Chapter 9
The Internet of Things and Opportunities for Pervasive Safety Monitored Health Environments

Vaughan Michell
University of Reading, UK

ABSTRACT

This chapter discusses the opportunities for new ubiquitous computing technologies, with concentration on the Internet of Things (IoT), to improve patient safety and quality. The authors focus on elective or planned surgical interventions, although the technology is applicable to primary and trauma care. The chapter is divided into three main sections with section 1 covering medical error issues and mechanisms, section 2 introducing Internet of Things, and section 3 discussing how IoT capabilities may address and reduce medical errors. The authors explore the existing theory of errors expounded by Reason (Reason, 2000, 1998; Leape, 1994) to identify perception-, decision-, and knowledge-based medical errors and related processes, environments, and cultural drivers causing error. The authors then introduce the technology of the Internet of Things and identify a range of capabilities from sensing, tracking, control, cooperative, and semantic reasoning. They then show how these new capabilities might be applied to reduce the errors expounded by the discussed error theories. They identify that: IoT enables augmentation of objects, which provides a massive increase in information transfer, thus improving clinician perception and support for decision-making and problem solving; IoT provides a host of additional observers and opportunities, which can shift the focus of overworked clinicians from constant monitoring to undertaking complex actions, such as decision making and care; IoT networks of sensors and actuators, through the addition of semantic and contextual rules, support decision making and facilitate automated monitoring and control of pervasive safety-monitored health environments, thus reducing clinician workload.

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1. INTRODUCTION

1.1 Patient Safety

The safety of patients and the avoidance of iatrogenic or unintentional harm to patients has grown in importance as medical procedures and technology complexity accentuates traditional human factor failings (Nolan, 2000; Lin *et al*, 2001). These and other publications such as Hoff et al (Hoff et al, 2004) have highlighted the risk of unintended impacts of mistakes and medical errors. Whilst most studies have focused on the cause of error and human factors (Caryon et al, 2010; Patterson *et al*, 2002; Benning et al, 2011; Holden, 2009), less work has been undertaken on technology to reduce error (Ball et al, 2003). One of the key problems in medical situations is that the human agent is often both the executor and monitor of actions. In many medical interventions we still rely on 'the human in the loop' and depend alone on the reliability of their perception, cognition and decision-making. The fallibility of an often-overworked brain, trying to make sense of complexity (Nolan, 2000), or the distracted social animal, lacking in independent and reliable action information and facts, is often the cause of many of the errors. Whilst information systems, decision support systems, robots and medical information have reduced the errors in mundane tasks (Ball et al, 2003), their sensors and ability to offer corroborating or alternative facts has been limited to points and focused solutions until now. With the introduction of the Internet of Things, the promise of small, cheap and ubiquitous sensors allied to actuators and smart logic offers opportunities to provide appropriate facts, and historical information, to support independent decision making and care-control at the point of need. This capability, as an augmentation of the human agent, has the potential to improve patient safety despite the increased cost and scarcity of clinical skills that health institutions are now facing.

1.2 Medical Processes, Activities and Actions

This section defines basic terms for medical processes, activities and actions that are used widely throughout the chapter. Humans can be defined as actors in an environment. A medical actor has a set of formal goals and actions to achieve as part of their clinical work activities. Any medical process can therefore be depicted as being a sequence of work activities to achieve a goal with each work activity involving a number of actions or movements by one or more actors to support the activity (e.g. selecting an anaesthetic, or injecting a patient as part of the anaesthetic process). Actors may be human (e.g. a scrub nurse) or intelligent machines. A process (and constituent activities and actions) involves the transformation of a set of resources to achieve a goal (see Figure 1).

We differentiate between active resources that can transform the environment (which is a resource that drives the transformation) and passive resources (which are themselves transformed) (Michell, 2011). Resources, apart from human agents, can be categorised into: machines that are non-consumable (e.g. tools that leverage human resources, machines that can act independently (e.g. a pump), and general equipment and consumable resources (e.g. drugs, swabs etc.) that are converted as a part of the action. Each activity involves the interaction of specific resources in a specific pattern to transform those resources from a starting state s1 to a new state s2. State s2 has a set of quality measures on the properties of the transformed resources. Outside the organised resources there is an environment comprising structured and unstructured objects (e.g. chairs, doors etc.), which may or may not interact in the process.