CONFIDENCE INTERPRETATION AND PREVENTION SYSTEM

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ABSTRACT

This paper presents the interpretation and prevention system as a part of the product developed at the EU FP7 project Confidence. This system is able to detect falls and general disability. The tests show that it is reliable and ready for real-world usage.

1 INTRODUCTION

This paper presents the work at the work package 3 of the EU FP7 project Confidence [1]. The main objectives of this work package are the development of a subsystem that reconstructs the user's body in the environment and the development of a subsystem that interprets the body posture within the environment producing an alarm when hazardous situations are detected. Both subsystems have to be integrated in the final system that must be able to gather user position and acceleration from a real-time position and acceleration systems and has to send alarm messages about the detected hazardous situations to an independent portable device. This device is used to communicate with the user and is able to decide whether a hospital or a specialized care-giving institution has to be noticed.
The described system has already been developed. It uses the Ubisense, a real-time localization system [2], and an acceleration system developed at the Fraunhofer Society [3] in order to get the positions and accelerations of the user from dedicated body tags and sends the alarm messages to a simulated portable device. The next steps are the integration of the system with the systems of the other partners on the Confidence project and extensive tests. The system is presented in details in the following sections.

2 IMPLEMENTED SYSTEM

The presented system recognizes hazardous situations from user's movement and reports them to the user/caregiver. In order to do that, several modules have been developed and integrated in the final system. In the following subsections we firstly present the architecture of the whole system. Secondly, we present each module/method that has been developed. Besides, we present the interface that was developed as an extension of the portable device, namely control panel, for the advanced users, system developers and for presentation purposes.

2.1 System architecture

The system has been developed as a set of independent modules/threads. They are organized as a pipeline where a module gathers the data from the previous module(s), processes them and sends them to the next module(s) in the pipeline as shown in Figure 1. The main modules are the reconstruction modules (consisting of posture modules) and interpretation modules (consisting of interpretation and prevention modules). In addition, the communication modules were also implemented that communicate with a localization system and portable device, and that show the system status in details on the computer screen.
The following subsection describes each of the modules in the pipeline. For each module we present its functionality, the previous modules from which it receives the inputs, and its outputs.

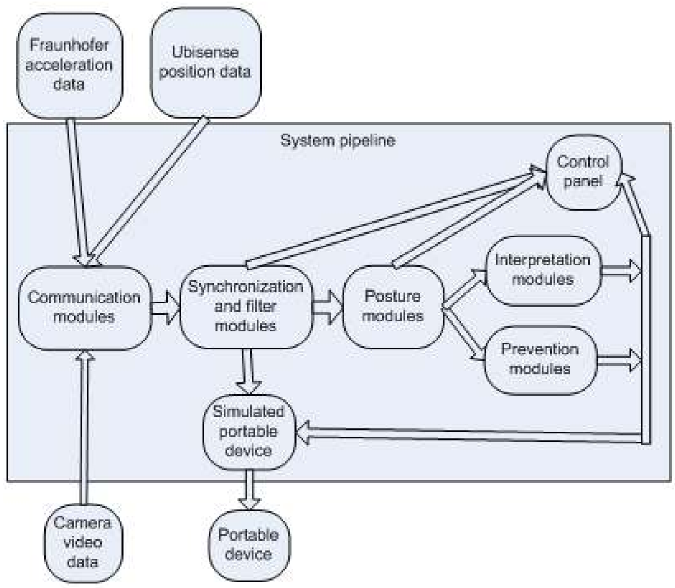

Figure 1: *System pipeline*

Figure 2: *Portable device normal screen*

2.2 System modules

The first modules of the pipeline are the communication modules that gather the localization data from the Ubisense localization system and the acceleration data from an acceleration system developed at the Fraunhofer Society. In addition, they are able to receive the data from a camera for demonstration purposes. They work asynchronously since the input devices are not able to synchronize with other systems. The received data is stored in a queue in order to be preprocessed with higher-level modules.

Besides the communication modules for sensor data there are two modules that communicates with the user. The first one is the (simulated) portable device. It sends the messages produced by other modules to the user. These messages are short, simple and understandable. When there are no problems, it shows the message in Figure 2. When a button with no special function is pressed, a help screen is shown (Figure 4). The other messages are related to the specific modules and shown in Figure 9 and Figure 11.

In addition to the simple portable device screen, the system has the advanced control panel module. This module shows the system current status and the status of all modules as shown in Figure 3. The screen is divided in the following areas. Ground plan viewer and side view show the position of the user (his/her tags) in the controlled rooms and his/her

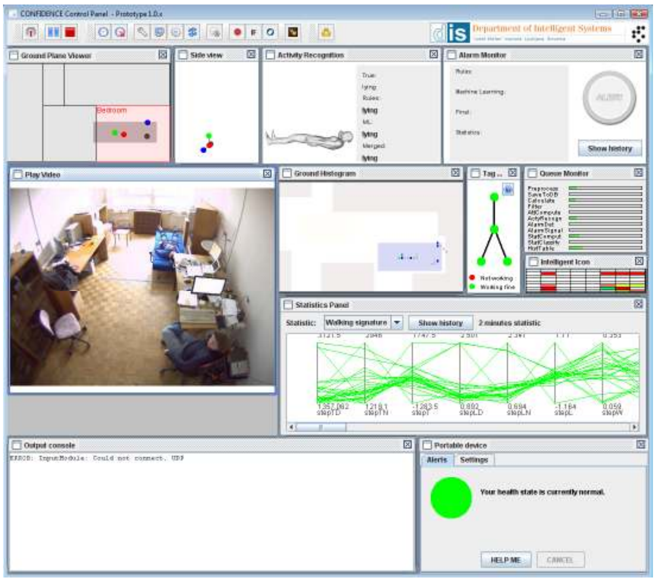

Figure 3: *Control module*

posture. Besides, they show the positions where the user is allowed to lay and the current room name where the user is, as shown in Figure 5. Tag status and queue monitor show the system status, precisely its possible problems as shown in Figure 6. Tag status shows the working and non-working tags while the queue monitor shows if the data in the pipeline are processed in real time or if there is some problem and the data is not processed in real-time, which is shown as data accumulation in some of the showed queues. Video screen shows the current video if the camera is present as shown in Figure 3. At the bottom left side of the screen the system errors are shown. At the bottom right side the simulated portable device is shown. The other windows are connected with the functionality of the other modules and therefore are presented in the following figures: Figure 7 for activity recognition, Figure 8 for alarm monitor, and Figure 10 for ground histogram, intelligent icon and statistics panel.

The data from the communication modules for sensors are sent to the next modules in the pipeline, i.e., synchronization and filter modules, that have two tasks. Firstly, they synchronize the data from different inputs. This is done with a lower frequency compared to the Ubisense frequency in order to have at least the position data of all

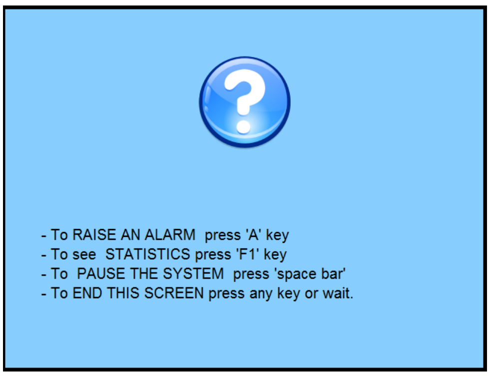

Figure 4: *Portable device help screen*

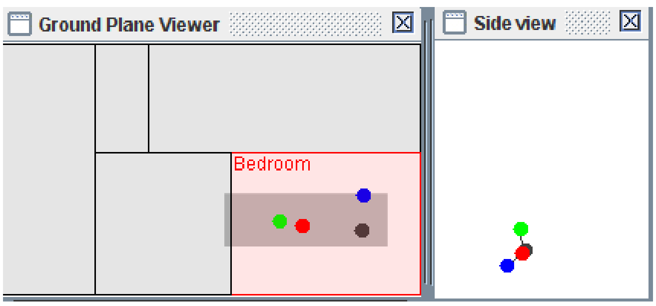

Figure 5: *Ground plane viewer and side view*

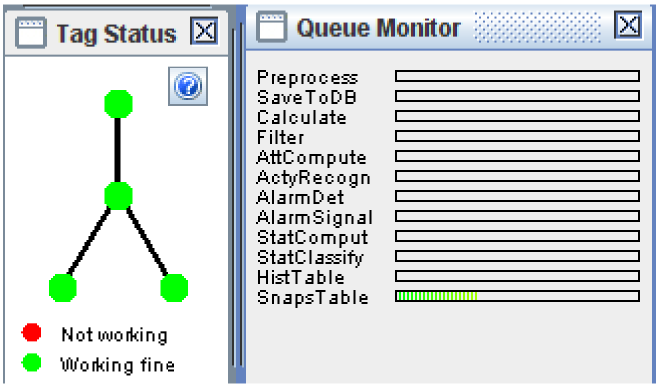

Figure 6: *Tag status and queue monitor*

body tags. Nevertheless, some position (and acceleration) data can be missing. In order to bypass these shortages the filter modules approximate the position of missing tags. The second task is to filter the noise and smooth the tags' data. This is done with six independent methods. For example, one method corrects the data by taking into account the body anatomic constraints.

The filtered data is the input to the posture modules. These modules consist of two modules working in parallel. The first module uses Random forest classifier [4] in order to get the current user posture, e.g., sitting, standing and walking. The second module consists of expert-knowledge in the form of a set of rules that classifies the current posture. The final posture is selected using heuristics and Hidden Markov Models [5] for smoothing the posture transitions. The detected user posture is shown on the control panel (Figure 7).

At the end of the posture modules the pipeline data flow splits into two directions since user posture is used as the input to the two sets of modules: interpretation and prevention modules.

Interpretation modules detect situations that are potentially dangerous for the user. An example is the user lying immovable for a prolonged time at an unusual place. Such situation may indicate that the user has lost consciousness. This is potentially hazardous/alarm situation and therefore it

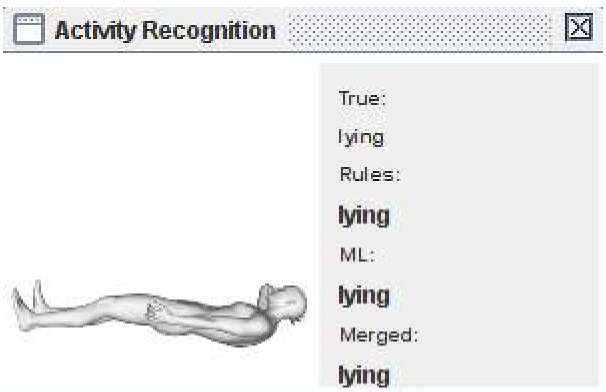

Figure 7: *Activity recognition showing the current activity*

Figure 8: *Alarm monitor showing an alarm*

is reported to the user and in the case that there is no response from the user, the hospital or care-giving center is informed. In order to recognize hazardous situations two modules have been implemented. The first module uses expert knowledge while the second uses machine-learning algorithms in order to recognize alarms. The expert knowledge was retrieved from experts' know-how while the machine-learning algorithms, namely C4.5 [6] and SVM [7], use prebuilt models. The final decision is given by fusing both predictions using heuristics. If an alarm is produced, it is shown in control panel (Figure 8) and portable device (Figure 9).

Prevention modules monitor how the user moves and recognize the development of a disability. This is done by collecting the statistic data about the user movement, i.e., monitor user behavior. When monitoring the behavior for a prolonged time, the changes in behavior can be observed. If the change is significant, it may indicate that something is wrong with the user, e.g., if the user begins to limp, he/she might have had a stroke. The behavior change is calculated with LOF [8]. The collected statistic data are gait, turning, activity and spatial characteristics, which are constantly updated with the recent behavior that enables automatic adaptation to the user behavior. When the modules recognize a change at any of those statistics, a warning is fired and shown on the control panel (Figure 10) and portable device on user's request (Figure 11).

Figure 9: *Portable device showing an alarm*

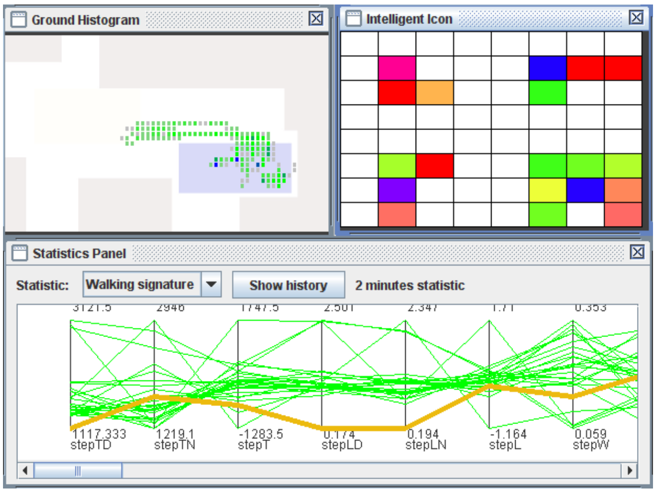

Figure 10: *A warning showed in control panel with the yellow line*

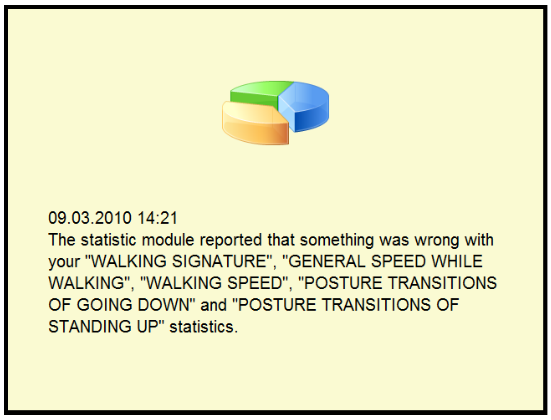

Figure 11: *Portable device showing a warning*

3 MANUALS

Several manuals have been produced describing the presented system and its functionalities. The first one it the System manual that describes the whole system and all of its modules in detail. In addition, it describes the installation of the system and the tag placement.

The second manual is the Recording instructions. It presents how a user can record the data for testing purposes step-by-step. In addition, the preferred scenarios for testing are also described.

The third manual is the User manual that describes the portable device and the possible interaction with it. It shows all the possible screens and messages and the keys that can be used to manipulate with the portable device.

The last manual is the Init wizard. It describes the required initialization of the system when it is used for the first time. It also describes which actions have to be recorded, possible errors during the initialization, and which data must be inserted by the user.

4 SYSTEM TESTING

The system testing was focused on the interpretation and prevention modules. Therefore, the interpretation modules were tested with the following scenarios, where the accuracy is given in brackets: a normal behavior (100%), lying down normally (100%), tripping (97%), fainting (91%), sitting down quickly (possible false alarm, 97%) and lying down quickly (possible false alarm, 100%). In addition, the prevention modules were tested with the following scenarios where results are given in brackets: a normal day (no warnings), a limping day (all the statistics produced at least one warning out of five behavior testing) and a slow day (all the statistics produced at least one warning out of five behavior testing, one statistic produced four warnings).

5 CONCLUSION AND FUTURE WORK

This paper presents the system implemented for the work package 3 of the EU FP7 project Confidence. It describes the functionally of the whole system and all its modules. The tests show that the system is reliable and is ready to be tested in the real world.

The future work includes the long-term testing. In addition, this system has to be integrated with the other systems into the final product.

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