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Intelligent Fall Detection and Notification System

for IoT based Smart Home Environments

Throughout the history of technology, various mechanisms to support the elderly and the disabled have been introduced as a remedy for the inadequacy of caregivers to provide them with the required assistance in leading an independent and secure living. Among all those mechanisms, smart homes and social robotics appear to play a significant and effective role in assuring a comfortable and safe environment for the elderly and the disabled who prefer to live independently without causing an extra burden on their families.

However, most of the existing assistive systems lack the required levels of accuracy and timeliness which causes increased probability of resulting them in higher risk of damage after encountering an emergency while staying alone at their homes. Therefore, in order to ensure the availability of timely assistance and support, the introduction and development of effective emergency detection and notification systems is an essential necessity in the present world.

With the intention of catering this requirement, Tharushi Kalinga, a member of the Intelligent Service Robotics Group (ISRG) of the Department of Electrical Engineering, University of Moratuwa, recently defended her MSc under the Thesis Title: Intelligent Fall Detection and Notification System for an IoT based Smart Home Environment, with the supervision of Prof. Buddhika Jayasekara and Prof. Indika Perera.

This research introduces a Smart Home System consisting of three subsystems integrated together over an IoT (Internet of Things) Cloud with the main objective of improving the quality of life of the elderly and the disabled by providing them with ample support in performing their activities of daily living without compromising their safety and independence.

The proposed system presents a novel vision-based method of detecting falls from standing or walking positions that is also capable of distinguishing the identified falls among three types so that the medical attention could be easily focused. A special subsystem is also introduced for the identification of sitting postures and detection of falls from wheelchairs for the people with mobility impairments. The fall detection and posture identification are carried out with a social robot called MIRob (Moratuwa Intelligent Robot), which receives visual input through a Microsoft Kinect Sen-

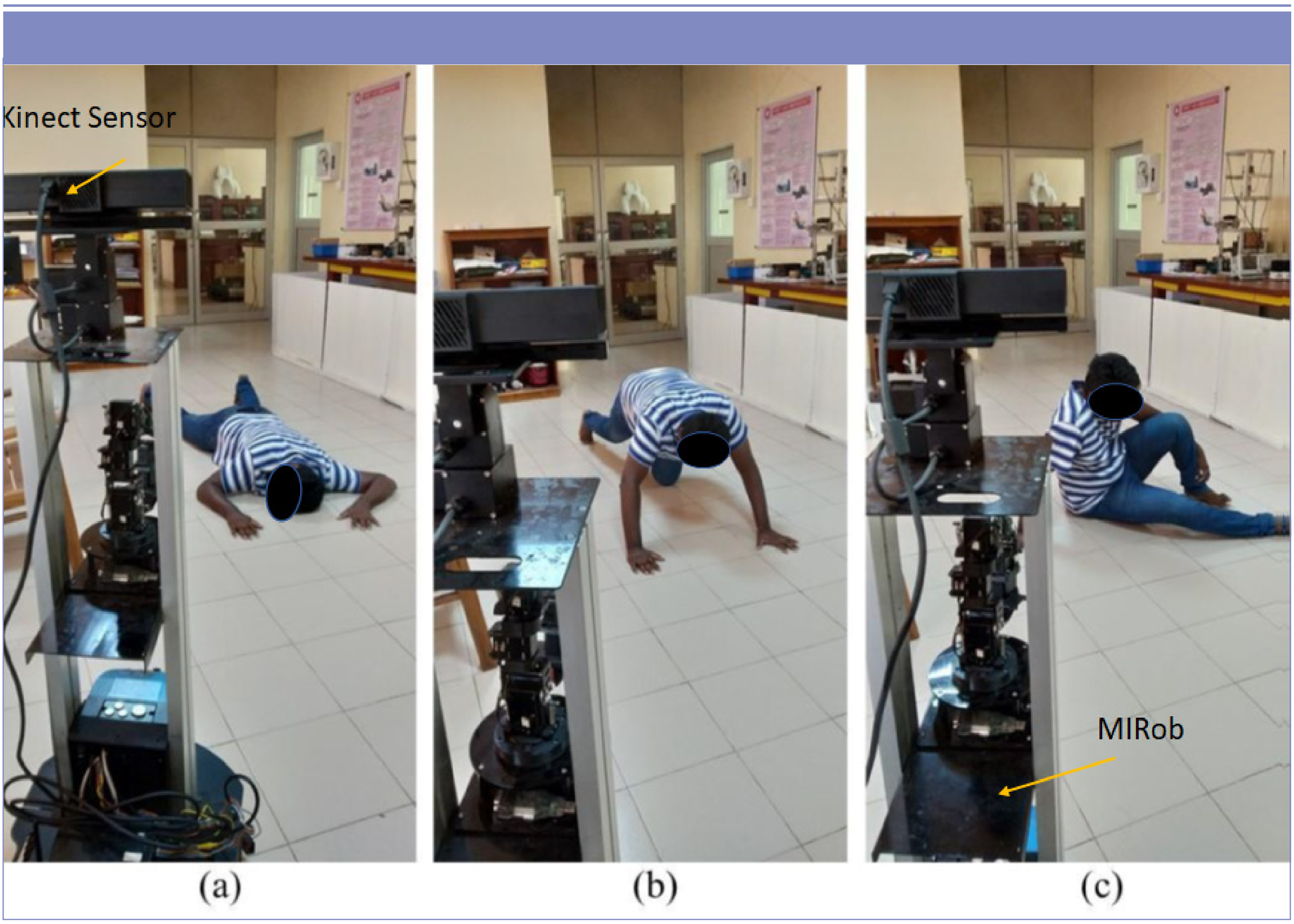
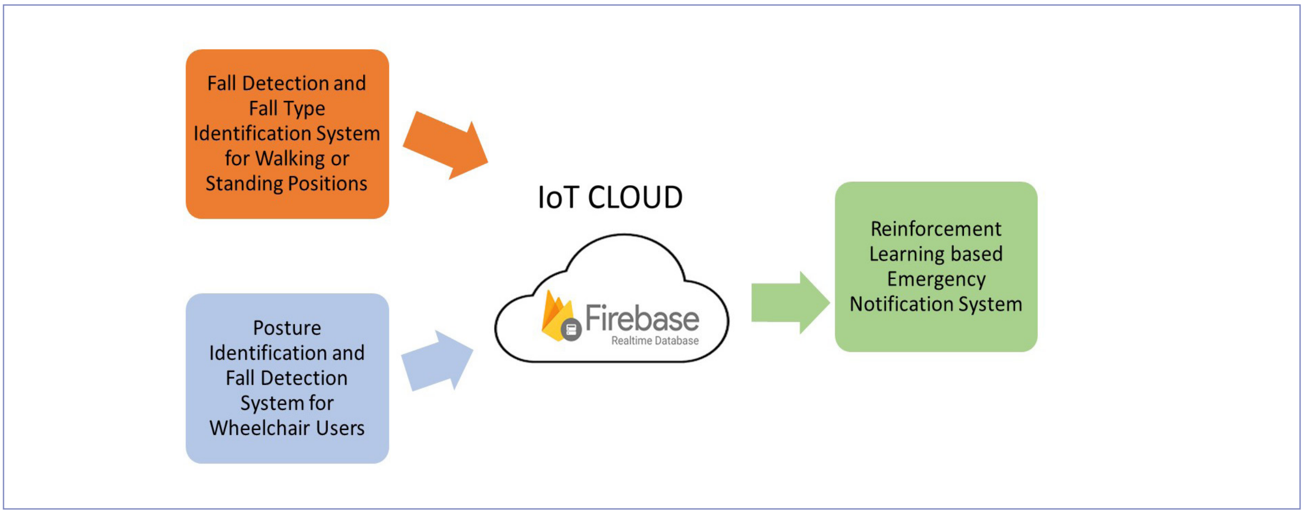


Figure 1: Types of fall (a). Prone Position, (b). Crawl Position, (c). Kneel Position

sor. A novel emergency notification system is also presented where, the notification is performed by implementing a Q-Learning algorithm using a Reinforcement Learning agent via an Android application.

The overall proposed smart home system is shown in Figure 1. It basically consists of three subsystems namely, 'Fall Detection and Fall Type Identification System for Walking or Standing Positions', 'Posture Identification and Fall Detection System for Wheelchair Users', and 'Reinforcement Learning based Emergency Notification System', which are integrated over an IoT Cloud developed using Google Firebase Real-time Database. The three subsystems work together to provide the elderly and the disabled with two main services; Fall Detection and Emergency Notification and promise to offer great support and safety in leading their daily lives.



The functionalities of the three subsystems are described in detail below.

1. Fall Detection and Fall Type Identification System for Walking or Standing Positions

This is a novel vision-based approach of detecting falls using the skeleton data obtained from the Microsoft Kinect sensor. This is implemented in real-time and ensures timely detection of falls. Further, the system overcomes the limitations of the existing similar systems. A fall is detected by considering the velocities of three body joints; Spine Shoulder, Spine Mid and Spine Base, and the orientations of two body vectors; Spine and Femur. A fall is distinguished from an activity of daily living by waiting for 't' seconds, after encountering a 'Transition Period'. Once a fall is detected, it is categorized in to one of the three types of falls; Prone, Crawl and Kneel, which enables more focused medical attention. Example scenario is given in Figure 2.

2. Posture Identification and Fall Detection System for Wheelchair Users

This method of posture identification and fall detection for wheelchair users is a novel vision-based mechanism involving a Microsoft Kinect sensor and Vitruvius Framework. This operates in real-time and detects falls quickly and effectively. This system provides solution to the limitations of already available similar systems. The system is capable of discriminating among four sitting postures; Proper Sitting, Lean Forward, Lean Left and Lean Right by considering the angles made by the torso in three directions as in Figure 3. A fall from the wheelchair is detected by observing the distance from waist to floor and the velocity of waist.

3. Reinforcement Learning based Emergency Notification System

This is a novel method of emergency notification using a Reinforcement Learning agent with an Android application. This assures timely notification with a proper feedback mechanism. This system solves the limitations found in other similar systems. The system utilizes two parameters namely, probability of

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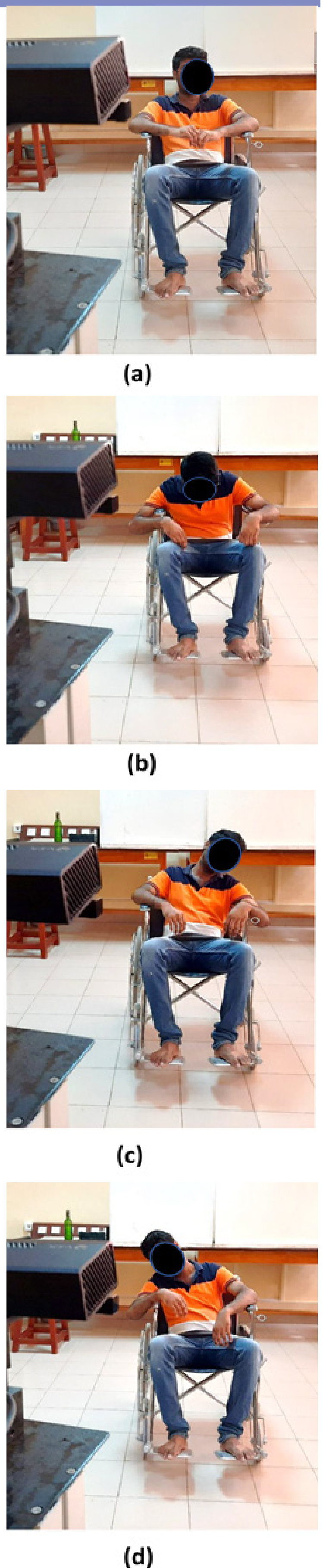

Figure 2: Four Sitting Postures Identified by the System)a). Proper Sitting, (b). Lean-Forward, (c), Lean-Left, (d). Lean-Right

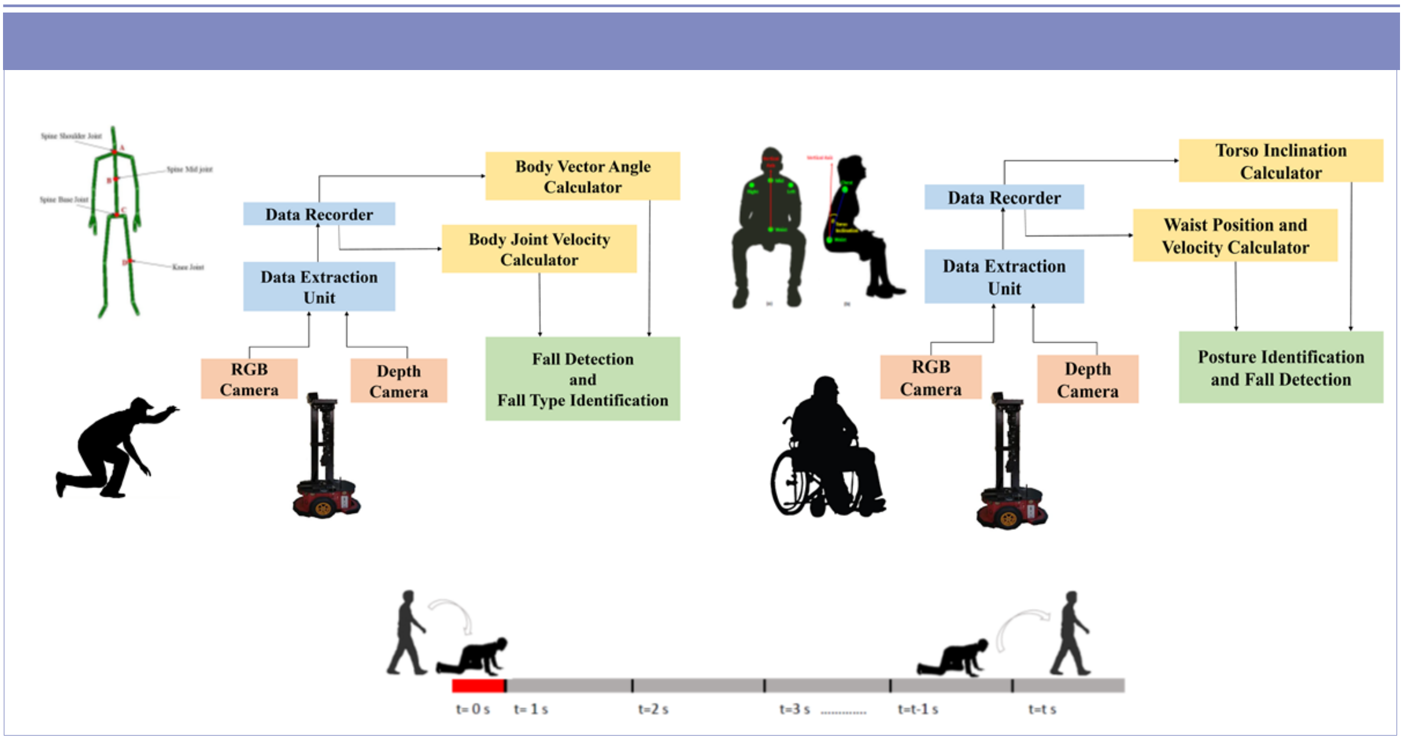

Figure 3: Overal system indetail

answering and level of being busy of the contact persons to come up with an order of calling based on a Q-Learning algorithm. The GPS location data is also taken into account when preparing the order of making calls. As an elder is more likely to become nervous when making decisions during an emergency, this automatic notification system is more effective in notifying emergencies to responsible parties during emergencies.

Fall detection from both standing and seated positions as well as sitting postures are detected by the system automatically with the help of the service robot MIRob, where the detection system is capable of automatically triggering the Emergency Notification System. If the user detects any other emergency that the system cannot identify automatically, then the system provides the user with the facility of signalling the IoT cloud manually by providing an 'Emergency' button in the Android application.

Once the IoT cloud receives an emergency signal either automatically or manually, the emergency notification system starts to operate. Thus, a responsible person will get informed regarding the emergency in time, so that the elder or the disabled person will get support quickly enough to minimize any possible negative consequence.

Through experimental studies the overall proposed system has promised to guarantee acceptable levels of accuracy and timeliness in providing assistance to the elderly and the disabled. Thereby, the proposed overall system is capable of providing the elderly and the disabled with adequate support as well as ensure safety and improve their independence and quality of living.

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