CogWatch: Cognitive Rehabilitation of AADS. Hand Tracking system based on Kinect for cognitive rehabilitation

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Introduction

- **CogWatch** is a STREP project under **EC FP7 Programme 2011-2014**. The project exploits **intelligent tools**, **objects** and **wearable devices** to provide personalized **cognitive rehabilitation** at home for stroke patients with **Apraxia and Action Disorganization Syndrome** symptoms.
- Start date: 1st November 2011.

PARTICIPANT	COUNTRY
Birmingham University (UOB)*	United Kingdom
Universidad Politécnica de Madrid (UPM)	Spain
Technische Universität München (TUM)	Germany
The Stroke Association (TSA)	United Kingdom
Headwise (HW)	United Kingdom
BMT Group Ltd (BMT)	United Kingdom
RGB Medical devices (RGB)	Spain

OUTLINE

- Introduction
- Main objectives
- Kinect for tracking movements
- Experiments and results
- Conclusion

Introduction

- Cerebrovascular diseases usually change the way of living. **Apraxia and Action Disorganization Syndrome** (AADS) is one of the most frequent cerebrovascular diseases that 68% of people suffer after stroke.

- It causes **long periods** of time for rehabilitation and too much dependence on clinicians.

- **Novel** systems are required in order to **reduce hospitalization time**, **increase quality of living** and improve rehabilitation rates.

- Implementation of **low-cost devices** that helps during cognitive rehabilitation.

Introduction

- **Possible consequences** of cerebro-vascular deseases:

- Paralysis
  - Weakness
- Cognitive deficits
  - Apraxia
  - Agnosia
  - Absence
- Deficits in language
  - Aphasia
- Pain
  - Emotional

Introduction

- **Action Disorganization Syndrome:**
  - ✓ Neuropsychological disorder after brain injury. First described by Schwartz. Characterized by a high proportion of **cognitive errors**, is not caused by a motor deficit.
- **Apraxia:**
  - ✓ **Disorder of skills** affecting the ability to control motor movements and gestures properly.

TYPE OF APRAXIA	DEFICIT INVOLVED
Ideo motor	Hard moves using tools or making gestures
kinematic	Dexterity, manipulation
Ideational	Secuential tasks with multiple objects
Conceptual	Knowledge of tools and their use

COGWATCH PROJECT

COGWATCH PROJECT

- Main users of the CogWatch project are:
  - Patients
  - Clinician/Hospital.

- Sites and tasks to carry out:
  - Sites: Birmingham, Munich and Madrid.
  - Scenarios: kitchen, bedroom, bathroom, lounge.
  - Tasks: preparing coffee, eat a toast, washing hands, etc.

COGWATCH PROJECT

- The main objectives of the whole system are as follows:
  - ✓ **Monitor the actions** AADS patients carry out in their daily living.
  - ✓ Facilitate **successful completion of tasks** by preventing AADS errors through action guidance multimodal cues.
  - ✓ **Correct AADS errors** through feedback loops that use multimodal cues that make patients aware of their errors and how appropriate actions should be carried out in order to correct them.
  - ✓ **Prevent** risky situations.
  - ✓ Improve rehabilitation outcome through **continuous and persistent errorless practice**.
  - ✓ **Kinematics analysis**, behavior and physiological factors to **assess progress** and detect possible new episodes and/or deterioration of the syndrome.

DEVICES AT HOME

Task objects

- **-** Kettle.
- **-** Cup.
- **-** Tea bag.

VTE monitor

- Multi touch screen.
- **Virtual task execution**.
- **Storage** of image/video data and hand position.
- **Computation** of simulation graphs and error detection.
- **Generation** of vibration signals, statistics.
- Post-processing of video data.

Kinect

- **Hand position/motion** detection.
- **Video recording**.

Wearable device

- **Vibration** as alert feedback.

DEVICES AT HOME

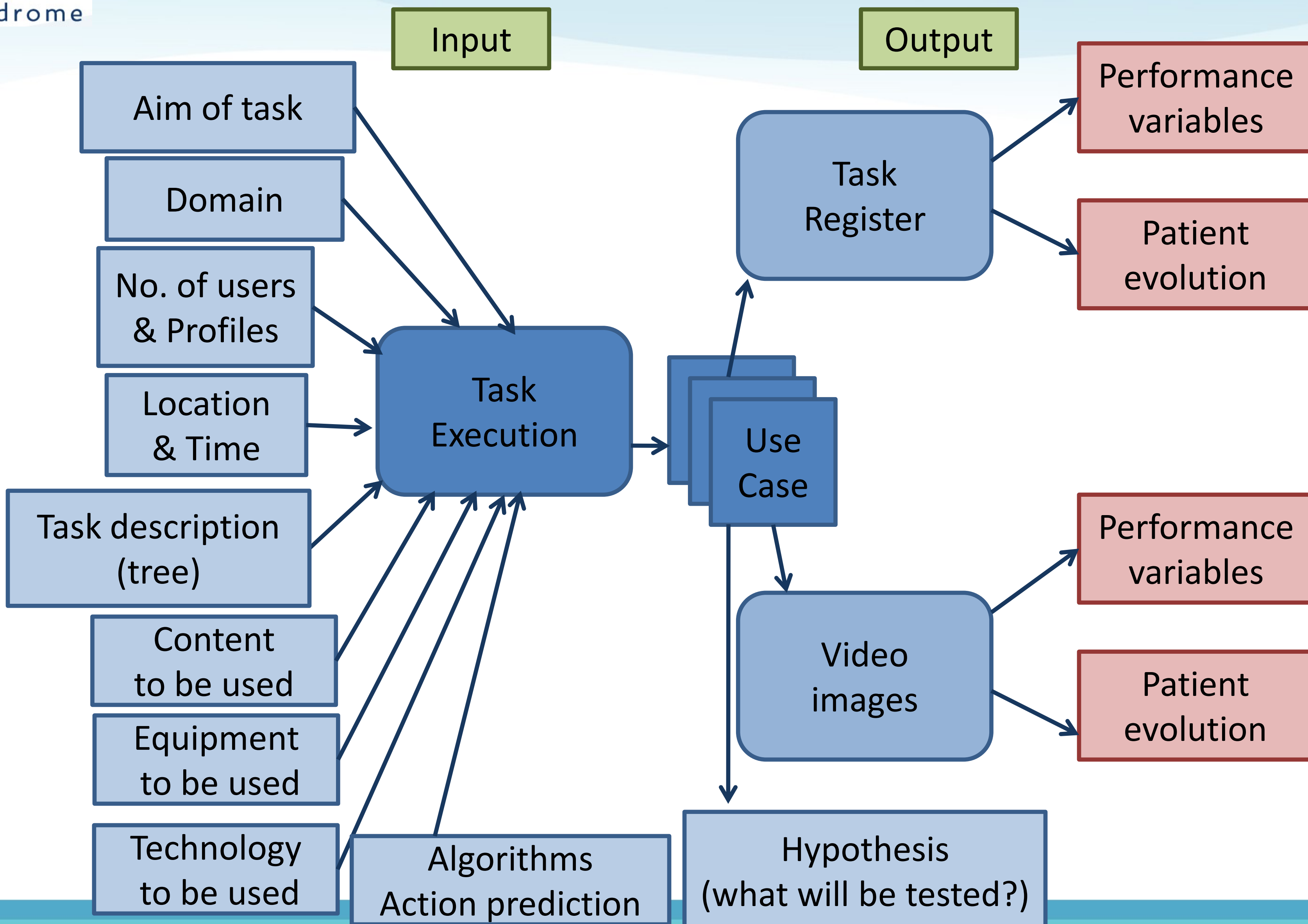
- "**All-In-One**" computer (**VTE monitor + central processor**) improves the flexibility, ergonomy and simplicity of the system.

- Wearable device is a **brand – new watch** that the patient must wear on the wrist.

- Task objects will be equipped with **grip sensor**, **accelerometers** and **RFID** in the future.

- Kinect provides a good method of **tracking and video recording** in a low-cost way. Microsoft is working on new versions of this device, so best features for the project can be available. Having two cameras and the infrared projector a good motion tracking can be done.

COMPONENTS AT HOSPITAL



Tasks definition

Level 0: task name

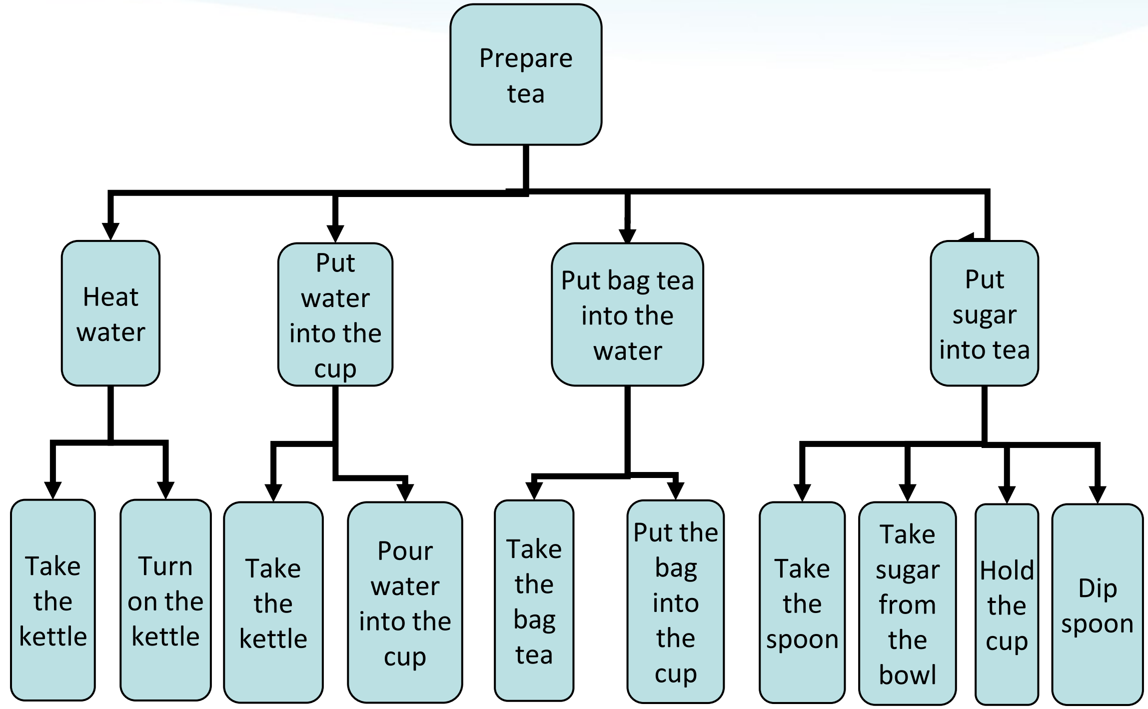
(sound and text)

Level 1: main steps

(text and pictures)

Level 2: detail execution

(graphical simulation)



Can be used the resolution level as a metric of patient evolution?

KINECT

- Components of Kinect:

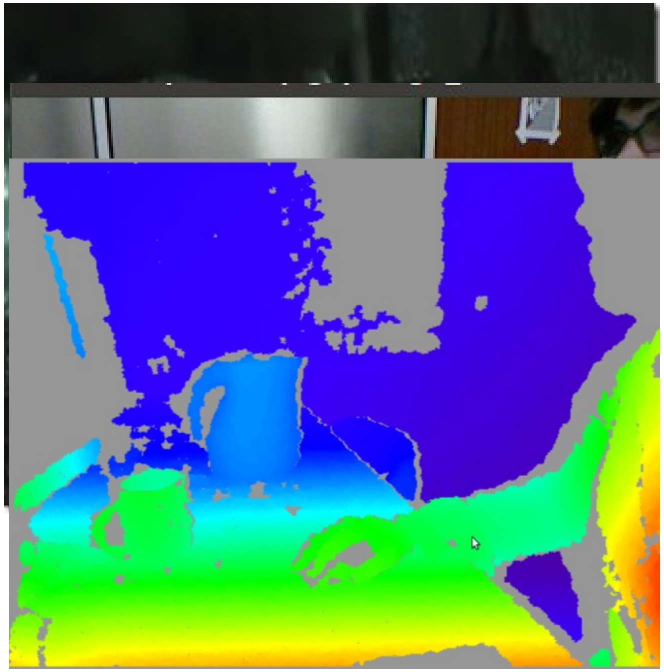
✓ **Infrarred** projector.

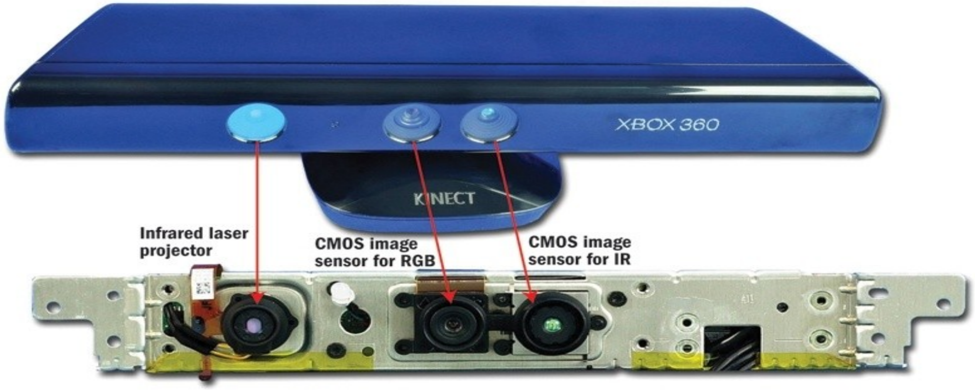
✓ **RGB** camera.

✓ Infrarred camera.

✓ Motor.

✓ Microphones.





KINECT

- For patients/clinicians:
  - ✓ Inputs: **None**.
  - ✓ Outputs: **Hand movement tracking** and **video recording of the scenario**.

- For system specifications:
  - ✓ Inputs: - **43º vertical by 57º horizontal** field of view.

    - A mechanized tilt range (vertical) of **+/- 28º**.
  - ✓ Outputs:

    - **30 frames per second** of color, depth and 3D stream.

    - Resolutions: depth stream = **320x240 (QVGA)**;

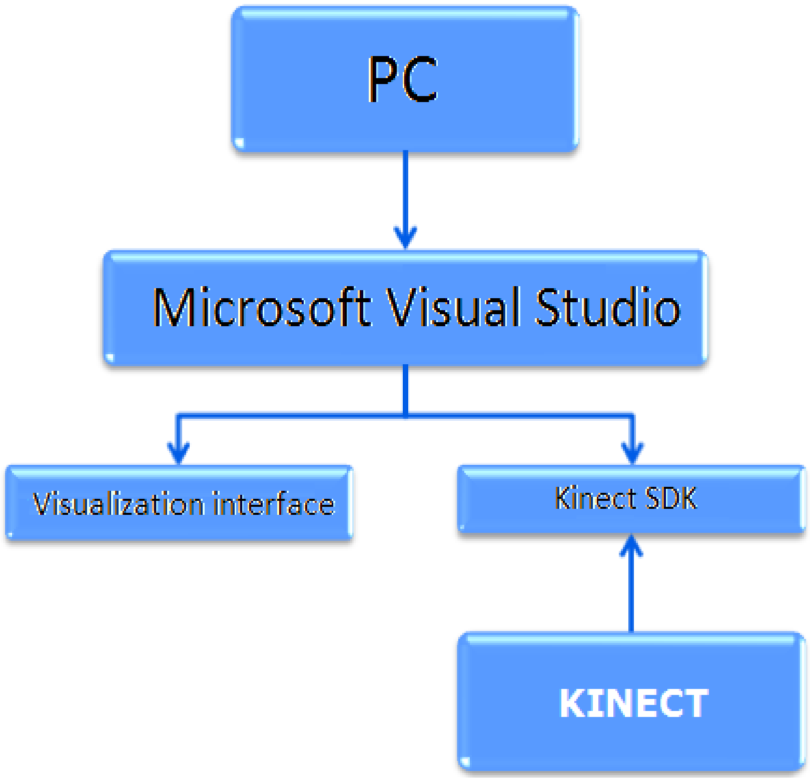
      color stream = **640x480 (VGA)**.

    - **X, Y, Z coordinates** of hands position.

KINECT

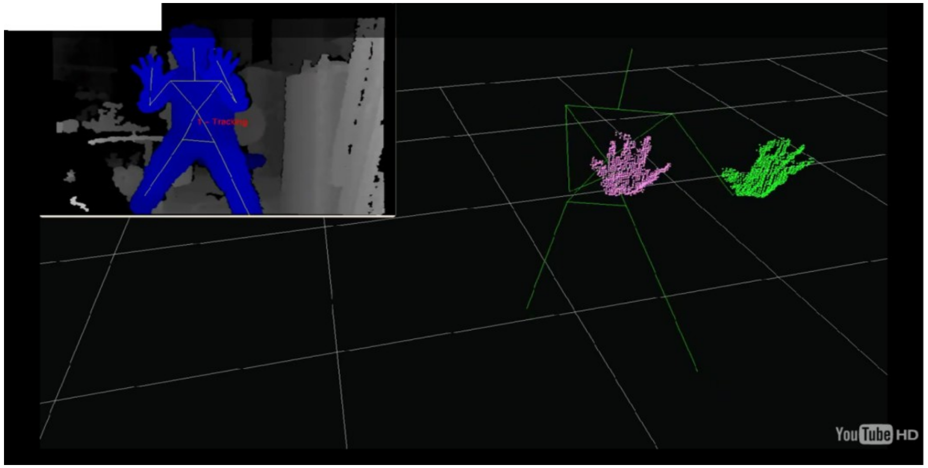
➢ Patient detection and tracking:

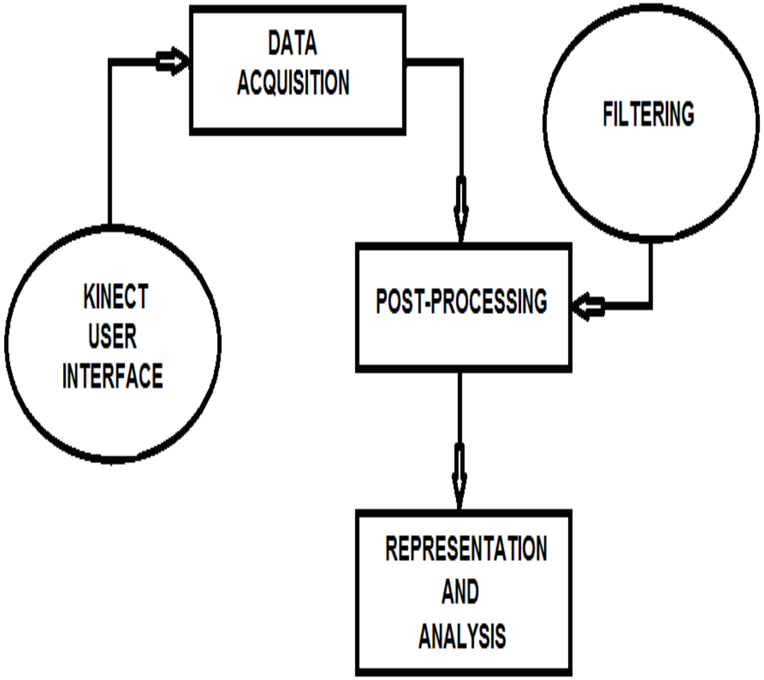
1. **Video** is provided by Kinect cameras.
2. **Kinect SDK** which provides the different functions for the communication with the device and the patient detection and movements.
3. Monitor data acquisition and develop user interface by using **Microsoft Visual Studio**.



KINECT

- Hands motion data processing:
  1. Inputs from user interface.
  2. Data acquisition.
  3. Post-processing (filtering).
  4. Analysis.





CoG WATCH
Cognitive Rehabilitation of Apraxia & Action Disorganisation Syndrome

KINECT

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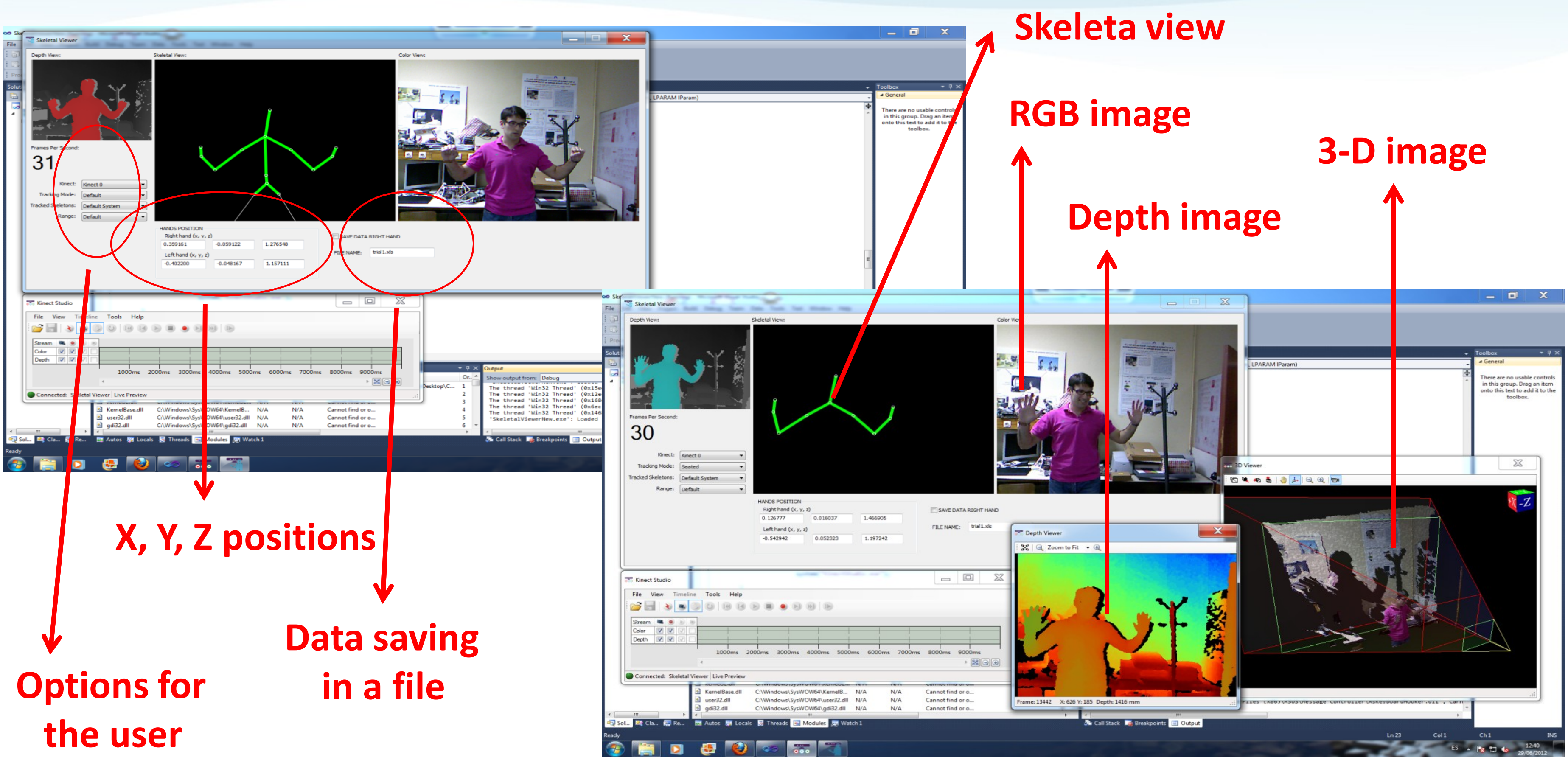


KINECT

- For hand movement tracking, lighting condition **is not relevant**.

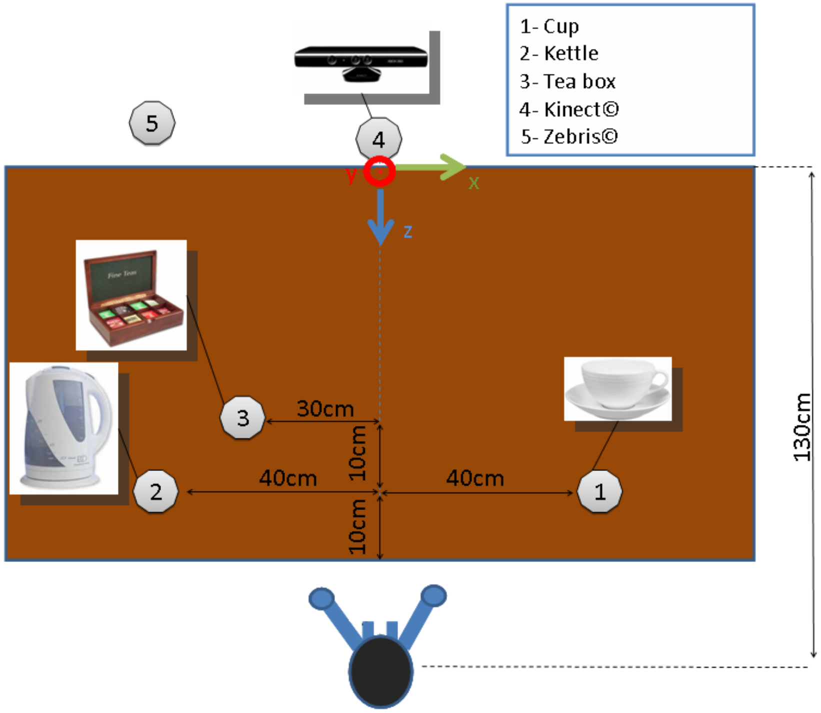
- Optimal distance between Kinect and patient = **1.2 to 3.5 m**, preferably, **1.3 m**.

- **No need of calibrating** Kinect on Windows.

- Error increases as distance to Kinect increases. **Error ≈ 2-4 cm when** located at the nominal distance. At larger distances, the quality of the data is degraded by the noise and low resolution of the depth measurements.

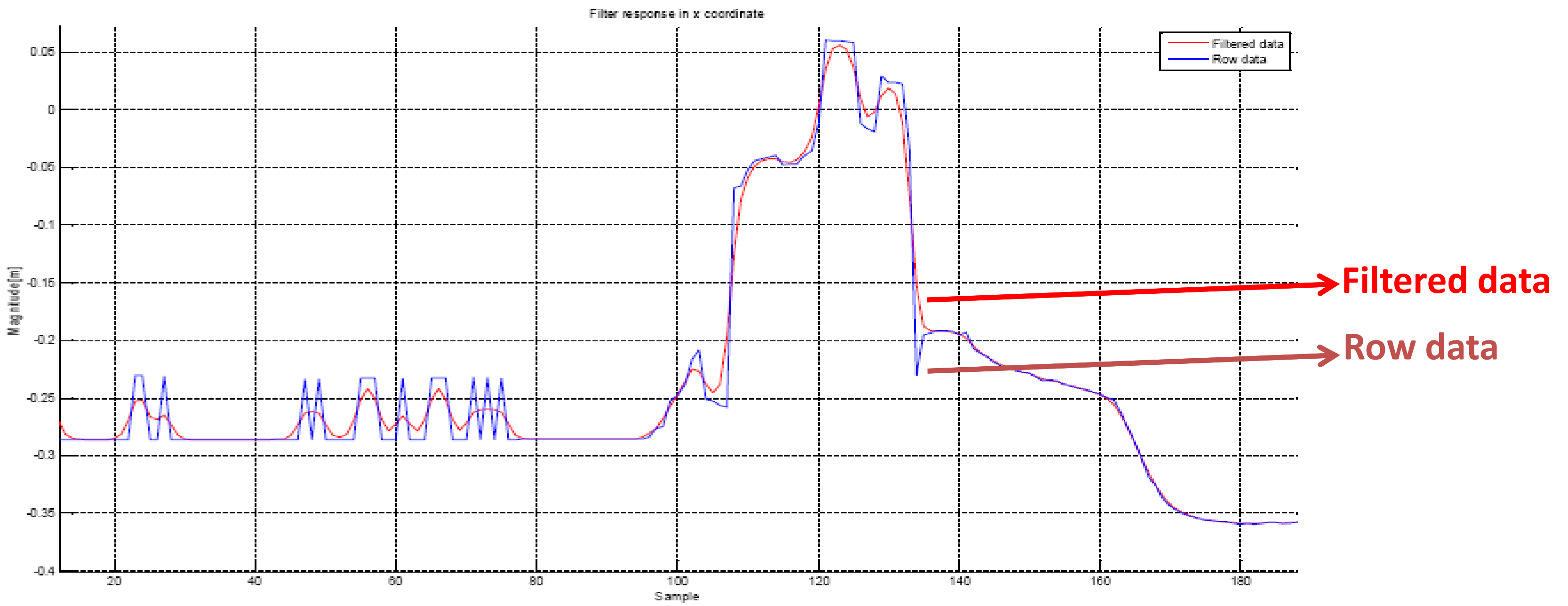
EXPERIMENTS AND RESULTS

- The task performed is composed by the following steps:
  1. Reach and grasp the cup.
  2. Transport the cup to target position.
  3. Reach and grasp the tea bag.
  4. Place the tea bag into the cup.
  5. Reach and grasp the kettle.
  6. Transport the kettle to position over cup.
  7. Pour the water from the kettle into the cup.
  8. Place the kettle back on table.
  9. Reach the tea bag.
  10. Stir the tea bag in the cup.



EXPERIMENTS AND RESULTS

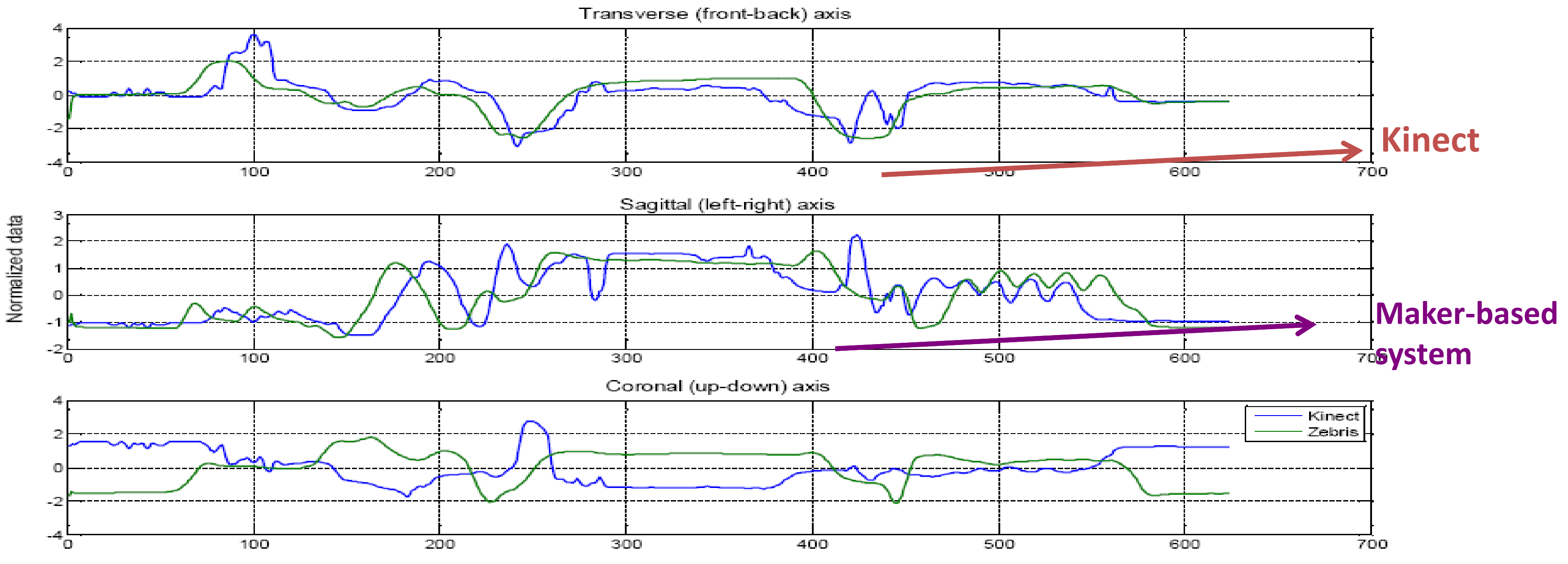
➢ Kinect data is filtered using a **Butterworth filter**:



EXPERIMENTS AND RESULTS

Workshop: Perception in Robotics

- For kinematics analysis and proof of suitability for Kinect, the data is **compared with a marker-based ultrasonic motion capture system**:



EXPERIMENTS AND RESULTS

- The average **Mean Square Error** (MSE) and **cross-correlation values** for each dimension are obtained:

	Mean square error (MSE)			Cross – correlation		
	Transverse	Sagittal	Coronal	Transverse	Sagittal	Coronal
Mean	1.143	0.938	1.074	0.427	0.489	0.525
Variance	0454	0.417	0.453	0.114	0.137	0.075

EXPERIMENTS AND RESULTS

- Average MSE values **are similar for all dimensions**, and ranged from 0.938 for the sagittal axis, 1.074 for the coronal axis, to 1.143 for the transverse axis.

- The cross – correlations between Kinect and the marker-based system are: 0.427 for the transverse axis, 0.489 for the sagittal axis, and 0.525 for the coronal axis. Based on **Cohen scale**, these results indicate a medium correlation between both systems for the transverse and sagittal axes, and a **strong correlation** for the coronal axis.

- In summary, the results show that motion capture with Kinect is feasible and suitable for kinematic analysis of **Activities of Daily Living** (ADL). So, the current experiment demonstrates the potential use of Kinect system in cognitive rehabilitation.

EXPERIMENTS AND RESULTS

- The experiment is carried out by healthy people in order to assess the performance of the system.

- Main advantage of Kinect: its **continuous development**.

- **Up to 4 Kinect** sensors can now be plugged into the same computer and no calibration is needed (using Windows), which is quite interesting in order to improve and increase accuracy in tracking and future possible recognition of the movements taking into account the kind of patients to be treated.

CONCLUSIONS

- Kinect is able to track 3D hand position adequately, from which relevant kinematic variables can be calculated.

- The applications developed in the CogWatch project will be initially used by clinicians, but as proven in the results, Kinect could also be a useful tool for home rehabilitation, which is the main objective to be reached at the final stages of the project.

- Overall, while more research could be done within the capabilities and limitations of the device in physical rehabilitation, this work verifies Kinect as a **highly potential tool for cognitive rehabilitation** for both clinicians and stroke patients.

FUTURE WORK AND ACKNOWLEDGMENTS

➢ Future work:

- ✓ More detailed experiments will involve **multiple ADL tasks** (e.g., making toast, putting on a shirt, etc.).
- ✓ Various AADS patient populations (e.g., left-brain damage, aphasic).

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