Investigating aneasthetic activity detection via ultrawideband RFID

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***Abstract*— Measuring activity in the operating theatre is a difficult but important task. Using ultra wideband active RFID tags (UWB) we were able to track and Anesthetist and anesthetic technician during a simulated operation. A number of parameters were calculated including gaze direction, distance travelled and separation were calculated. Some characteristic movements were identified, including head and torso rotation. Ultra wideband RFID may form part of a suite of sensors that can begin to identify activity during operations.**

Keywords—Anesthesia, Activity Analysis; RFID

Radio Frequency Identification (RFID), is becoming widely adopted in the medical domain for tracking objects and people, in order to increase efficiency and safety [1]. There has been considerable interest in the use of RFID in the operating theatre, as part of a pervasive computer system[2] . Previous work has also identified an attempt to use Autoidentification as part of a project Towards Automated Detection of Anesthetic Activity [3].

Anesthetics safety is a continuing area of concern, and anesthetic workload is a particular area for research and improvement [4]. The concern is that clinical errors are more likely to occur when clinical workload is high, and that anesthetic spaces must be designed so that the anesthetist and anesthetic technician and other staff can work efficiently and calmly even during high-workload events.

Anesthesia is a complex activity, where procedures, including the giving of potentially harmful drugs have to be precisely choreographed to fit in with the needs of the patient, and in response to the surgical procedure being performed. Complex monitoring systems are used to examine the state of the patient, activity levels vary from the languid to the intense, and communication between health professionals needs to occur constantly. As with many other fields of human activity, errors tend to occur as part of a chain of events, rather than a single point error. The modern operating theatre is as complex as the flight deck of an airliner, but with more people and one of them in danger of death.

If an automated error detection system is to be feasible it must not interfere with normal operations, have a high specificity and sensitivity and be acceptable to users. There already exist a number of frameworks for of identifying error in human activity [5, 6].

The process of task-analysis and workload measurement includes reviews of the literature, observation and discussion with subject matter experts[7]. However observation in particular is difficult because of the nature of overlapping tasks and simple physical access. Video can be used, but this is complex and time-consuming, often requiring the involvement of expert observers to identify errors.[8], In addition, prospective identification of potential errors may well require automatic identification A "bottom –up" approach would seek to identify physical actions and record data about them and then see the effect of interventions. This project used UWB RFID tags in order to explore potential uses for physical. RFID based activity detection does have disadvantages in comparison to other sensor technologies. The data it produces tends to be both noisy and incomplete [9], so data cleaning may be more difficult. As with any device that emits radiofrequency energy there is some risk of interference with electrical equipment and there is some evidence that RFID can create electromagnetic interference with other electronic medical devices common in the OR in certain circumstances [10], however this is not commonly reported and our research has shown that such interference would not be an issue in our intended deployment strategy. [11].

As part of a pilot trial of a new device for use in the operating theatre, a series of simulated operations took place in a hi-fidelity simulation suite. The device is a radically different integrated anesthesia workstation, described at www.iaconsole.com.

In this study the objectives were to identify relevant activity, by the anesthetist (a medical doctor) and the anesthetic technician. The technician is a trained staff member who assists the anesthetist, particularly during times of high workload [12].

I. METHODS

A. Setting

Hi fidelity simulation suites [13] are set up exactly like clinical operating theatres, but are used for training of staff. The patient is replaced by an instrumented mannequin which can simulate and the room is provided with video and sound recording facilities Three Simulated surgical operations took place, with at least five personnel in the room, a Surgeon, Scrub nurse, Circulating nurse and anesthetic technician. Only the Anesthetist and the anesthetic technician wore tags. As part of the simulation there were some “emergencies” generated in order to increase workload and stress.

B. UWB setup

Data was collected using an Ubisense UWB system with 10 tags, and 10000 data points were recorded over 15 minutes giving approximately one read of each tag every second... However, in some cases, reads were missed, because tags were not able to be detected due to positional shielding.

Ubisense tags were attached at five locations on the Anesthetist and Anesthetic technician’s clothing (Figure 1)

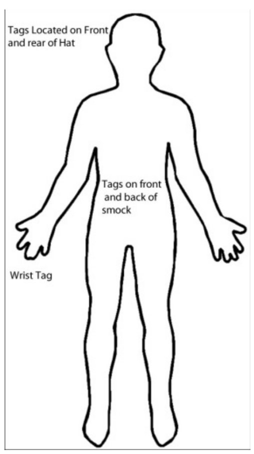

FIGURE 1 :TAG LOCATIONS

II. RESULTS

The majority of movement data was interpreted in the x-y plane only, for simplicity. After recording the data a number of analysis approaches were used in order to answer the following questions: how far did each participant travel during the simulated operation, how much time was spent observing the patient’s head area, what characteristic movements could be observed, how far were the Technician and Anesthetist apart from each other and where did the anesthetist spend most of his or her time?

Because there was no synchronized video the interpretation of the RFID information is not able to be confirmed by other input sources. However, the data analysis is designed to demonstrate the potential of this approach.

A. Distance travelled

This question was asked because this study was part of a larger one that was looking at rearrangement of the operating theatre to reduce effort and error. Table 1 shows the results for all three operations.

TABLE 1 : DISTANCE TRAVELLED OVER ALL THREE OPERATIONS

Tag location	Distance travelled (cm)
Anesthetist head front	700,208
Anesthetist head back	650,895
Anesthetist body front	504,016
Anesthetist body back	228,476
Tech head front	445,055
Tech head back	312,176
Tech body front	580,251
Tech body back	137,983
Anesthetist wrist	56,832
Tech wrist	374,739

This apparent discrepancy between these figures can be explained if we note that rotational movements will increase the distance travelled by a particular tag. Because the tags are never sampled at exactly the same time, building a model of the whole body is problematic. However, the rotational aspect is supported by some observations (Table 2) of the anesthetist tags during one simulated operation using around 1000 data points. In this case the velocity of each tag, given by the distance travelled in the x-y plane, divided by the number of time slices between each sample is used. This approach is self-correcting in terms of missed detections.

TABLE 2 : VELOCITY OF TAGS IN CM/TIMESTAMP

	Head	Body
Anesthetist		
Front Tag	0.180	0.011
Back Tag	0.006	0.017
Technician		
Front Tag	0.006	0.011
Back Tag	0.008	0.012

For the technician data, the figures are roughly comparable, implying that a technician does not perform a great deal of rotational movement during a simulated operation. However the anesthetist does. This data implies two things, the front of the head moves a great deal more quickly than the back of the head, and that the back of the body, moves more quickly than the front. This appears a reasonable description of movements where the anesthetist rotates his or her body around a central point in front of him or her– for example moving around a drug trolley or intubating a patient, or keeping the body still and scanning his or her head around

B. Gaze direction

Much of the anesthetist’s role involves observing the patient, or at least being aware of any changes to the patient’s status, by direct obsevation. This is more likely to be possible if the patient’s head is within the potential viewing area.

Because tags were located on both the back and front of the hats, a calculation could be made of a vector $\overline{a}$, at an angle to the room coordinates α. If the back of the head tag is represented by (x_b , y_b) and the front of the head tag is represented by (x_f , y_f) then

$$\alpha = ATAN\frac{(y_f - y_b)}{(x_f - x_b)} \qquad (1)$$

Clearly the magnitude of the vector ($|a|$) should be constant, as the head size should not change However in practice because of movement between sampling, a plot of these vectors (Figure 2) does show considerable variation in magnitude. Overall we decided that in most cases, the direction of view would not vary enormously, if the subject was moving, assuming they were looking where he or she was going.

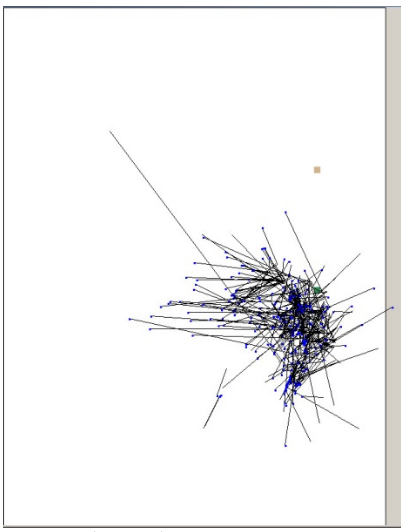

Figure 2: Display of a set of vectors during a simulated operation

In order to calculate the gaze direction, the angle between two vectors was calculated. For simplicity, this operation was only performed in two dimensions.

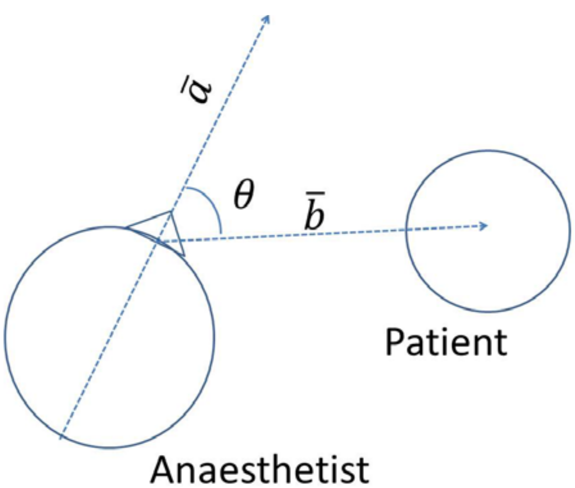

Figure 3 : Gaze calculation

$\overline{a}$ is the vector created by drawing a line between the location of the back of head tag and the front of head tag. $\overline{b}$ is the vector created by drawing a line from the front tag to the location of the center of the “patients” head. The angle between the two is given as θ in equation 1.

$$Cos\ \theta = \frac{|a.b|}{||a||b||} \qquad (1)$$

The obvious drawback to this approach is that people are able to move their eyes around, independently of head movement. The human effective field of view is reduced dramatically when there is a high cognitive load [14]. As a very rough calculation, we assumed that the head of the patient would be within the field of view of the Anesthetist if θ was less than 1 Radian. For this operation this was calculated as being around 57% of the time.

C. Separation between technician and aneasthetist

The separation between the Anesthetist and anesthetic technical was calculated between the locations of the back tags for each person at timestamps that were within 10timestamps (approximately 1 second) of each other. The average distance was 173 cm with a standard deviation of +/-86.3 cm. The variation in distance is shown in Figure 4.

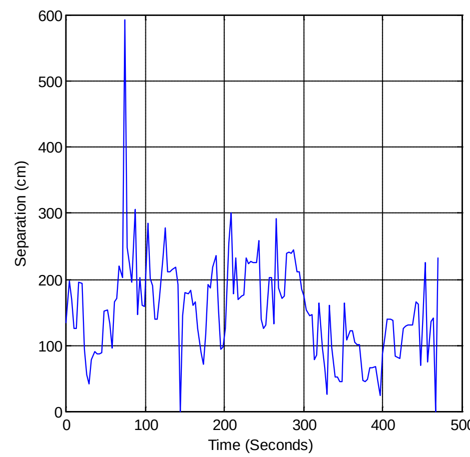

Figure 4: Plot of distance between anesthetist and technician back tags

D. Characteristic movements

All these measurements took place on only the first operation’s dataset, to reduce data cleaning issues, and because this simulated operation was more conventional than the others with fewer complex emergencies introduced.

1) Body Rotation

A number of characteristic movements can in theory be deduced by the tags used in this experiment. Velocity calculations were used, which are the distance travelled divided by the number of timestamps, this is roughly equal to cm/0.01 seconds, but this absolute value is not used in the calculation. Figure 5 shows some of the data used where body rotation is being measured. In this case the velocity of the front and back tag are measured. If the person is moving hi or her torso with a center of rotation in front of the person, as for example one would if sitting on a swivel chair, the velocity of the front tag is greater than that of the back tag. The reverse situation implies that the person is moving around a center of rotation in front of them, for example when he or she may be maneuvering around an object to examine it from all aspects.

Figure 6 shows the result of plotting the difference in velocity between the front and the back tags of the Anesthetist during the whole operation. A positive value means the back tag is moving more quickly than the front tag. The large spikes may represent periods where the Anesthetist is rotating his or her torso, in most cases the centre of rotation is in front of the body This fits with observations where an Anesthetist is likely to move around a point of interest, for example during intubation or moving around a drug preparation table. Overall the "front" tag average velocity was around 40% of the back tag velocity.

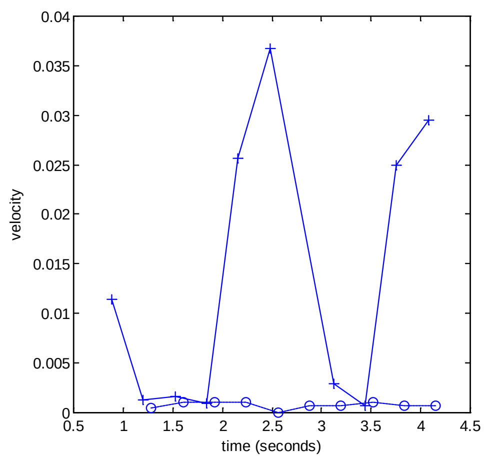

Figure 5 :Rotation of body, where o is front and + is back tag

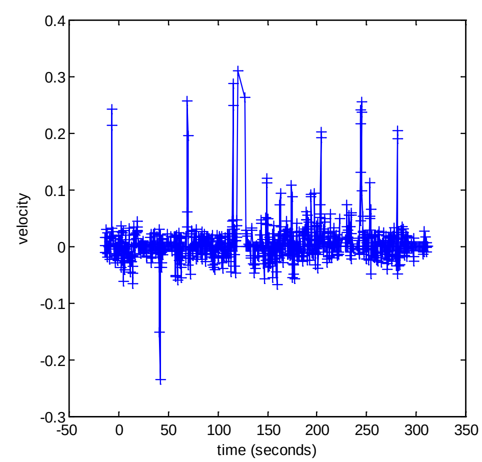

Figure 6 :Body rotation, positive values mean the back tag has higher velocity than the rear tag.

2) Standing up or sitting down.

Another characteristic movement that was of interest was detecting whether the Anesthetist was standing up or sitting down. In order to attempt to detect this we averaged the height value of adjacent front and back tag reads. This initial value was very noisy, partly because the tags are attached to the clothing (surgical scrubs) of the subject which are rather loose. To attempt to overcome this we took the median value of an overlapping window of 10 averages (Figure 7). However, this plot does not seem very illuminating. This may be due to the fact that as the simulated operation was relatively short there is no time for prolonged sitting and, the Anesthetist is in fact crouching rather than sitting.

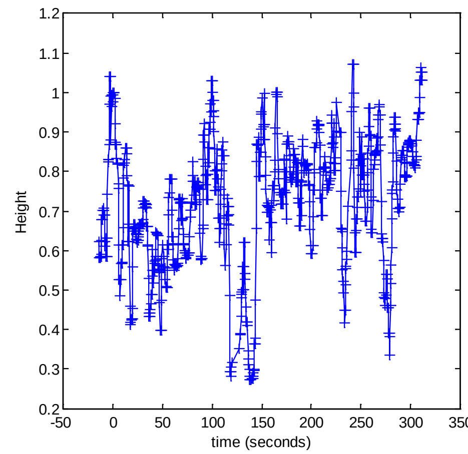

Figure 7 :Average height of tags, smoothed over a 10 read window.

3) Head scanning

This refers to the action of moving ones head from side to side. Again this is actually a rotational motion. Figure 8 shows the difference in velocity in the x-y plane between the front and back of the Anesthetists' head.

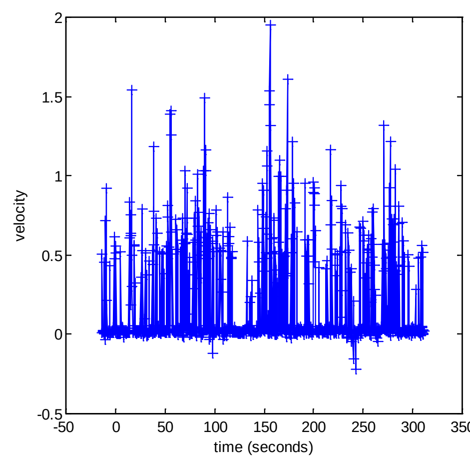

Figure 8 : Head scan, velocity difference between front and back of head

In this case, excursions are overwhelmingly positive, showing that it is much more common to move the front of the head faster than the back of the head. This fits with a movement where the center of rotation is behind the subjects head. This is consistent with the subject moving his or head to scan an area, for example looking around the patient body or a bank of monitors. It may be that the degree of movement would be related to the effective field of view, where the subject would have to move his or her head more when cognitive load is high.

E. *Location distribution*

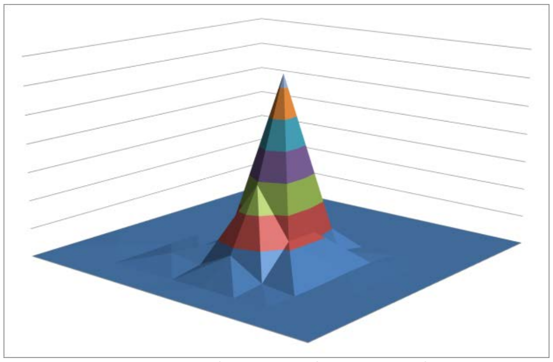

Figure 9 :Distribution of location of anesthetist front body tag

Finally the time spent in a number of roughly 50 by 50 cm cells, again in the x-y plane was calculated for the Anesthetist front tag (Figure 9). The peak represents 37% of the time, i.e. 37% of the time was spent in the most frequently occupied cell.

III. DISCUSSION

This study was designed to investigate what variables could be extracted from UWB sensors, without a direct comparison to a “gold standard”. However similar UWB systems have previously been used for improving estimation of pose[15] and activity [16] The measurements reported in this paper were chosen because they appeared robust and potentially relevant Because the tags were not in general attached to anatomical landmarks, generalized modelling of limb movement based on anatomical models[17], for example, was not possible . However this may not be important for activity recognition. It appears realistic to identify head direction and movement as well as overall distance travelled and possibly separation between individuals. This may be important in terms of understanding activity, and the ergonomics of the operating theatre. The UWB setup was well tolerated by the subjects and did not seem to interfere with normal activity. One issue is the need to have recognizable events recorded on the same time sequence, and ways of calibrating velocity. In most cases data from only one or two axis was analyzed, this could be extended if more complex analysis was seen to be needed.

A. *Future work*

Tagging the world can have sinister connotations – the operating theatre is traditionally a private space, and visitors are admitted on the clinician’s terms. A system designed to second-guess peoples actions will not be turned on. If adopted clinically an automated activity system could cause both personal and professional difficulties if it was used to identify and punish clinicians who have demonstrated potentially risky behavior. However, as with the airline industry there has been a great deal of interest in identifying causes of error- particularly when such errors seem to be due to human factors. There have been very extensive investigations of distraction for example based on observation logs[18] Confidential reporting of adverse events and near-misses, and root-cause analysis of errors have become more common and widely accepted . Another benefit is in the area of research into layout and work practices [19].

This work is based on the hope that automated systems will be able to record information that may be able to prevent errors. The operating theatre is a potentially rich source of activity because the region of interest is small, many of the activities are well known and the potential for catastrophic error is high

This will require use of collected data and discussion with experts – particularly observers. In order to be selected the ideal actions would only occur in particular subtasks, or at the very least have to occur in a particular subtask. If more than one action can be detected then sequence information can be used. If there is potential variation in a sequence, then we have previously used edit (Levenshtein) distance [20] to identify which subtask is most likely to be taking place . In our experience Markov chain and other approaches are less successful than this approach[21], partly because the detection process tends to have a low sensitivity and high specificity.

Although specific actions are relatively hard to detect without video confirmation or other sensors, we are investigating the possibility of using data that seems linked to level of workload, in order to monitor, and possibly warn of potential cognitive overload.

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Staff of the University of Auckland Clinical Skills center assisted greatly in this research and the clinical team performing the sham operations were particularly tolerant. JF contributed funding for this work in the context of testing a new commercial product.

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