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Real Time Location Systems in the Hospital Environment

The idea of real-time location has been in the popular culture for a long time. The concept of knowing where someone or something is in real time has always been enticing. It has been a recurring theme in science fiction (e.g. Star Trek) and fantasy (e.g. Harry Potter) and has long been a technology on the verge of reality. It has been in the popular mind so long that this has actually created one of the barriers to its implementation; specifically, this technology in evolution has trouble meeting the expectations set up by these ideals.

What are Real-Time Location Systems (RTLS?)

Real-time location systems are systems of technologies designed to let the end-user answer the questions what, where and when– what is it you are looking for, where is it and importantly when was it last at that location (as close to real-time as possible). This is in contrast to conventional inventory systems, which tend to focus more on what and where with relatively little focus on temporal resolution.

Real-time location systems can be considered, metaphorically, as indoor “GPS”. However, satellite based GPS do not work indoors. This is due to a variety reasons, predominantly, because of the buildings themselves – the stone, concrete, wiring and plumbing, shield the interior from satellite signals from the outside. Real time location systems have been developed using a variety of signal modalities: radio-frequency (including WiFi, UWB, etc.), infrared, and ultrasound. These categories breakdown further into functional modalities: active, passive or hybrid. Each form has its strengths and weaknesses. Passive Radio-frequency identification (RFID) is perhaps the most widespread form of RTLS. This is in part due to its use-legacy and familiarity in inventory management. Passive RFID systems are used everywhere from inventory control in shops and warehouses to highway toll booths and monitoring where people are while running marathons.

Passive RFID systems consist of an antenna which broadcasts a radio signal, a tag with an integrated circuit with its own antenna which receives the Radio-frequency (RF) signal which in turn reflects back a signal with tag specific information to be read by a third component, a fixed receiver. In Active RFID systems the tags themselves are powered transponders whose RF beacon is read by passive antenna/receivers. The RF based systems use a variety of algorithms to locate where the tag is that are usually based on a form of triangulation, tri- or multi-lateration. Infrared systems work similarly, though at a different end of the electromagnetic spectrum. Ultrasound devices tend to act as active systems, i.e. the US tag is powered and emits the signal. Loosely, RF signals have the advantage and disadvantage of not being easily obstructed. This allows the tag to be seen continually by the system but can lead to issues such as ambiguity as to "what side of the wall am I on". IR and US have the opposite problem. There is less ambiguity as to which side of the wall you are on but more frequent dropped signals from the system due to obstructions. Current systems are evolving towards multimodal hybrids - using each mode’s strengths to compensate for the other’s weakness.

Its Role to Date in Healthcare

RTLS made their first inroads into the healthcare environment as a form of more sophisticated in-ventory management for expensive mobile assets such as infusion pumps, ECG machines, and beds. What was found was that with RTLS, nurses and other staff spent 10-30% less time searching for equipment. This in turn led to reduced local hoarding of these assets, e.g. hiding equipment in closets or above ceiling tiles, etc. If you need an infusion pump for a sick patient you don’t want to hunt for it, hence local caching. Hospitals with these systems reduced procurement and inventory of these items by 20-30%. This had a significant impact on reducing wasted man-hours looking for items as well as reducing rental and inventory costs to hospitals. The systems have also allowed for improved maintenance schedules as well as reducing the amount of lost or stolen inventory. The same systems role in standard inventory improved just-in-time inventory management, reduced lost and stolen supplies, reduced the rates of non-charged consumables and reduced search time.

In this case RTLS act as substitutes for traditional inventory management systems with some added functionality. However, the temporal and spatial demands for this use are relatively low. For this use case RTLS only need a temporal resolution of approximately half to one day and a spatial resolution of a room to ward section. Recently, RTLS has been moving into the role of operation measurement, operational analysis and intervention. Here the temporal and spatial demands are significantly higher - a spatial/temporal resolution on the order of 1-2 m2/10 seconds. This is necessary, in order to track the movement of patients and staff who move rapidly, often come into contact briefly and often unpredictably in close and constrained spaces.

Clinical application or RTLS is still at a relatively early stage but solid work has been done already in the area of contact tracing of infectious outbreaks in hospitals to bed management in emergency rooms. In our own work at Massachusetts General Hospital we have be have begun mapping how these tightly coupled clinical systems behave, what is the effect of providing information feedback on wait time, face time and flowtime to clinicians, linking process measures derived from RTLS such as face-time to clinical and laboratory databases to explore the effect of time on resource utilisation and outcome and using RTLS to help measure hand hygiene compliance.

Implementing RTLS

Implementing these systems for clinical and managerial purposes faces several challenges. On the technical side, these systems often are not as good as our cultural expectations (see above), they may demand and often have limitations with regard to temporal/spatial granularity, latency and signal to noise. The information generated can be complex to analyse, interpret and present. These systems have their own inventory concerns surrounding tag supply, cost and loss. In addition, there are clinical concerns, such as, if the tags are reusable how do we sterilise them? Cultural issues are often related to the specific clinical unit cultures in which you wish to implement the technology, form factors – is a tag for the patient the same as for a clinician, and privacy. Big brother is often raised even though the same and much more information is broadcast regularly by peoples' mobile phones. It is important to remember any technology change is culture change.

The cost of installation depends on a variety of factors ranging from the extent and quality of existing IT infrastructure to the density of the floor plan and the age and construction of the buildings to the cost of tags, receivers and software. As a frame of reference, expect installation on a clinical unit to cost on the same order of magnitude as upgrading all of its computers.

The business model for RTLS in healthcare is essentially one of cost-savings, improved delivery of care and reduced errors rather than revenue generation. The return on investment for RTLS for mobile inventory management seems to be clear in this regard. The argument for RTLS in operations improvement is similar though the evidence is only now starting to come in, efficiencies gained and errors avoided should readily provide a positive ROI.

RTLS, Hospitals and the Future

In addition to the above-mentioned applications, hospitals have a great deal to gain from RTLS systems. One of the challenges facing general hospitals is how to deliver care efficiently. Unlike manufacturing facilities where one can physically line up all the resources needed to assemble a product. General hospitals are complex physical spaces where the needed resources can be located almost anywhere. RTLS in principle provides the mechanism to set up virtual pathways to deliver care. If guidelines are about delivering the right therapy or test to the right person at the right time, RTLS is the logical the facilitating technology. If privacy rules such as HIPAA, require only those providers in the patients clinical path have access to the patient's information, RTLS tags can provide the key. Finally, RTLS in one form or another will likely become the backbone of future pervasive sensing environments in hospitals linking EHRs, POC testing, and other hospital resources to the patient and provider.

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