Could the Internet of Things Be Used to Enhance Student Nurses' Experiences in a Disaster Simulation?

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Abstract

The Internet of Things (IoT) created opportunities for enhancing human lives. A recent undergraduate nursing disaster simulation experience prompted a thought as to whether IoT technologies could further enhance the educational experience of undergraduate nursing students in future disaster simulations.

Key Terms— Internet of Things; disaster simulation; tracking devices

Introduction

A recent disaster simulation for undergraduate nursing students proved to be a beneficial learning experience. The use of a paper triage tagging system and lack of other technologies however prompted thoughts as to whether the addition of Internet of Things (IoT) technologies could further enhance the experience. The authors previously introduced a structured framework for specifying, designing and implementing healthcare applications in the IoT (Laplante & Laplante, 2015; Laplante, Laplante, & Voas, 2016). The approach employed Rich Pictures and Use Cases to help in identifying stakeholders and elicit requirements. The elaboration approach defined an IoT healthcare system based on settings (acute, long term or community), and systems types (those in which the IoT tracks people, things, or both). This paper will draw from previous work and explore the possible future use of IoT in relation to enhancing a disaster simulation experience for undergraduate nursing students.

Disaster nursing has gained renewed attention ever since the events of the terrorist attacks on September 11, 2001. The care of populations affected by disasters requires an interprofessional team approach and specialized knowledge, including the use of technology. Undergraduate nursing students typically received an introduction to disaster nursing in the population health nursing course, and this knowledge could be further enhanced through the use of simulation, which addresses scenarios of natural disasters (e.g., severe weather events such as hurricanes) and man-made disasters (e.g., terrorism attacks such as bombings). The simulation that will be discussed in this paper focused on the impact stage where the disaster had occurred. Nursing students took on various roles, including that of the nurse who responded to the scene, assessed and triaged victims, tracked victims and disseminated information, and met the immediate needs of the community. That experience prompted thoughts as to ways to further develop the simulation and better engage students in future offerings.

Tracking Apps

There are hundreds of free and for purchase applications (apps) on the market that can be used for tracking victims. Some applications track according to a triage system, which is used to categorize victims based on their medical needs, while others can monitor traffic patterns during a disaster. A recent systematic review by Bachmann, Jamison, Martin, Delgado, & Kman (2015) initially uncovered 683 applications which was narrowed to 219 based on relevance for further review. The results highlighted the most useful applications, including an app from the American Red Cross for natural disasters, The Centers for Disease Control app for first responders, and the National Library of Medicine’s Wireless Information System for Emergency Responders (WISER) app which has been an excellent app for HazMat responders.

The FEMA mobile app (named as such) has many features, including disaster safety tips, an interactive emergency kit list, storable emergency meeting locations, and a map with open shelters. Also reviewed by Bachman and colleagues (2015) was the “911 Toolkit for Emergency Responders” a free app geared mostly towards firefighters, but also useful for paramedics, HazMat teams, and other emergency responders. The researchers of this systematic review provided information on many more apps, including those for the START triage method, social networking to recruit volunteers (“Team Red Cross”), and specific types of disasters including radiologic, blast injuries (e.g. bombings), and natural disasters (hurricanes, fires, earthquakes, etc.). Although this was an extensive systematic review, the researchers stressed how quickly these apps change and new ones are added.

There was some discussion in this review of apps linking, such as what can be done from the FEMA mobile app. Within the FEMA app there are numerous features that can be accessed: alerts from the National Weather Service for up to five locations, disaster reporter which allows for uploading of photos, maps of disaster resources, the ability to apply for disaster assistance (access DisasterAssistance.gov), custom emergency safety information, and safety tips (FEMA, 2017). The user of this app could link to these features by downloading this one single app thus accessing and sharing a large amount of information. A future consideration remains as to how to link multiple apps for even greater sharing of information and better disaster management. Clearly this is a field of rapid growth and change, and no one review could be considered an exhaustive list, however Bachmann and colleagues (2015) provided a review of the current most useful apps.

Previous and Related IoT Works

Since 2010 there has been a great deal of research and publication on IoT in healthcare in general and in nursing in particular, though significantly less on the use of IoT in emergency response. Most of the general research on IoT in healthcare has related to smart hospitals, remote monitoring, telemedicine and assisted living.

On the use of IoT in the emergency response domain, there have been even less works. Yang et al. (2013) discussed the use of IoT in the emergency management community. The authors proposed various uses for IoT technology for emergency responders, but did not mention the role of the nurse anywhere. Similarly, Liu, Wang, Wan, Xiong, and Zeng (2013) provided a survey of network communications in disaster networks using wearable devices, highlighting some of the challenges in gaining acceptance for such implementation by the public. Interestingly they mention nurses twice but only as examples of “authorized medical personnel.”

A comprehensive survey of general research on IoT can be found in Islam et al. (2015) which explored advances in IoT-based health care technologies and reviewed the state-of-the-art network architectures/platforms, applications, and industrial trends in IoT-based health care solutions.

With respect to the application of IoT in nursing Mieronkoski, et al. (2017) conducted a comprehensive survey of eight healthcare/medical databases on nursing and IoT with the intent to introduce IoT to the nursing audience. After retrieving more than 5000 papers that matched the keyword search, 63 relevant publications were reviewed. The researchers concluded that “nursing could benefit from a deeper understanding of concepts developed and used by other disciplines” (p. 79) and that the concept of IoT has not made its way into nursing research (Mieronkoski et al., 2017).

The aforementioned works were general in nature but there has been pioneering work related to using IoT technology to help manage disaster scenarios. For example, Lorincz et al. (2004) developed an RF-based technology called MoteTrack which was used to locate responders and patients within buildings during a disaster. A system, called Code Blue which dynamically integrated sensors and other wireless devices in a disaster response setting was also developed by Lorincz and colleagues at Harvard University.

Gao et al. (2006) developed a description of a real-time patient monitoring application that “integrates vital signs sensors, location sensors, ad-hoc networking, electronic patient records, and web portal technology to allow remote monitoring of patient status” to facilitate communication at disaster scenes (p. 66). Importantly it was highlighted that first responders often relied on radio frequencies which could become overcrowded, risking the loss of critical patient information. Based on this issue and others, Gao and colleagues developed technology-based solutions, including electronic triage tags called VitalMote, which built on the CodeBlue wireless sensor network. A test of this technology was completed in collaboration with Johns Hopkins University (2007), which engaged first responders in a disaster simulation. This test highlighted the benefits of the technology over the traditional paper triage tags, and offered encouragement to continue this work. A search for more current applications of VitalMote was unsuccessful, with the related website last being updated in 2007. Still, this work offered encouragement to use similar technologies in the education of nursing students participating in disaster simulations.

Aragüés et al (2011) surveyed existing wired and wireless technologies for use in healthcare systems, largely to guide uniform architectural design and interoperability. These works can be used to guide the implementation of any real IoT enabled disaster management system. Chen, Liu, Wang, Dou, Chen, and Li (2013) designed a study to test an early warning system in natural disasters using wireless sensor network (WSN) technology. Emergency response was one element considered in this study, with the researchers exploring issues of data transmission. Much of this study focused on the design, however a secondary finding focused on the application of WSN beyond tracking of patients, demonstrating another current area of development.

Literature specific to IoT tracking and disaster simulation for undergraduate nursing students could not be located. Most of the literature that explored IoT tracking was written from a technology exploratory focus, leaving the door open for nursing education and others to study the implementation of IoT in disaster simulations. In agreement with Mieronkoski et al. (2017) IoT has been “vaguely adopted” in nursing and nursing science could benefit from “involvement in engineering research in the area of health" (p. 78). This paper is presented from an interprofessional perspective, joining the disciplines of nursing and systems engineering.

The Disaster Simulation

A disaster simulation for senior undergraduate nursing students was recently implemented as part of a course requirement for a population health nursing course. The goal was to give students experience in disaster response and management, with students taking on various roles. The roles included: nurse, family member, victim, bystander, and observer.

The simulation took place outdoors on a metropolitan university campus, during a peak time of day. University members were alerted prior to the simulation as to what was happening, to avoid panic and confusion from bystanders. The simulation began around 9:00 am, and the campus was busy as students, faculty, and staff moved around to classes and other events. The scenario unfolded over the course of four hours, beginning with preparation of "victims", an overview of triage for students, and assignment of additional roles. Faculty were observers throughout the simulation.

The Disaster Scenario

There were approximately 50 people on the pedestrian walkways adjacent to the University's School of Nursing. Suddenly there was a loud screeching sound coming towards them. A large dump truck had gone out of control, and was headed directly into pedestrian traffic. The truck was carrying debris of wooden pallets and loose bricks from a nearby construction site.

The scene quickly became chaotic as numerous people were struck by the truck, and others were hit by debris that had been launched from the truck upon impact. The driver of the truck was disoriented and was grabbing his chest, yelling that he was in pain. His co-worker passenger was ejected from the truck upon impact, and was lying motionless on the ground near the truck. Several other University students, faculty, and staff were also struck by debris, and others appeared to be in shock as to what they had seen.

A Generic Structured Use Case Model

The disaster simulation described unfolded quickly, with nursing students assigned to take on numerous roles. For a first offering the simulation proceeded smoothly, however as with any experience there is always room for improvement. To better prepare the students for future experiences and help identify the set of people who would be involved in the disaster management system (i.e. the stakeholders) and to define the system boundary, a high-level model for the system could be created. The model should show direct and indirect interactions with other entities. Such a high-level systems model would be more useful when domain terminology was accurately defined, that required robust interaction between the systems engineers and the relevant stakeholders (e.g. first responders, nurses and administrators). A Rich Picture diagram could be useful (Laplante, Laplante, & Voas, 2016) to show the most relevant stakeholders for the disaster simulation, along with their representative concerns (See Fig. 1).

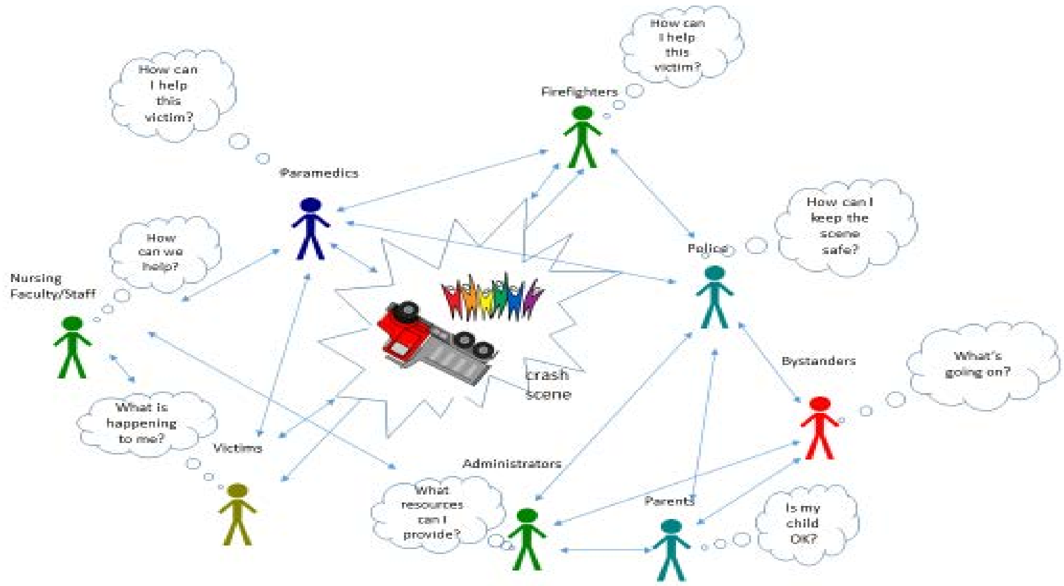

Fig. 1: Rich Picture for Disaster Scenario

The value of the Rich Picture would be to ensure that no important stakeholders were excluded from the discussions during system design and implementation, and to maintain correct interaction with entities outside the system (Laplante, Laplante, & Voas, 2016). A set of Use Cases formed the basis for the behavioral specification of the system, and were then developed from the fully elaborated Rich Picture.

A Use Case is an example of how a system is used under different operational profiles. Use Cases have often been depicted via Use Case Diagrams, which employ stick figure actors and bubbles describing the particular actions involving those actors as indicted by directed arrows. A Use Case for the disaster situation in which a nurse triaged a victim (i.e. decides where the victim should be sent) and then applied a colored barcode band on the victim and scanned the band into the system is depicted in Figure 2. The nurse could be the first on the scene to begin triaging, or this could be the first responders; in Figure 2 the role of the nurse is highlighted because of the focus on the undergraduate disaster simulation experience.

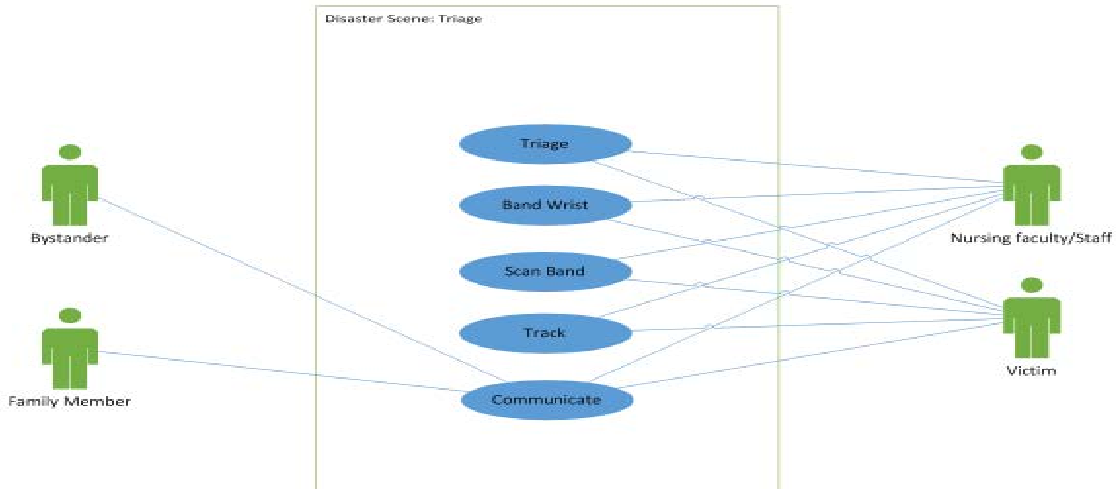

Fig. 2. A Particular Use Case Diagram for Disaster Scenario

The system now allowed the nurse to track the location of the victim (assuming that the victim's band is swiped at strategic points during their movement) and communicated that location to family members and other staff. Radio frequency identification (RFID) is technology that uses radio waves to automatically identify people or objects and has been widely used in IoT. In a disaster situation RFID technology would allow for more precise geolocation of victims, assuming that RFID readers were located at strategic locations. There would be concerns however about electromagnetic interference from the RFID technology and potential destruction of the RFID device and injury to the patient when imaging scans were taken in the hospital. A simple wristband with bar code system could be a safer tracking solution for these reasons.

Bystanders were shown in Figure 2 because they would likely also communicate with family and others about the location of a victim (if known). This iterative process of elaborating Use Cases will involve one or more stakeholders from each group and uses shown in the Rich

Picture of Fig. 1. This process would continue until all perspectives are heard and interactions with other entities identified.

Describing the IoT System

Real problems could occur when designing complex systems that bridge multiple disciplines with different prevailing standards (e.g. fire protection, electro-magnetic compatibility, medical device safety). Such a situation is termed “standards confusion” by engineers (Voas & Laplante, 2007). Therefore, from an interprofessional perspective, there would be value for nurses and other health care providers to collaborate with systems engineering professionals in the design and implementation of these systems. The US National Institute of Standards and Technology (NIST) DRAFT Special Publication provided a template for IoT implementations (Voas, 2016) that can be applied to the disaster simulation experience, providing a common language for IoT healthcare systems stakeholders from all disciplines. The NIST SP 800-183 template included the following:

1. Sensor: an electronic utility that digitally measures physical properties and outputs raw data. For example, in a disaster response scenario sensors could be simple barcode tags to identify patients, or more sophisticated devices such as those to measure blood pressure, pulse-oximetry, or location via GPS system.

2. Aggregator: a software implementation based on mathematical function(s) that transforms/consolidates groups of raw data into *intermediate* data for transmission. In the disaster response, the barcode reading device would be the aggregator if only passive barcode sensors were being used. However, if victims were connected to more

sophisticated sensors, then another type of reading device would be needed to collect this information from victims.

3. Communication channel: a medium by which the data is communicated between sensors, aggregators, communication channels, decision triggers, or *e*Utility. In a disaster response setting, for example, there could be a Wi-Fi network of sensors/clusters/aggregator or a barcode beacon to a reader device.

4. *e*Utility (external utility): a software or hardware product or service, providing computing power that aggregators will likely need in the IoT. In the disaster response utility there could be software running on a tablet computer or command center computer that would accept the flow data from the aggregators and help decision makers. Other eUtilities could be accessed from remote computing sites, such as from FEMA.

5. Decision trigger: creates the final result(s) needed to satisfy the purpose, specification, and requirements of a specific IoT (Laplante, Voas, & Laplante, 2016). In a disaster response scenario the aggregator function could simply determine the patient location, or could make decisions about the patient's status based on vital signs.

The examples given above are summarized for future use in a disaster simulation and are presented in Table I.

Table I: Partial Model Realization

Model Factor	**Application to Simulation**
1. Sensor	Wi-Fi enabled bar code scanner; blood pressure sensor; pulse-ox sensor; GPS locator

2. Aggregator	Barcode reader; blood pressure, pulse-ox sensor reading device; GPS reader.
3. Communication channel	Wi-Fi___33 network of sensors/clusters/aggregator, barcode beacon to reader.
4. *e*Utility	Onsite – tablet based software or software on board the command center computer; Remote – computing resources from remote sources, such as FEMA.
5. Decision trigger	Geolocate victim; indicate patient in distress.

There are other aspects of describing an IoT system found in SP 800-183 which played a major role in enhancing the trustworthy interoperability built from any IoT components, services and commercial products (Laplante, Voas, & Laplante, 2016). The basic IoT elements described in NIST publication 800-183 can be used to reconcile (i.e. “harmonize”) conflicting standards, providing an application of this advanced technology to the undergraduate nursing disaster simulation experience.

Faculty Reflection on the Experience

For a first time experience, the simulation progressed well. Faculty observed that not all students actively engaged, and will need to consider this in assignment of roles in the future. This disaster scenario allowed for multiple roles and varying degrees of injuries. Faculty experienced in moulage techniques had prepared “victims” with bleeding wounds and injured limbs. The victims were set in place outdoors, and then the remainder of the class came on the scene, in their assigned roles, as the simulation started. The students were aware that a disaster had occurred but were not told in advance of the types of injuries to expect. As the simulation unfolded it was interesting to watch the “nurses” attempt to triage “victims”. Some victims had obvious wounds while others did not, requiring more advanced communication techniques. Many nurses were drawn to the most critical victims such as the truck passenger and avoided victims that did not have obvious wounds.

Local first responders participated in this simulation, so once they arrived the nurses worked with them. As is the case in real life, the first responders assumed command of the situation, and the students were informed that this would be the case, making them ready to work together. Paper triage tags were used in this simulation because that is what the first responders used in real life. Paper tags were observed lying on the ground at times, away from “victims” therefore questioning whether the triage was accurate or complete.

Student responses to the simulation experience were positive; anecdotally students expressed gratitude in the debrief session as they believed this experience will be of value in future practice. Ideas to improve the simulation were offered during the debrief session, such as a longer triage introduction before beginning, and addition of counselor roles. The “bystanders” felt anxious at times because they observed “nurses” were not doing what they would have if they were the “nurse”, and “nurses” found it hard to decide at times on a triage tag. Several “nurses” acknowledged that they left the tags after the initial assessment, and did not pay attention to assuring the tag moved with the “victim”.

Once “victims” were triaged they were transferred into ambulances on the scene, and driven away to another location on campus, simulating that the patient was transported to the hospital. Given the number of people involved in this simulation it was often hard to remember who had been transported; if IoT tracking had been used could there have been better oversight? If an app such as the FEMA app was used by all participants, could the app links provide better data collection and sharing of information? These were thoughts that occurred while listening to the debrief session.

Future Implications

As mentioned previously the paper triage tags were left on the ground in many instances, which was not an efficient use of resources, and a potential safety issue for patients. IoT tracking using barcode scanning could be added to a future disaster simulation to address some of these issues. This equipment would include colored barcoded ID tags for triage categories, WiFi enabled readers, and an appropriate information management system that would make it possible to identify victims at the disaster scene, those leaving the scene on their own (walking wounded), or those being taken away in ambulances.

Ultimately, the goal would be faster identification or location of the victims and more effective triage of patients and allocation of resources (Laplante, Voas, & Laplante, 2016). The addition of IoT technologies, such as disaster apps, could further engage students in the simulation, as most are tech savvy already using some form of smart device on a daily basis. Students will be exposed to more IoT technologies as they begin professional practice, therefore an introduction at the undergraduate level would be beneficial. IoT tracking devices already exist to monitor traffic in disaster situations, along with the numerous management and response apps discussed at the beginning of this paper. The use of these apps in a future simulation in collaboration with first responders could provide a means for more efficient tracking and enhanced communication for all parties.

The students in the reported simulation played several of the roles depicted earlier in the Rich Picture. Possible future scenarios could include: a mass shooting on campus, a multi-vehicle crash, airplane crash on campus and others. Upon completion of the simulation faculty would continue to debrief students as is the norm in simulation experiences. Part of the debrief could include questions as to student experience using IoT in the simulation, including ideas for future use in disaster nursing. Research could focus on comparison of tracking outcomes with and without IoT technologies. Expected outcomes related to IoT would be a better understanding of the issues surrounding victim tagging, tracking, potential for improvement of victim/patient outcomes, communication, and responder/victim dynamics. Students would also experience an interprofessional experience as they were introduced to IoT technologies and their use in health care applications.

Conclusions

We proposed a basic use of IoT for tracking patients using barcodes, as this could be the first time that undergraduate nursing students would be exposed to IoT technology in a nursing experience. By having them be exposed to these technologies, even simple ones, and having a real life experience, it would be beneficial as they will work with more complex technologies later on. As soon to be registered nurses, these senior level students enter a healthcare practice that is rich in technology therefore this experience gives them a glimpse into their future as healthcare practitioners.

The benefits of an IoT disaster management system will require effective and reliable interoperability of all of the IoT systems involved, including the victims' personal trackable devices, such as phones or IoT enabled wearables. Other devices in range such as vehicles, businesses, and smart buildings could also interact with the medical and emergency equipment.

These devices could be helpful (e.g. to rapidly obtain a victim's medical history, or problematic (e.g. by triggering a security response that could block signals) (Laplante, Voas, & Laplante, 2016). It is important to collaborate with first responders and other professionals in this simulation to learn what is already being used and assure there is no interference of different apps or technologies. Experts in IoT technology must also be consulted so that realistic application and integration can take place. The many apps that already exist would be a place to begin, adding to that IoT tracking, future disaster simulations could provide valuable information for improving the care of victims, and support for families and the health care system as a whole.

Tracking of supplies and equipment in a disaster situation could also be of significant benefit, especially if these were linked to victim tracking. In this case, RFID tags or active signal technologies could be employed, further allowing for more precise location of the victims. The simulation described here could easily be expanded to include active technologies, tracking things, exploiting existing technologies such as cell phones and other wearables held by victims, bystanders and responders.

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Legend

Figure 1: Rich Picture for Disaster Scenario

Figure 2: A Particular Use Case Diagram for Disaster Scenario

Table I: Partial Model Realization