On Visualizing Movements and Activities of Healthy Seniors
An Overview

Shahram Payandeh
Experimental Robotics and Graphics Laboratory, Simon Fraser University,
8888 University Drive, Burnaby, British Columbia, V5A 1S6, Canada

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Abstract: Increased life expectancy and motivational support for the pursuit of independent living for active seniors have been introducing a number of challenges for the families and care monitoring personnel. In general, this class of aging seniors are healthy enough that they can afford to continue to have the independent living life styles but also are old enough that one still needs to have some levels of monitoring of their movements and activities in their private dwellings. These motions and activities can be monitored through a network of connected sensors at each individual's dwelling where they can be networked to form a monitoring cluster. The objective is then to be able to present and visualize such movements and activities information to the monitoring personnel. This paper reviews various sensing modalities which can be used in monitoring movements and activities of seniors and presents an overview of visualization techniques which have been utilized in various similar applications. In addition the paper highlights a conceptual framework which can be used to visualize movements and activities in a cluster of such sensor network.

1 INTRODUCTION

Visual monitoring of elderly through cameras in either independent living dwellings or senior care giving facilities has been a center of attention for a number of years (Zouba, N. et. al (2010)). One of the benefits of such monitoring set-up is the direct viewing access where family members and care giving staff can visually observed movements and activities of the seniors (NiScanaill, S. (2006)). Another very important benefit of visual monitoring of movements and activities is through visual analytic where it is possible to predict any future abnormalities using long-term historical movements and activities data of seniors (Forkan, A. at. el (2014)). Such early anticipation of anomalies can improve the rate of disease prevention.

One of the key challenges in effectively utilizing the existing video technology in common living areas is its lack of protecting privacy of seniors while individual is being viewed through video camera network (Islam, R. et. al (2009)). The other main challenge of deploying the automated version of the current video technology is the lack of effective information display and visualization associated with the movements and activities where seniors can feel comfortable to share and also informative enough for the family members and care giving staff to view (Lu, Y. and Payandeh, S. (2008)). Other types of technology have also been introduced which require the senior to wear various sensors and monitoring devices (Maki, H. et. al. (2011)). Although in comparison with the visual monitoring through cameras, these alternative monitoring technologies can preserve privacy of seniors in their dwellings; it requires them to wear these sensors which can introduce other types of inconvenient and discomfort to the aging population. Similar to home security system, on/off and proximity switches and sensors can also be deployed in the private residence of seniors. These sensors can be integrated in a design of smart homes (e.g. beclose.com) that can give a crude information in regard to, for example, the opening and closing of doors or presence or absence of the senior in a room. Other newer multimodal technologies are also being evaluated which in addition to allowing visual monitoring of the scene through the video camera, it can also supply information about the relative location of the object with respect to the camera and sense the source of audio inputs (e.g. Kinect-II from Microsoft).

In deploying a network of sensors for monitoring the movements and activities of seniors, a num-

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ber of questions should be concurrently addressed. For example, by explaining the features of the sensing technology to seniors, the first question which can be asked should be: a) what would the senior and their family consider adequate collection of information when using a proposed sensing technology?; b) to the care giving personnel, what would be considered as an adequate amount of graphical display information in regard to monitoring movements and activities of the elderly?; c) what main features of a sensor like Kinect-II technology can be utilized in order to explore approaches for collecting and monitoring the movement and activities of the elderly and d) what are various approaches which can be used based on the sensing technology to visually update and display the monitoring information of the seniors to the care giving staff. For example, the sensing technology such as Kinect II (sometimes it also referred to as ambient sensing) can be used to identify some unsafe behaviors such as leaving the bed or chair. Bed and chair alarms sensing devices can be used in private living areas of some seniors but these alarms are costly and not very reliable due to existence of large number of false alarms.

2 SENSING THE MOVEMENTS AND ACTIVITIES

Similar to standard home security system, various on/off and proximity swicthes can be deployed and be integrated at various locations of the senior's dwelling. These sensors can be used to detect opening and closing of doors, sitting on various furniture and detect presence and absence of the seniors in various rooms (Figure 1). Similar to home security, these sensors can be networked and dispatched to a central monitoring stations.

Figure 1: Schematics of living area of a senior. Circular icons are used to show various locations where on/off or proximity switches can be integrated into the living area.

Another sensing modality which has been very popular for direct video capture of the seniors in their dwellings is through usage of video cameras. Unlike the integration of the switches and proximity sensors, this technology do not require to equip the furniture and appliances with sensors. The monitoring personals can directly observe the movements and activities of the seniors at a given central station (Figure 2). In some cases it is possible to utilized various image processing algorithms in order to assist the monitoring personnel through the overlaid visual analytic to access the monitoring environment. For example, Figure 3 shows an example of how the movements of a person can be tracked over a number of video frames. Figure 4 shows an example of how by proper location of multiple cameras (one stationary and the other with pan/tilt/zoom capabilities), the fall of a person can be detected and the event can be trigged other cameras for collecting increased levels of details. In another example, Figure 5 shows how movements of one person away from the simple crowd can be identified and be tracked which can then trigger a visual alarm for the monitoring personnel.

Other recently introduced sensors can offer more versatile and economically feasible solution to monitoring movements and activities of seniors. These sensors can address visual privacy issues associated

Figure 2: A monitoring station consisting of a number of cameras distributed within a cluster of a city block.

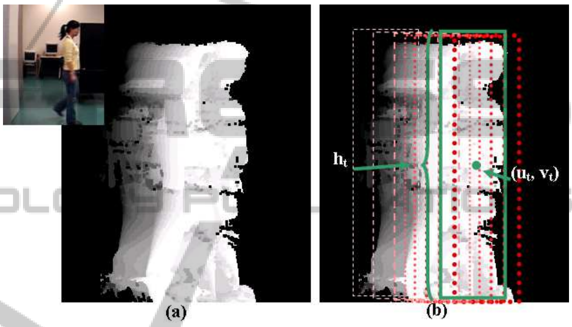

Figure 3: (a) The motion history image (MHI) of a walking person. (b) The person's position and size are indicated by the green solid rectangle, which is the weighted sum of N red dashed rectangles.

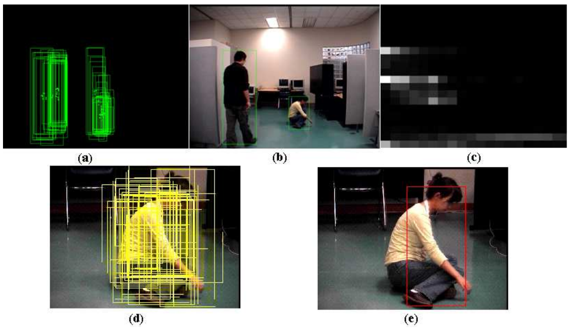

Figure 4: (a) Trajectories and sizes of people over last 30 frames till falling is detected in the stationary camera (b) Screen shot when fall happens (c) The 2-D 20×20 hue-saturation histogram of the fallen person (d) Samples generated in the active camera (e) Target's location and size.

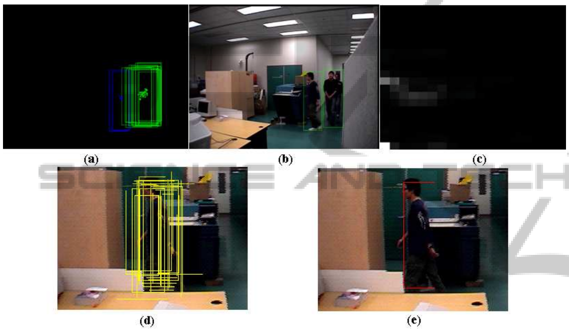

Figure 5: (a) Trajectories and sizes of people over last 30 frames till wandering is detected in the stationary camera (b) Screen shot when wandering happens (c) The 2-D 20×20 hue-saturation histogram of the wanderer (d) Samples generated in the active camera (e) Target's location and size.

Figure 6: An example of sensing the movements of people through Kinect II sensor and various examples of the visualization of such movements.

with conventional video camera systems. Sensors like Kinect II offers a number of sensing modalities including the IR sensors, depth sensors, positional microphone sensor and also a video camera. For example, some of the privacy issues regarding the direct visual monitoring of the seniors through video camera can be addressed through utilization of the depth sensing. Figure 6 shows an example of monitoring the movements through the IR sensor and also shows various reconstruction of sense data for visualization. One of the main challenges of the current deployment of this sensing technology is the restriction it introduces in regard to the placement of people with respect to a single sensor and association of the movements of seniors between a network of such sensors.

3 MOVEMENT AND ACTIVITY VISUALIZATION

Visualization of the movements and activities of seniors in their private dwelling shares some similarities with other related areas of information visualizations. The overall objectives are to convey to the care giving staff, who are in charge of monitoring a cluster of senior dwellings, information which at various levels of detail about the movement status and activity health of each individual. Figure 7 shows and example of visualization of 96 known activities of a person showing one per ring (Zhao, J. et. al. (2008)). The author proposed that generalization of such movements consists of three operations; spatial, temporal and activity abstraction. Three types of techniques are distinguished: suppression, aggregation and codifications. Here, suppression is defined as a way of reducing dimensionality by retaining certain important components or dimensions from the original data set. Aggregation refers to operations that merge, combine or summarize similar or related objects/elements into a new and higher-level abstraction. This can further be divided into two types: spatial aggregation and temporal aggregation.

Figure 8 shows another example that illustrates the movements of an individual during one week (Kang, C. et. at. (2008)). Every individual has a daily activity program consisting of a number of out-of-home activities, including activities that are spatially and/or temporally fixed for certain individuals and others that can be undertaken at various locations or times of the day.

(Buono, P. et. al (2014)) also extended the notion of ring and time space to present a visualization technique for people's activities. They proposed the use of graphical representation of the *boxplot* with different semantics for easier user interface. For example, in Figure 9 , the external circumference has 24 h indicated on it. Six stripes are visualized which represent the users and color histograms for each members represents their activities after, before and the expected activities after the current time.

An interesting approach was proposed for representing activities using the density map (Wang, S. and

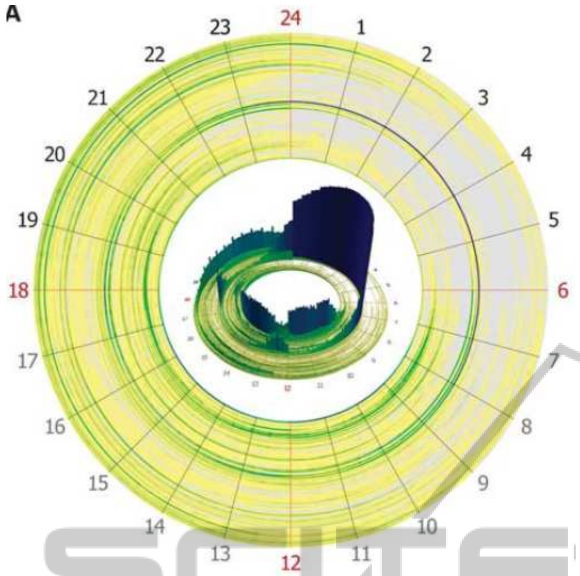

Figure 7: Daily visualization of activities of a person as concentric ring topology.

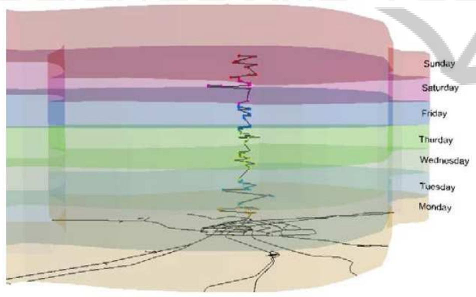

Figure 8: A week-long individual travel-activity path.

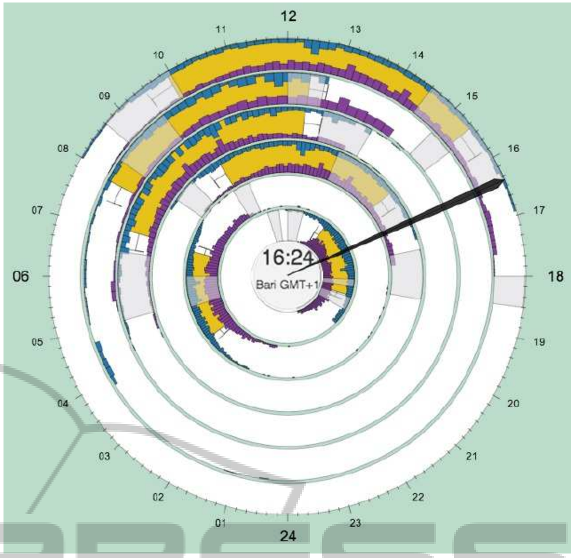

Figure 9: An example of iOS developers in a team of six are visualized, starting from the time shown in the center (15:24) up to the next 24 hours. The activities of the developer at the top of the list are represented in the outmost stripe, the others are represented in the more internal stripes according to the list order. Gray zones in a stripe show person unavailability.

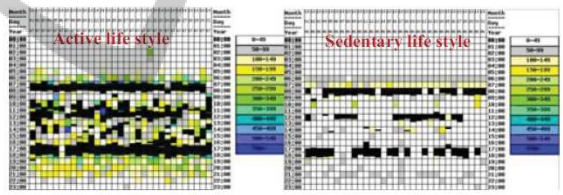

Figure 10: An example of density map showing an active and sedentary life style.

Skubic, M. (2008)). Here, different colors are used to represent different levels of density in the motion sensor data. The density is computed as the number of all motion sensors during an hour divided by time at home during that hour. Figure 10 shows an example such visualization technique where the x-axis is the hours in a day and the y-axis represents days in the month of an active lifestyle. The color bar on the right of the figure shows the colors of different densities. Black represents time away from home. White means that no sensor activated. Colors change from light grey, yellow, green, light blue to dark blue as the density per hour increases. The dark blue color represents the highest density of 550 or more events per hour. The sedentary life style map is much less colorful, green is the darkest color in the map, and the corresponding density is around 300 times per hour. The black areas of cover much less time than the density map for the active life style.

An integration of a single fish-eye camera for determining the speed and activities of a senior was proposed by (Zhou, Z. et. al. (2008)). Through single camera image processing, they proposed a coarse classification of human actions based on their physical locations and speeds. The objective here was to develop a low-complexity, efficient, and robust scheme for action recognition. Various actions such as walking, sitting on the couch, standing up, sitting at the dinning room table, preparing meals in the kitchen, visiting bathroom and going outdoors are classified. Figure 11 shows an example of senior activities classification based on the physical location and speed. The physical location in the room provides important contextual information for action recognition.Figure 12 displays the sequence of actions performed by two persons over a one hour period. It can be seen that person B is much more active than A.

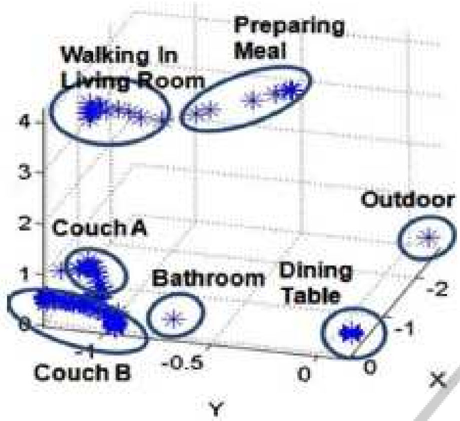

Figure 11: Recognizing major activities of daily living using location and speed.

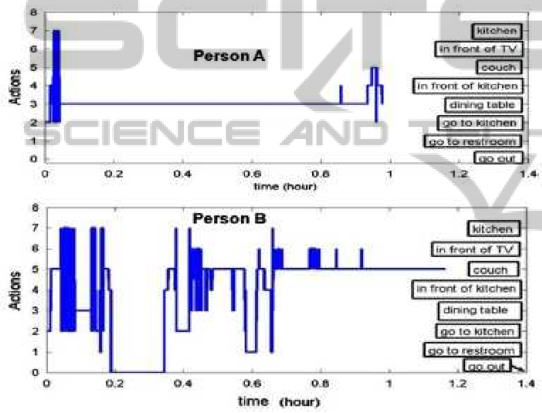

Figure 12: Action sequences of two persons over a one-hour period.

4 VISUALIZATION CHALLENGES

Similar to any visualization approaches of real physical events that rely on sensors, visualization of the movements and activities of seniors is also dependent on the types and modalities of such sensors. In contrast to most cases of monitoring people in public places, viewing and monitoring seniors in their private dwellings introduced additional constraints on the monitoring signals that encompasses the privacy considerations of the individual. In addition, costs and integration of any monitoring sensors can play a vital key in overall acceptance of monitoring systems.

The long term objectives of any monitoring and visualization techniques of healthy seniors is prediction of future abnormalities. This can be accomplished by using long-term historical data through context aware monitoring system in order to detect progressive changes in human health and behavioral patterns. Failing to detect symptoms early can result in severe disease or other serious consequences. For the case of healthy seniors, the monitoring of gait patterns and hand manipulation patterns can also signifies an on-set of some muscular disease or disorder.

Existing sensing system which is similar to home security set-up consists of on-off switches which needs to be integrated with the existing house-hold items. These sensor can only supply low level monitoring information in regard to presence and absence of movements and activities. Deployment of video cameras in private dwellings for direct video monitoring has been always face privacy challenges. Image processing of live video streams can be carried to allow some levels of view distortion for the monitoring personnel. However, detecting the gait patterns and even establishing a robust image processing algorithm for monitoring movements of seniors in various lighting conditions have been a major challenges. Other new type of sensors such as Kinect II can address some of the limitation of the above mentioned sensing modalities. For example, depth sensor can be used to estimate both presence, movements and gait patterns of the seniors which can also mask and protect the privacy of the individual. However, the network of these sensors needs to be deployed and calibrated in the living space of the seniors. In addition to the standard camera (i.e. RGB sensor), these sensors also are equipped with the IR type imaging which is less dependent on the illumination conditions. Kinect II also offers a directional microphone which can be exploited (in addition to the depth sensing) to trigger various visualization tool in the event of presence/absence of movements and activities.

Given such state-of-the-art in sensing technology it can be seen that there exist various limitations in their deployments such as inaccuracy in their measurement/processing or their effective range and acceptability. Such limitations can also be extended to the visualization of the sensed information for the monitoring personnel. In particular when such individuals is in charge of monitoring the movements and activities of a number of seniors located within their monitoring clusters. The following are some working proposal which can be followed in order to design and developed an effecting visualization techniques. a) The visualization of movements and activities of seniors in a monitoring clusters should be structured in an increased-levels of detail; b) at the highest level, the living space of each senior can be normalized and mapped to a patch on a sphere; c) the movements of the seniors can be mapped to a point in its corresponding patch; d) the activities of the senior can be mapped to an animated figure similar to the image of Vitruvian Man where the positions of the hands and legs can correspond to certain activity ; e) color can be associated to a point on a patch representing the position of the seniors and to each limbs of the figure representing the relative health of the activities the seniors with respect to the historical normal activities.

5 CONCLUSIONS

The paper gives an overview of the state-of-the-art in the sensing technology which can be used to monitor the movements and activities of the seniors. In addition this paper presents some overview of various visualization techniques which have been proposed in the literature for addressing problems similar to propose monitoring environment. Being able to monitor the movements and activities of seniors located in a cluster of connected dwellings is a major issue which needs to be effectively address. This is due to the increased life expectancy and motivational support for the seniors to continue and pursuit independent living life-style . The overall objective is to enable the monitoring personnel to effectively visualize the status of a senior, within a network, at various levels of details. For this a 3D textured graphical sphere where the senior activities and movements can be mapped to and can be interfaced by the personnel through various user interface devices (such intel RealSense Technology) can play a dominant role in effectively visualizing and interacting with the displayed information.

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