Automated Privacy-Preserved Bed-Exit Prediction and Prevention System Utilizing Thermal Imaging Smart Video Analytics

STUDY AIM & OBJECTIVES

- This project is a collaboration between Tan Tock Seng Hospital (TTSH) Nursing Department and CoNEX Systems and Services Pte Ltd (CoNEX), a Singapore-based engineering solutions company.
- It aims to study the feasibility of an automated fall detection and surveillance system using thermal imaging that allows smart video analytics whilst preserving privacy for high-fall risk inpatients.
- The objectives include developing predictive algorithms to identify patient's movement in bed to predict bed-exit intention. This will provide crucial response time for caregivers to intervene before an actual fall can occur.
- The usage of thermal imaging allows study on patient's movement, that can be played back and provide opportunities for system learning.

TEAM MEMBERS

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BACKGROUND

- Falls injuries often resulting in hip fracture, and head injuries, require medical attention, increase hospital costs and length of stay, add burden to the manpower-starved healthcare industry. A cost analysis performed in TTSH showed that every inpatient fall with major injury cost S$32,189.
- It is calculated that 65% of the inpatient falls in TTSH occurred at bedside and 50% occurred without presence of a witness. This lack of accurate information on how falls occurred, lead to missed learning opportunities to prevent falls and to address them through optimising workflow and environment design.
- Current findings showed no conclusive effectiveness for hip protectors, movement alarms, or low-low beds that were originally thought can reduce falls or injuries in hospital settings. Effective falls prevention strategies leveraging on technology can reduce bedside falls and the burden on resource utilization.

METHODOLOGY

- The study is conducted in single-bedded, air-conditioned rooms. Baseline study includes understanding various bed exits scenarios (41 types of bed exit scenarios) and the ability to differentiate or identify objects (including blankets, pyjamas, infusion pumps, hot meal trays). The thermal imaging unit is then deployed in a general ward for 13 months, with 80 patients recruited for this study.
- A preliminary model is built by using image recordings from first 10 patients to train the system on generic objects and around the room such as bed, chair and human. A secondary model is thereafter trained to identify bed exits and different patient positions. An artificial intelligence system is then built to recognize and predict such activities and the system is integrated with alarms and front-end graphic user interface for system validation.
- The observational study was conducted in three phases, and summarised in the flowchart in Figure 1.

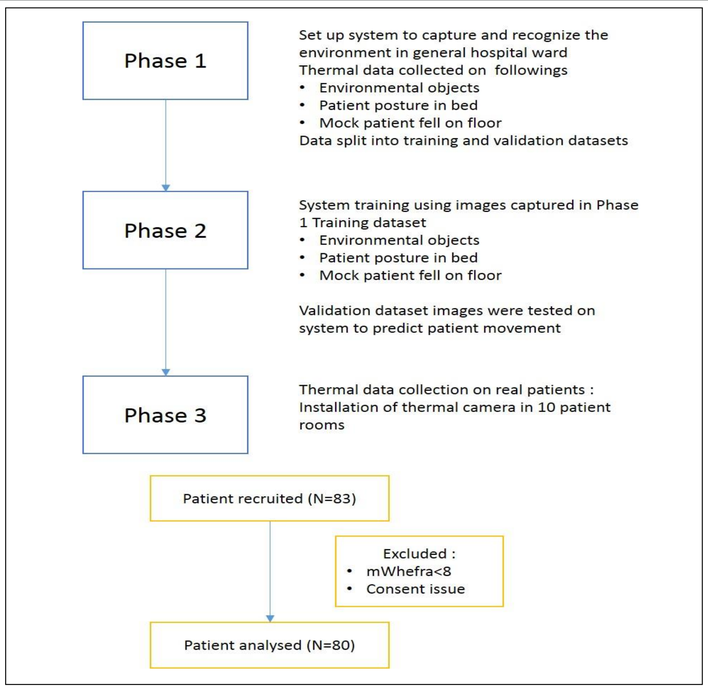

Figure 1. Flowchart of the study

FINDINGS

Phase 1 and 2

- The system developed in this study Phase 1 and 2 has demonstrated the ability to identify the entire process of movements resulting in a bed-exit.
- The large amounts of annotated data acquired from the information collected has enabled the team to train a state-of-the-art neural network architecture that can recognize objects of interest including "Person", "Bed", "Chair" from thermal images as well as predict the approximate bounding box of the highest likelihood of the object's presence in the scene.
- Therefore it is capable to detect and identify objects, and recognize a series of movements and interactions as the desired action of interest.

Phase 3

- A total of 80 patients were recruited between 24 May 2017 to 19 April 2018.
- As presented in Table 1, 46 were male (57.5%), age range from 26 to 95 years, with median age 77 (IQR 18.5).
- The length of stay of the 80 patients ranged from 1 day to 114 days, with median of 8 days (IQR 16.5 days).
- A total of 11,572.9 hours of video captured.

Table 1: Patient Profile

Variables	Count
Male	46 (57.5%)
Median age (IQR)	77.0 y (18.5)
English speaking	66 (82.5%)
Median LOS (IQR)	8 d (16.5)

Key patient's activities captured on the thermal imager (Figure 2)

- There were 70 times patient exit bed unassisted when he/she was alone. 109 times unassisted bed exit with the presence of family member or carer.
- 562 times patient were assisted by nurse or carer when leaving the bed.
- No incidence of fall at bedside during the study period observed.
- The system successfully identified and triggered alarm when patients are sitting at bedside, as their limbs were extended outside the bedframe boundary, and 69 times when patient exit bed unassisted.
- The only episode system did not detect occurred when a third person left the surveillance area, before the system was armed back on, thereby did not trigger an alarm when the patient exited bed without assistance.
- The sensitivity reported was 99.7%. None of the false alarm triggered on when patient was staying within bedframe. The specificity was 100%.

Figure 2. a - d A typical setting of thermal imaging system in single-bedded room.
Note: Thermal imaging allows smart video analytics whilst preserving privacy for patients.

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