2015) as well as the development of a conceptual architecture to handle information generated in emergency situations (Nascimento et al., 2016). Models that mine geo-located social media data during floods and typhoons have also been developed (Porto de Albuquerque et al., 2014, Xu et al., 2016) as well approaches to volunteered geographic information (VGI) systems where citizens are able to produce spatial information to be used in emergency management systems via their personal mobile devices (Hedley, 2012, Senaratne, 2017). We have also seen development of an information ontology to aid emergency management data integration (Galton & Warboys, 2011) as well as the use of geovisual analytics approaches for display of situational awareness information (Tomaszewski et al., 2007).

While all of these efforts make a vital contribution to research and spatial systems outcomes for disaster managers, we have yet to focus on an 'open' *integrated* approach for future spatial systems development to produce 'inter-connectedness with inclusiveness' as it relates to community resilience and disaster management.

SPATIAL FUTURES FORUM

A great proportion of the advances in information and technologies for personal use, commerce, academic research and government systems, have been made possible through recent developments in the Spatial Sciences, be it digital communications, mobile systems, visualisation, field robotics, remote sensing or mobile and satellite technologies. The demand for knowledge about how we can develop and use spatial systems, is set to grow exponentially with requirements for expertise in big data analytics, autonomous vehicles, logistics, designing the urban environment, emergency services, and many new and 'in development' technologies, which rely upon ubiquitous location information services.

The aim of this forum was to bring together researchers and practitioners to share ideas and new knowledge on the current state of spatial systems development with various leaders from different fields in government, business and academia, and also develop an understanding of where these systems are heading in the future.

The Forum was a one day event with five invited presentations from key spatial experts and senior policy makers, as well as a concluding panel with all presenters. Presentations covered the following topics:

- Spatial drivers and opportunities;
- From GIS to ubiquitous location intelligence: how technology waves are amplifying the use, users and benefits of location information;
- Digital planning tools for envisioning city futures;
- 3D models and the digital built environment; and

[6] CRC for Spatial Information http://www.crcsi.com.au/about/what-is-spatial-information/ - last accessed 05/09/2018

[7] statista The Statistics Portal https://www.statista.com/ - last accessed 05/09/2018

- Future trends in the spatial arena.

IDENTIFYING KEY MESSAGES FOR DISASTER MANAGERS

Each presenter had roughly 30 minutes to discuss their ideas from their respective area of expertise. The audience was then invited to ask questions and further develop ideas with each presenter for 15 minutes. A panel was convened with all 5 speakers in the afternoon session to further discuss matters of importance to the forum participants.

A research team from the IEERG, comprising of 2 senior researchers, 1 post doc and a PhD student was allocated to take detailed notes during the Forum. The research team then met a few days later to discuss and synthesise their notes and highlight areas of critical importance that emerged from the Forum. These notes were then consolidated and 'key messages' regarding the future development of spatial systems were distilled from this analysis. Three key areas emerged that included development of:

- Coherent and cohesive spatial systems to connect the 'islands' of spatial information generated by, and stored in current systems;
- A real-time 'data on demand' spatial systems development approach which overcomes location addressing, system and data integration problems and which sets a direction for a skills and training focus to meet anticipated skills shortfalls; and
- 'Virtual identities' for individuals that address ethical, legal, property ownership and risk issues as well as the integration of virtual and real worlds.

This paper contextualises these key messages for disaster managers by providing some examples for consideration, as the future of spatial systems will underpin the systems and technologies that are critical for developing community resilience and situational awareness in preparation for, response to and recovery from a crisis or disaster event.

Development of Coherent and Cohesive Spatial Systems

Spatial information systems have largely been developed as discrete and unconnected system 'islands'. Typically they require an expert in spatial science to compile and analyse data that is generated, before it can be presented for use by the decision-maker(s).

Although this situation has lately been disrupted by the likes of Google Maps, there are still limits to the effective use of spatial information in real-time in an interconnected and inclusive way, to deal with emerging current and future crises and disaster scenarios, where time and timing are of the essence.

Figure 1. Field Data Collection (Real-Time) NSW Fire & Rescue Remote Pilot Aerial System

Important aspects of crisis and disaster management such as field operations and their interactions with community and NGO activities, could be more effectively integrated and improved by a more coherent and cohesive approach to spatial information system development and use — for instance, the potential for a drone to deliver real time video or thermal imaging information to a central crisis centre or to fire fighting units in the field, while integrating this information with data on the real-time location and status of individuals who live and work in the area of a flood or fire.

But future information systems — say, 5G mobile and precision GPS — must be able to continuously and accurately provide data as to the drone's location in relation to other people and things (to avoid colliding with an aircraft, another drone, building, person, car etc.) as well as to marry the imaging to the location and status information of individuals in the vicinity of the emergency incident.

This will not be an easy operation until the data the drone is seeking, can be accessed from other non-compatible or unconnected spatial information systems at real-time speeds. These unconnected and often proprietary or commercial system 'islands' form a significant barrier to advancement of a coherent and cohesive spatial systems architecture for disaster managers.

Data on Demand

Discussion at the Spatial Futures Forum canvassed a wide variety of technologies and scenarios focussing on the needs of communities over the coming years, and the solutions to those needs.

One such need is consistency in location addressing standards and location data collection. Addressing this requirement will be essential to improve the effective delivery of public and private products and services, such as the dispatch of ambulances and police, faster delivery of resources to disaster sites, and better coordination and provision of transport and evacuation services. These will all rely on accurate and complete addressing data, including the present position of a caller. Interesting work is currently underway in this area with what3words[8] who have developed an application to convert GPS co-ordinates into a three word addressing system, thus providing an effective human interface to a complex addressing problem. For delivery to an address we need only a three-word code to pinpoint a location. This approach is particularly useful for remote communities and for individuals who do not have what most of us think is a standard address, such as a: 1) house number; 2) street; 3) suburb; 4) state; and 5) country name.

Another focus of discussion was the strategic alignment of spatial data management strategies with business IT initiatives across government and the private sector and an eventual end to spatial digital 'islands'. Increasingly, 'interconnectedness with inclusiveness' will come to rely on our ability to bring spatial data together — accurately, quickly and comprehensively — from disparate sources. For instance, the ability to effectively plan our cities and 'future proof' them from disaster, will rely on integration of accurate data supplied by state governments, councils, housing developers, geographers and local communities to provide complete 3D interactive models of current and future developments, in order to improve land use, reduce development costs and ensure that the risk and impact of possible disaster is considered and minimised.

There is also a need to develop spatial information systems using a data 'on demand' model. How might this approach affect our current thinking on real-time spatial system integration? Can disparate systems be better utilised to supply spatial data in new configurations as required, for advances in autonomous systems? For example, in a fire disaster situation could autonomous fire-fighting vehicles and drones be effectively deployed minimising human exposure to fire hazards? Recovery services could also be offered to individuals using immediate online identification services, giving them instant access to money and the location of emergency housing. Personal digital communications could also be leveraged by government agencies to supply up-to-date information based on location in order to reassure, warn or influence actions and decision-making during the time of the disaster.

The skills required for jobs in the future, is also of prime concern. If successful and effective spatial data modelling and analysis, system development and integration techniques and systems use, are contingent on advanced science, technology, engineering and maths (STEM) knowledge in the future, how should we be educating students now? For instance, is geospatial data analytics an important and critical future skill for our crisis systems developers and disaster managers? How do we work with organisations across the education sector to ensure that programs are being developed to address spatial knowledge and skills development?

Disparate and unconnected spatial system 'islands' are, therefore, also inhibiting our ability to develop a real-time 'data on demand' approach to the use of spatial information. Ensuring that we educate future crisis system architects and disaster managers to develop skills and approaches to integrated spatial data analytics and system design is a step towards navigating these islands.

Living in a Virtual World

There are ethical considerations that impact a 'virtual individual' who 'inhabits' the 3-D spatial environment. As

[8] WHAT3WORDS https://what3words.com/about/ - last accessed 05/09/2018

we develop technical solutions to better integrate spatial information and systems, how should we effectively integrate the 'virtual self' into these systems, which itself is comprised of islands of information? For example, what changes in law are required to deal with traffic in an era of autonomous vehicles? What legal exposure might a fire service have if they send an autonomous vehicle to fight a fire and the result is less than optimal? What are the ethical issues surrounding the definition and rights of a virtual individual who the government may wish to monitor in times of crisis and disaster? Do we need to develop different legal frameworks to give recognition and legitimacy to the 'virtual self'? What constitutes the rights, trusts, relationships, contracts and communications between virtual individuals and between virtual and physical representations of individuals? How do all of these issues relate and equate to the notions of community and community resilience when a 'community' may be comprised of 'virtual' and physical individuals who are geographically scattered across the globe and therefore subject to different legal jurisdictions?

And there are risks associated with spatial information systems integration. As access to spatial information becomes more readily available — for instance, as spatial information models and the sensors supplying the data become more integrated to assist in the development of community resilience and situational awareness — what sort of risks does this pose to our infrastructure e.g. terrorism and cybercrime? Cohesive spatial data models and shareable locational information are essential for the safe and effective operation of digital technologies, but this situation may in turn present vulnerabilities i.e. an 'all our eggs in one basket' scenario, that will need to be closely monitored and managed.

There's also the issue of defining the demarcation or integration of real and virtual worlds. As more integrated spatial information underpins the development of augmented reality systems that combine real and virtual experiences (such as remote operation of autonomous resources through virtual reality interfaces), how can we meaningfully navigate and relate the virtual and physical worlds and facilitate relationships of individuals, groups and organisations within them?

The functional capabilities of smartphones — combined with the Internet of Things and the range and reach of large information platform providers such as Google — will mean that system users have an unprecedented ability to network, communicate and share information to achieve interconnectedness with inclusiveness. For instance, the NSW Rural Fire Service has developed the 'Fires Near Me'[9] application to supply spatial data to inform the public of imminent danger from bushfire. This application has changed public expectations — providing a better understanding of imminent fire danger. How will community expectations of government and emergency services change as spatial systems become more integrated into our everyday life? What are the implications for emergency services agencies? How can they plan for the future and anticipate the changing attitudes of the general public towards their role during an emergency?

CONCLUSION

Emergency managers are heavy users of 'spatial' data and information e.g. computer aided despatch; GIS; aerial and satellite imagery, photo and multi-spectral; GPS; mapping and modelling systems – however there is no integrated strategy for developing 'best of breed' spatial technologies for disaster and emergency management applications in Australia.

Developments in emergency management are mostly prioritised towards improving response and recovery during recurring emergency events, without giving much attention to less probable events, which may have lower likelihood of occurring but if they do, have higher significant consequences. For example, an earthquake in an Australian capital city, or a cyclone near a heavily populated area in New Zealand would have devastating consequences, as these are unexpected events.

Development of the capability to consider and model extreme event impacts of less likely and less common incidents is mostly excluded from existing academic and commercial research. Similarly emerging technologies, like drones, autonomous land and water vehicles, digital communications, the 'internet of things', real-time traffic information etc. are not seen as a domain specific or as having a unifying common spatial theme for either emergency management professionals or academic researchers.

As well as this, the development of spatial systems that could integrate data and facilitate sharing of information between agencies with community's needs in mind, need to be made a higher priority by government, and have appropriate funding support.

The regulated virtual world of the future, has important implications for human rights and obligations and also for disaster and emergency managers, as people become more at ease communicating in the virtual world with

[9] https://www.rfs.nsw.gov.au/fire-information/fires-near-me

their ever improving smart technologies, and while information on individuals will become generally more available in digital form.

Successfully connecting and integrating 'islands' of spatial information, developing a real-time spatial 'data on demand' approach and careful curation of an individual's 'virtual identity' as it relates to an integrated spatial systems future, are all critical areas requiring further investigation and research commitment to develop effective integrated and cohesive spatial systems for disaster management.

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