Localisation and Activity Detection in Operating Rooms via Active RFID using Self-Organising Maps

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Abstract

Recording activity by staff in operating rooms (OR) is both challenging and an important part of supporting pervasive computing in that environment (1). Radio Frequency Identification (RFID) is an attractive tool for activity recording as it is unobtrusive and does not interfere with clinical activities. Self-organising maps have been tested to attempt to resolve issues with lateration, and are being compared to video analysis

Introduction

Studying the activity of anaesthetists is particularly interesting, and important for improving anaesthetist workload and patient safety (2). Hierarchical task analysis (HTA) has assisted in modeling anaesthetic work, providing a basis for protocols to improve safety (3). Human observers are expensive and may make errors when fatigued, obstructed, or viewing rapid, complicated events. Sensors, such as RFID, can potentially allow constant, low-cost, automated recording of activity for both research and clinical uses.

Previous research on this approach has tended to focus on localisation in open spaces, such as LANDMARC(4), or localising only to the room- or corridor-level in multi-room environments (5). Our system will need to localize in a very different environment. As can be seen in figure 1, the anaesthetist's work area is only a few square metres, but it is very complex.

Figure 1 : Operating environment

To aid in activity recognition we are using RFID to sense not only location, but also orientation and stance.

With these aims in mind, we have designed a system using active RFID equipment (Wavetrend), and tested it in a high-fidelity simulation suite. These suites allow OR staff to experience simulated problems in a realistic environment. The suites are equipped as normal operating theatres but with instrumented mannequins replacing real patients, and with extensive video coverage.

We have used three categories of tag positioning. Firstly, two are attached to the anaesthetist's scrubs, one front and one back (worn). Second, several tags are placed on known landmarks, such as the drug trolley, the operating table, and the anaesthetic machine (landmark). Third, six tags are on roof mounted brackets (ceiling). Three small RFID readers were deployed around the room at roof level. These record the tag ID and received signal strength (RSS) from each tag every 1-2 seconds.

References

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Methods

Early experiments in our laboratory demonstrated a significant variability between RSS and distance across different tag-reader combinations, and over time Because of this, simple lateration was not possible. Instead we have investigated other means by which the RSS data from the tags could be used to distinguish combinations of location, orientation and stance (LOS) reliably. Figuer 2 gives a LOS map from video observation On two different days we performed 15 common LOSs, maintaining each LOS for 2 minutes. The RSS data was then clustered using the Self Organizing Map (SOM) function in MATLAB's Neural Network toolbox.

SOMs (6) are a means of unsupervised clustering, that are widely used in this type of exploratory data analysis.

For each day's data SOMs of three different sizes (5x5, 8x8 and 10x10) were created for each grouping of the three tag categories (worn, landmark and ceiling). The precision of each SOM was calculated based on whether all the RSS data recorded in each 2-minute period was clustered together. 1000 SOMs were created for each combination of size and tag grouping. The most precise SOM for each combination was selected for comparison across all the combinations.

The most precise SOM overall for each day was then applied to the data collected on the other days.

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Figure 2 : Location and orientation heatmap derived from Video

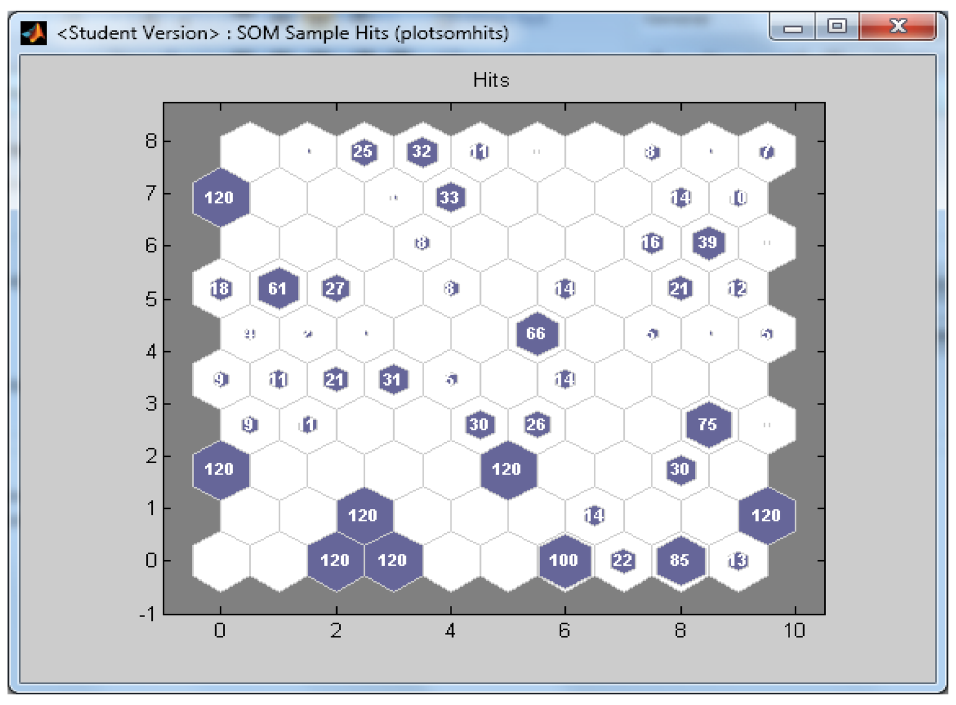

Figure 3 : Example of a Self-organising map

Results

The best SOM model created for each day's RSS data had precision in excess of 99%. For day 1, the best SOM model was size 10x10 and used RSS data from all three tag categories. For day 2, the best SOM model was also size 10x10, but only used RSS data from the landmark and ceiling tags.

However when each of these SOMs was applied to the other day's data, precision dropped to around 35%., This may be due to a slight change in the precise layout of the simulation suite, or a minor difference in the way we performed the LOSs, or some additional electronic interference in the environment.

Discussion

This work demonstrates that using SOMs to cluster RSS data can provide clear distinction between location, even when active tags may not provide data that allows accurate lateration results. However variation in RSS values caused by movement of equipment etc. still poses an obstacle. It may be that in the OR, SOMs cannot be reused, or require regular re-calibration.

Current work is concentrating on analyzing the efficiency of SOM's for multiple readings and application to real world data. Use of SOM's as tools for feature extraction and the use of pre-cleaning methods such as SMURF (7) is being examined.

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