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Development and integration of CGA platform

Report on the development and the integration of the CGA platform including data management, cognitive and physical tests.

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Introduction

The ASSESSTRONIC solution is designed to do autonomously or assist the caregivers during the CGA process to assess patients' functional, mental and physical conditions.
It is a modular solution consisting on 2 different components to maximize the possibility of tests parallelization while limiting the costs for the hospitals. The idea is to allow the use of the technology that is strictly necessary for each test and avoiding unnecessary complexity (and consequently costs).
The solution proposed is structured on 2 modules:

- The tablet PC: it consists on an Android tablet pc running an interface that can be used by the patients and relatives for the tests and by the doctors both to perform the tests and to access to patients' data
- The workstation: it consists on a compact device for performing physical-based tests. This device communicates with the tablet PC user interface to launch the tests and display the results.

The workstation module can be used as stand –alone or can be mounted on a mobile platform, which can be a standard medical cart or a mobile robotic platform existing on the market. This last configuration can be used to perform physical tests that require big displacements of the user (more than 3 meters).

Hardware

The tablet PC used for the cognitive tests and for the doctor to have access to the patients' history has to run an Android OS and has to dispose of a frontal camera for filming the patients' face during the tests. These recordings are used for the facial expressions analysis and potentially for additional multimodal analysis (sound, gaze direction and so on).

The workstation module includes a powered 3D camera (Kinect v2), a processor and a couple of laser pointers (with adjustable orientation) for running physical-based tests. This module can be used as stand-alone or can be embedded on any telepresence mobile robot to guarantees the constant visibility of the patient, to increase the quality of the information (signal / noise ratio) gathered by the sensors, which would also simplify the signals processing and improve the algorithms performances.

Architecture

The system architecture is shown in the picture below.

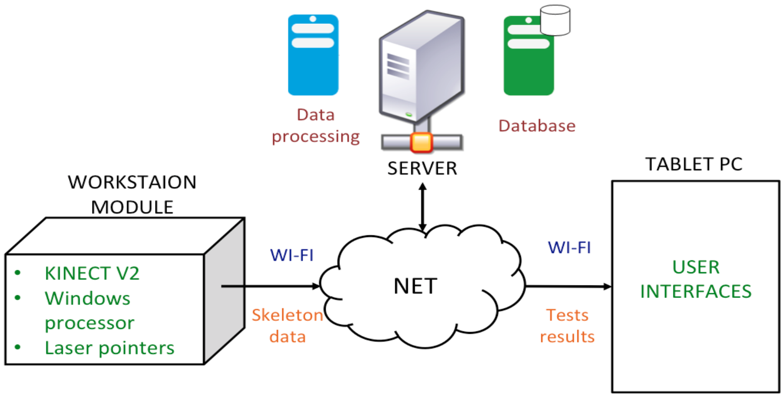
The user interfaces are runnable on Android tablets. The software can be run on 3 different modes:

- Patient mode, to present the survey forms
- Relative mode, to present the Barthel test form
- Physician mode, to perform manually the tests, to consult the tests results and manage the patients' data (including adding new patients in the database)

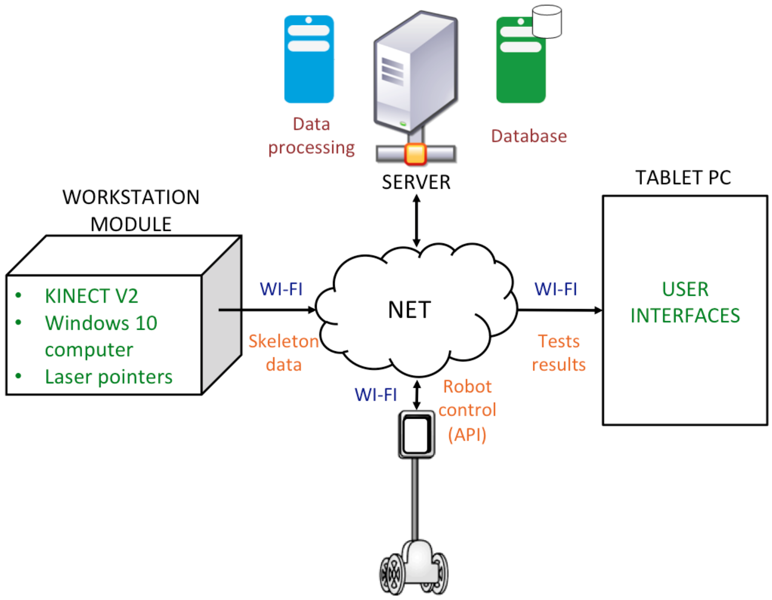
During the tests, the patient can interact with the system through the voice. Google speech recognition and synthesis have been integrated in the interface in order to offer to the user an interaction channel as natural as possible.
The workstation module processor runs a skeleton detector and tracker software during physical tests and collect the skeleton data by using a Microsoft Kinect camera. This data is sent to the server for storage and analysis. The laser pointers are used to spot on the floor the start and the end points of the physical test.

The server is used both as database to store raw and processed data (videos, audio tracks, tests results etc.) and as processor to perform the analysis of the collected data (to compute both the physical and cognitive tests results).

All the necessary backend services for client software are provided as webAPI in REST style.

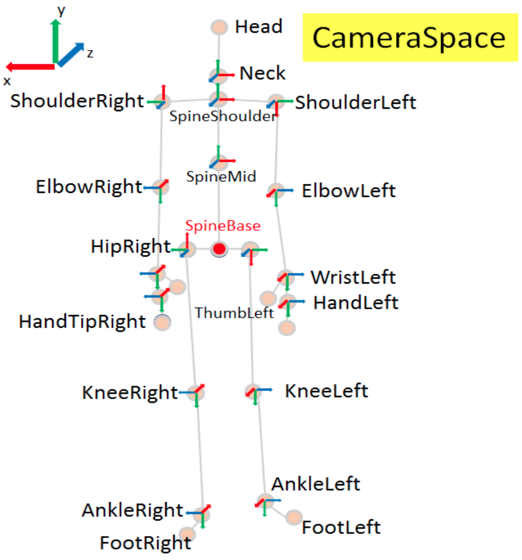


In the configuration including a telepresence robot, the architecture comprises an additional unit (see picture below). Provided that the platform control software is accessible through API, the server exploits the data collected by the workstation module to move the robot according to the users' movements and uses the information about the robot displacements in order to recalculate the users' displacements in a global reference frame.



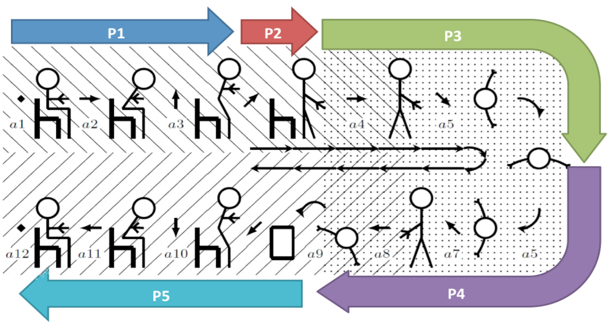
Physical tests algorithm

The workstation module collects the user's movement information by using the embedded Microsoft Kinect sensor. The 3-dimensional position of 25 body joints (see picture below) are extracted and used as input for the analysis algorithm. Raw and processed data is recorded during the test in order to allow further analysis and to verify the results given by the algorithm in any moment.



First of all the algorithm analyse the collected data in order to identify the different phases of the test. We have defined the 5 phases shown in the figure below:

- Phase 1 (P1): getting up from the chair
- Phase 2 (P2): standing before walking
- Phase 3 (P3): walking forward
- Phase 4 (P4): walking back
- Phase 5 (P5): sitting back on the chair



All the phases are analysed separately and the overall performance is scored with a scale from 1 to 5 meaning:

1. Well-coordinated movements, without walking aid -> No fall risk
2. Controlled but adjusted movements -> Low fall risk
3. Uncoordinated movements -> Some fall risk
4. Supervision necessary -> High fall risk
5. Physical support of stand by physical support necessary -> Very high fall risk

Different factors, including spatio-temporal parameters, which are considered to be relevant[1], are considered for the final score computation:

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[1] Wolfson, Leslie, et al. "Gait assessment in the elderly: a gait abnormality rating scale and its relation to falls." *Journal of Gerontology* 45.1 (1990): M12-M19.

- Time
- Step length
- Number of steps
- Step frequency
- Velocity gait
- Arm swing amplitude
- Upper-lower body synchrony

Besides the observed patient's motion behavior, the performance could be analysed by taking into account other sensorimotor and psychological factors. For instance, the patient's visual condition (acuity, contrast sensitivity and depth perception) as well as mood, pain, anxiety and depression have been proved to have a significant impact on the standing movement performance.[2] Knowing these patient's details, the overall assessment of his mobility condition could be even more accurate.

Cognitive tests algorithm

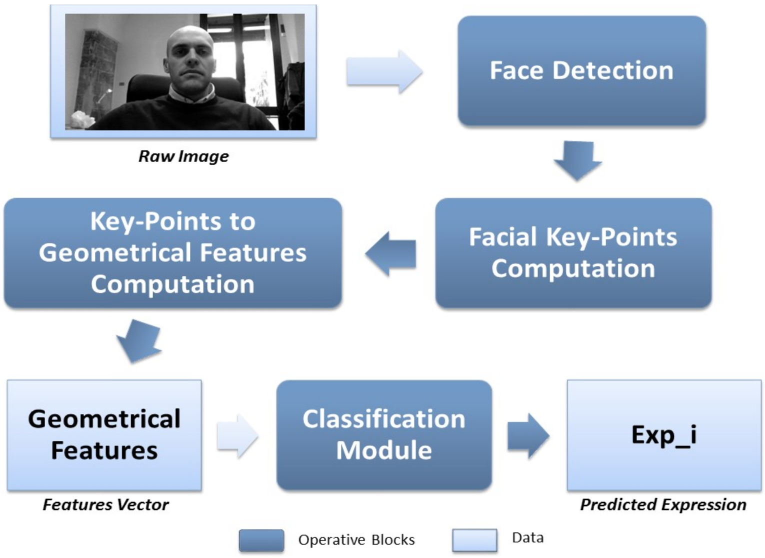
The cognitive tests are performed by the patients, the relatives or the doctor (if the doctor choses to perform the tests manually by himself) through a friendly interface on the tablet PC.
When the interface is running in patient mode, also a voice interaction is activated during the tests.

Additionally, the tablet face camera records the patient's face during the tests in order to perform the facial expression analysis.

The algorithm used for the facial expression analysis is based on facial geometrical features[3]. A set of 32 geometrical features is used in order to automatically recognize the six primary expressions plus neutral: AN=Anger, DI=Disgusted, FE=Fearful, HA=Happy, SA=Sad, SU=Surprised, and NE=Neutral.
The software is conceived to recognize frontal face facial expressions and several computer vision algorithms or steps are necessary. In the figure below each step is illustrated.

[2] Lord, et al. "Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people." *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 57.8 (2002): M539-M543.

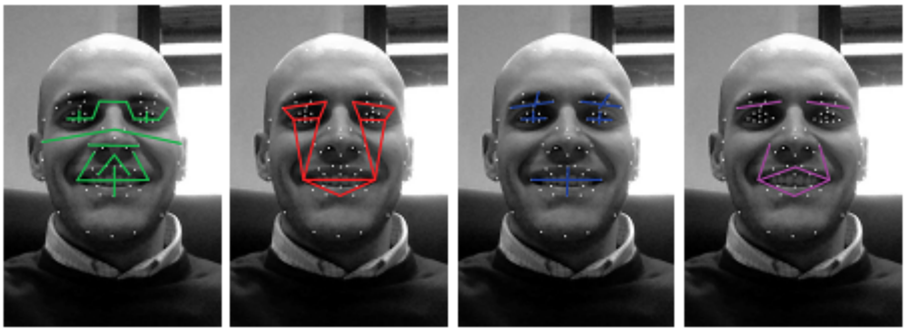
[3] Palestra, et al. "Improved performance in facial expression recognition using 32 geometric features." *International Conference on Image Analysis and Processing*. Springer, Cham, 2015. p. 518-528.



Face detection and facial key-points computation are the first steps. These steps are based on STaked Active Shape Model (STASM), a technique for locating key-points in images of human faces that uses OpenCV library. STASM works with the same OpenCV frontal face detector, an improvement of the well-known Viola and Jones object detector, and this technique identifies 77 landmark points on the face.
The next step of the software is the computation of geometrical facial features. Once the facial key-points are available they are given as input to the geometrical features computation module that computes 32 geometrical features.
The software uses 32 facial features related to four categories:

- linear features;
- polygonal feature;
- elliptical features;
- angular features.

In the figure below the geometric features are illustrated.



Finally, the computed features are analysed by a classification module to get a classification of the facial expression.