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Preliminary results on algorithms for multi-kinect trajectory fusion in a living lab

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Abstract

Everyday activity of an individual is related to his health status. In order to improve daily health monitoring at home, an indoor position tracking system has been designed. The latter is based on a network of depth cameras to detect and track people's position. The trajectories obtained from each camera are merged to reconstruct each individual's own entire trajectory within the apartment, from which home activities can be derived. In this way, the early detection of a change in daily activities of the elderly will highlight disabilities and loss of autonomy. Standard modules and software were implemented in the system architecture to integrate sensors and systems seamlessly to provide high flexibility and integration capacity for future developments. This system is meant to improve homecare health management for a better end of life at an affordable price for the community.

Keywords: Biomedical sensors; E-health; Depth Image Processing

1. Introduction

With aging, a subject is likely to suffer multiple chronic diseases and reduction in physical activity. The combination of these two effects induces a reduction in daily activities, progressive loss in autonomy and eventually inability for an independent living if appropriate adaptations are not foreseen. A strong relationship between health status, activity and autonomy was showed [1]. Furthermore, the autonomy of the elderly subject relies on his ability to perform the basic actions involved in his daily living. Thus there is a real interest in monitoring his daily activity together with the main physiological parameters (i.e. cardiac frequency, blood pressure, weight, etc.) directly at home.

Since activities are tied with places (one takes a shower in the bathroom), the first step of activity analysis is to locate the inhabitants at home. This paper proposes a proof of concept of a multi-user indoor location tracking system based on depth cameras. The early steps of the design and preliminary validation processes are described and discussed in order to address the future evolution of the system.

1.1. Problem constraints

Localization of humans indoor is mainly referred to in terms of space classification (each room is a class) and interactions (with equipment or person). Therefore we need a minimum resolution corresponding to the "sphere of interaction" of the human with a minimum reach of half a meter. It is consistent with the personal space corresponding to the area where humans interact with one another [2]. Furthermore, since several people can be simultaneously present within the area of a flat, the localization system must be able to differentiate the presence of several users in order to track their individual activities,

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Table 1
Design constraints summary.

technical constraints	spatial resolution of half a meter localize several people simultaneously
ergonomic constraints	low invasive low intrusive deployment in existing flat
economic constraints	lower cost than a nursing home

whether collaborative or independent. We arbitrarily fixed this number to 5 simultaneous subjects within a reachable area, in order to cope with most of the scenarios of daily interactions, from simple presence of a nurse to presence of some visiting relatives. A multi-user tracking system was proposed by Wilson [3], based on several ubiquitous sensors distributed around the house. It reached low resolution and high intrusivity. In this paper we propose a system based on a reduced number of sensors, though exhibiting a resolution better than half a meter which is compatible with the detection of social interactions. In addition, the system must remain low intrusive and low invasive in order to reduce the impact on the daily activities of the subjects. Additionally, the system cost must remain limited in order to be applicable to the largest population as possible. Still, the system we propose is merely a proof of concept (Technology Readiness Level 3–4), not yet fulfilling this last limitation, but once produced at large scale, it is expected to be less expensive than renting a room in a nursing home.

1.2. Comparison of existing indoor positioning systems

Following these first guidelines, we established the basic specifications of our indoor tracking system (Table 1), then we performed a survey of current location tracking technologies. In a precedent survey of active and passive indoor localization systems, Deak [4] proposed a classification of technologies in two main branches: systems including an embedded wearable part on the subject and systems without. This has a major impact on the acceptability.

As an embedded solution, Ubisense [5] proposed a wearable tag using ultra-wideband (UWB), time difference of arrival (TDOA) and angle of arrival (AOA) localization algorithms. The Ekahau real-time location system (RTLS) [6] use radio frequency (RF) communications in the 2.4 GHz band and a simple evaluation of distance from the received signal strength indicator (RSSI). The Active Bats [7] uses ultrasound waves time of flight. The SpotON [8] uses RSSI of radio-frequency identification (RFID) active tags. These solutions are compliant with most our specifications. They also bring the possibility for multiple users separation and identification. But the embedded device must remain always active and thus powered on, which implies the use of a battery with a limited lifetime. In addition, these embedded systems are unable to locate visitors who do not wear the embedded device, which is quite limiting in our case. Moreover, all these embedded solutions are invasive.

Among the systems without any embedded part, a detection floor composed of many capacitive tiles [9] offers a good resolution, but is costly and complex to install in a pre-existing apartment. Passive Infrared sensors (PIR) were widely used in smart homes [10], in particular to study circadian cycles [13]. These PIR sensors are affordable and perform well when tracking a single user but not when several users are close to each other. Computer vision based on stereo color cameras [11] can produce a depth image of the room and localize people. Unfortunately, the depth image resolution does not allow to differentiate two people close to each other, especially in low light. In a similar approach, Weerasinghe et al. [12] used a smart advanced device, the Kinect [14], to track construction workers. The Kinect is mainly composed of a color camera, a depth camera, and several microphones. The Kinect depth camera reaches the needed resolution and can separate up to six people close to each other. Additionally, a positioning system based on Kinect depth cameras is non invasive, low intrusive (it is already accepted), and can be installed in a pre-existing apartment with the provision of accessible electrical power plugs. The choice of the Kinect is a “low cost approach”; i.e. an existing and widely spread technology is reused in a way which was not planned initially (it was designed as a motion sensor for games) providing the support of a large community and limiting the device price. Existing software libraries can also be used to reduce overcosts for developing associated software. For all these reasons, this passive location tracking system based on Kinect depth cameras was chosen for our indoor location tacking system. The positioning systems comparison is summarized in Table 2.

2. Materials and methods

2.1. The sensor

The Kinect is a motion sensor, designed by Microsoft Inc. and released in November 2010 to be used as a remote con-

Table 2
Comparison of indoor positioning systems adapted from [4].

Positioning technologies	Resolution	Cost	Multi-person localization	Invasive	Intrusive	Deployment in existing home
Actimetric floor [9]	40 cm	Medium	Yes	No	No	No
Passive infrared [10]	50 cm	Low	Yes	No	No	Yes
Stereo cameras [11]	10 cm	Medium	Yes	No	Low	Yes
Depth cameras [12]	10 cm	Low	Yes	No	Low	Yes
Ubisense [5]	30 cm	Medium	Yes	Yes	Low	Yes
Ekahau RTLS [6]	2 m	Medium	No	Yes	Low	Yes
Active Bats [7]	9 cm	Medium	Yes	Yes	Low	Yes