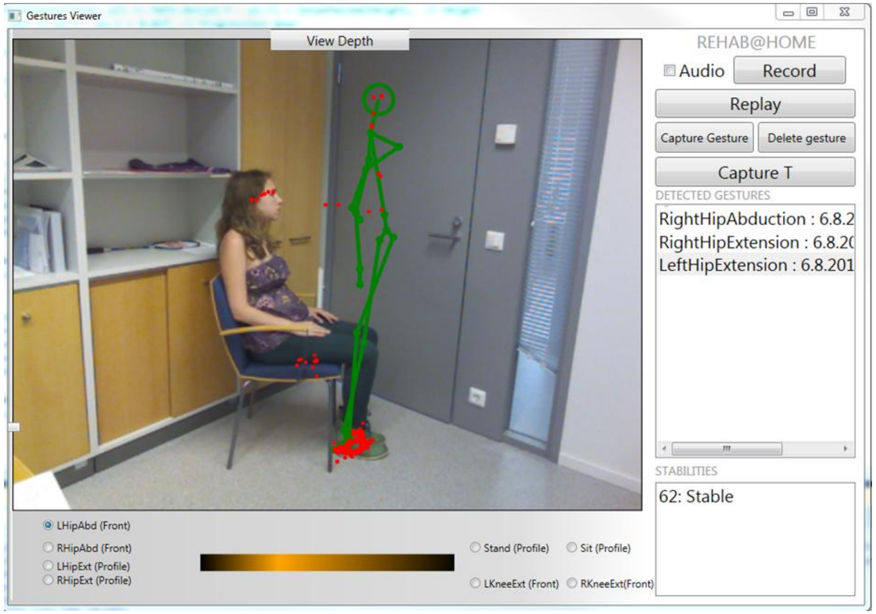
M3 interoperability for remote rehabilitation with Kinect



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Open International M3 Semantic Interoperability Workshop 12.11.13

Introduction

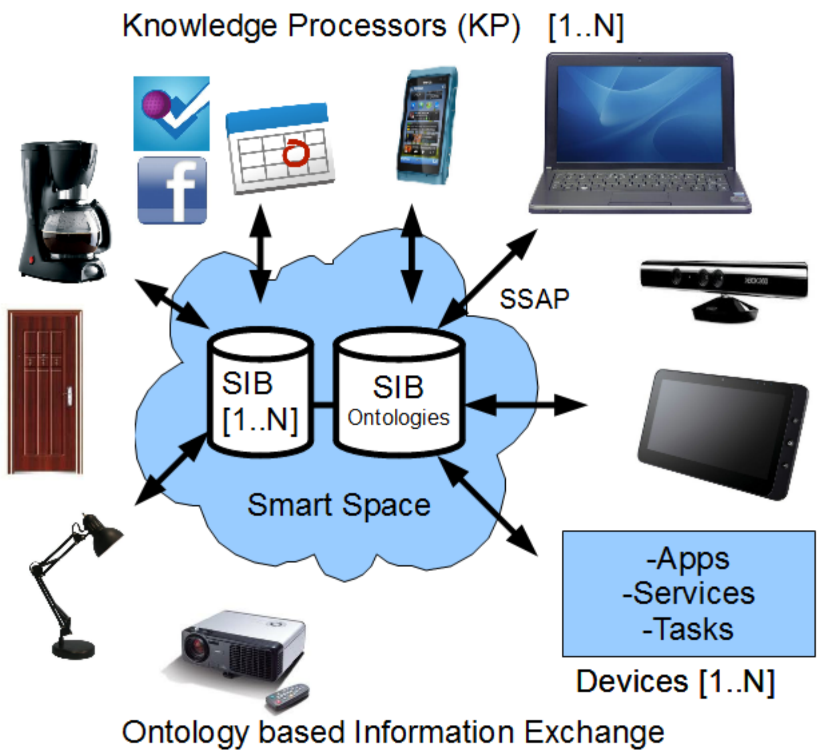
- Context:

Ambient Intelligence and Smart Spaces

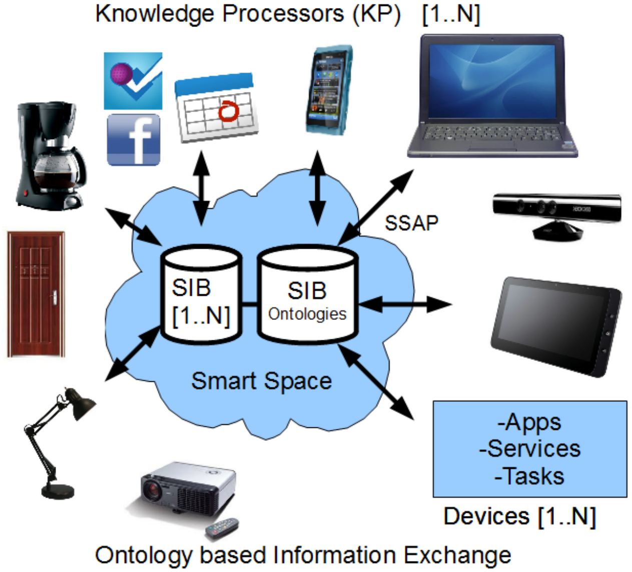
- A crucial task:

Human behaviour modelling and recognition

- Technology for detection of in home activities
- Elderly care



Introduction



- Context information:

  stress, heart rate, sleep quality, mood, etc.
- Semantic Technologies and Ontologies:
  – Independent knowledge sharing minimizing redundancy.
- Use case: Rehabilitation @home
- Input: 3-D Depth sensor
  – body movement and interaction

Related Work: exercising at home

- Different exercise applications based on 3D depth cameras
  - Virtual Social Gyms
  - Physical therapy
  - Eyes-Free Yoga

[http://mobihealthnews.com/22351/slideshow-7-startups-using-microsoft-kinect-for-online-physical-therapy/]

Proposal: Rehab@Home Application

- Aim:
  - Recognize & Monitor simple orthopedic exercises
    - After **shoulder, hip *or* knee surgery.**
    - **Sit-Stand** exercise.
  - Give feedback
    - To the **patient:** on quality & frequency of the exercise. Real-time.
    - To the **physiotherapist**: remotely
- 3 Ontologies:
  - AHA platform with heterogeneous sensor data
  - Privacy and security ontology
  - Kinect Ontology[1]

[1]To be presented in UCAmI'13: *Understanding Movement and Interaction: an Ontology for Kinect.*

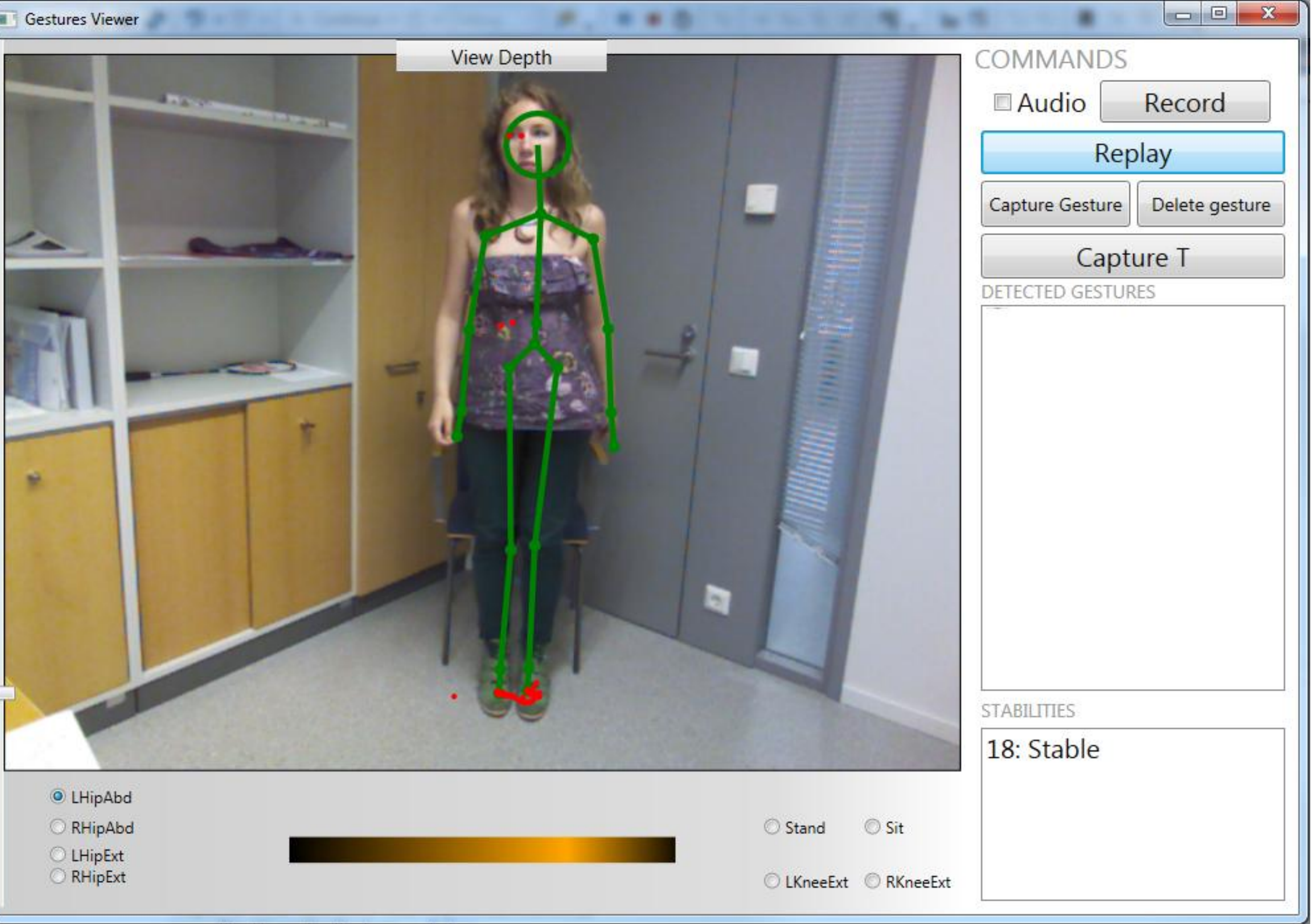
Implementation

- Tracking & recognition: Kinect for Windows SDK C#.
- Postures & session info: input to M3 (visualized in *WebSIBExplorer*).
- Aim: run in ARM processor
  - Atm: Kinect drivers don't allow it => we use linux Atom board running M3.
    - Dual core Atom N2800 @ 1.86GHz 4 GB RAM SSD storage (Power consumption: 16W, ~12W in idle)
    - Future: Odroid cluster (~24W, 8W in idle).
  - Efficient cluster, low-power, persistent & distributed M3 architecture (for now RedSIB)
- Gathering sensor info, allows execution of semantic queries (SPARQL) and further knowledge reasoning (e.g. long term evolution of back posture).

User Interface

Allows feeding patterns from new users realizing exercises for the system to learn:

- **Record** and **Replay**: Records a session for training the system. Audio option activates and ends recording via voice ("*Record*", "*Stop*")
- **Stabilities**: Indicates the degree of stability of the skeleton tracked.
- **Capture** and **Delete Gesture**: Adds (and deletes) a template gesture to a gesture learning model.
- **Capture T**: adds a template posture to a posture learning model.
- **View Depth/View color**: Shows depth/color image
- **Exercises** to be trained & recognized:
  - In FRONT position with the camera:
    - **Left and Right Hip Abduction**
    - **Left and Right Knee Extension**
  - In PROFILE position with the camera:
    - **Left and Right Hip Extension**
    - **Sit and Stand**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View Depth
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Capture Gesture
Delete gesture
Capture T
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STABILITIES
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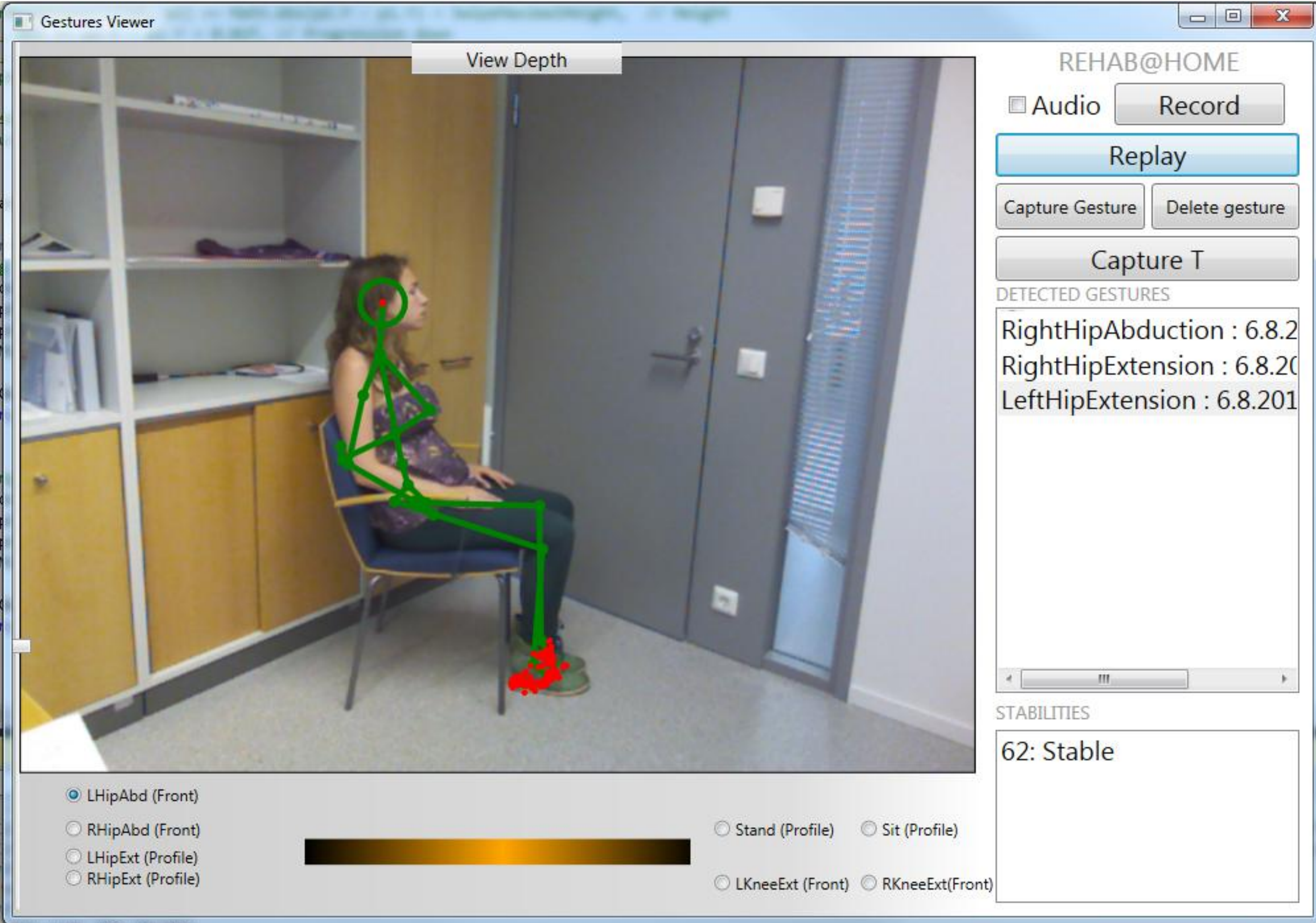
RHipExt
Stand
Sit
LKneeExt
RKneeExt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RightHipExtension : 6.8.20
LeftHipExtension : 6.8.201
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62: Stable
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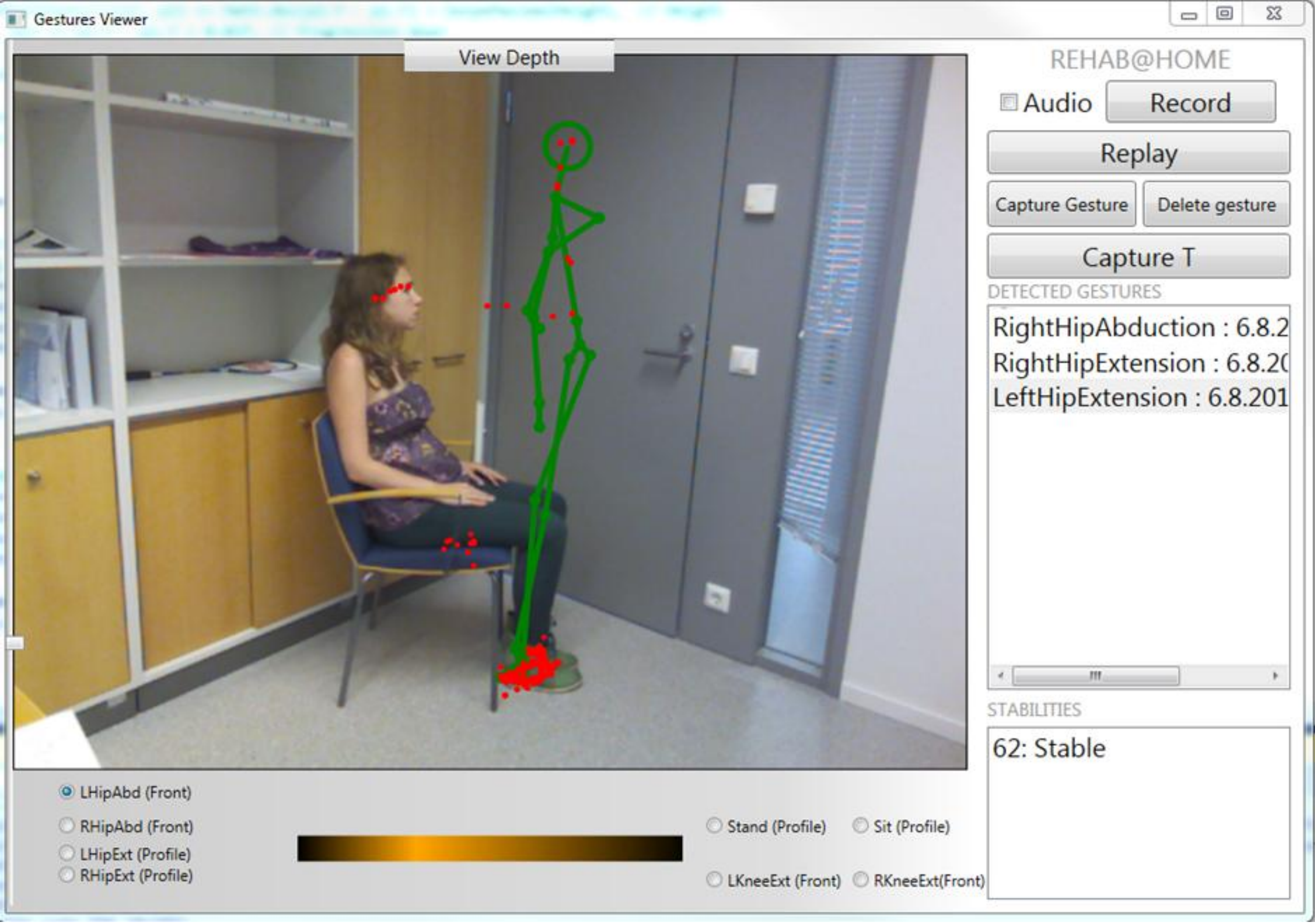
RHipAbd (Front)
LHipExt (Profile)
RHipExt (Profile)
Stand (Profile)
Sit (Profile)
LKneeExt (Front)
RKneeExt(Front)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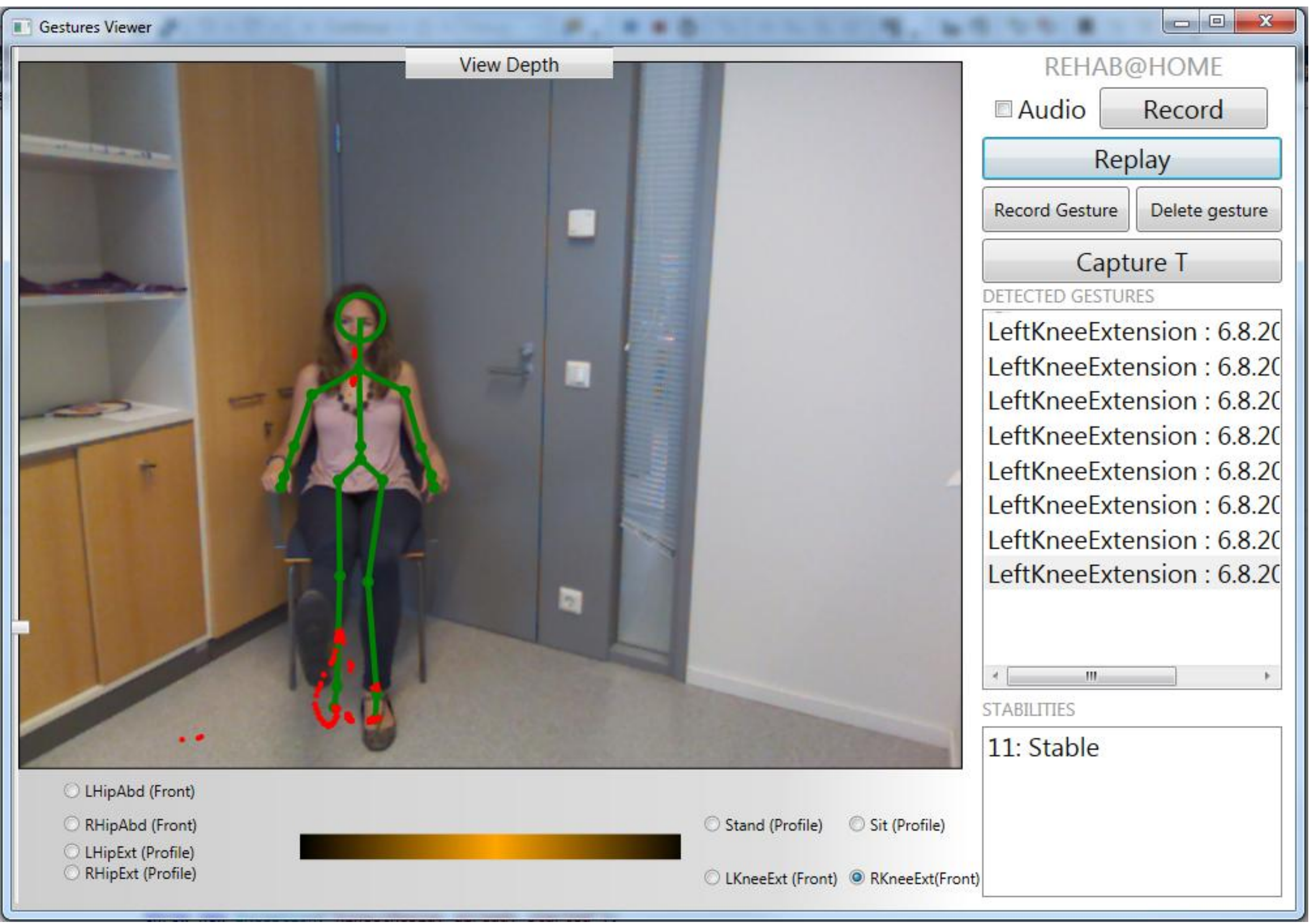
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5 times Sit to Stand Test (*)

- Metaanalysis results "demonstrated that individuals with times for 5 repetitions of this test exceeding the following can be considered to have worse than average performance" (Bohannon, 2006)

  60-69 y/o 11.4 sec

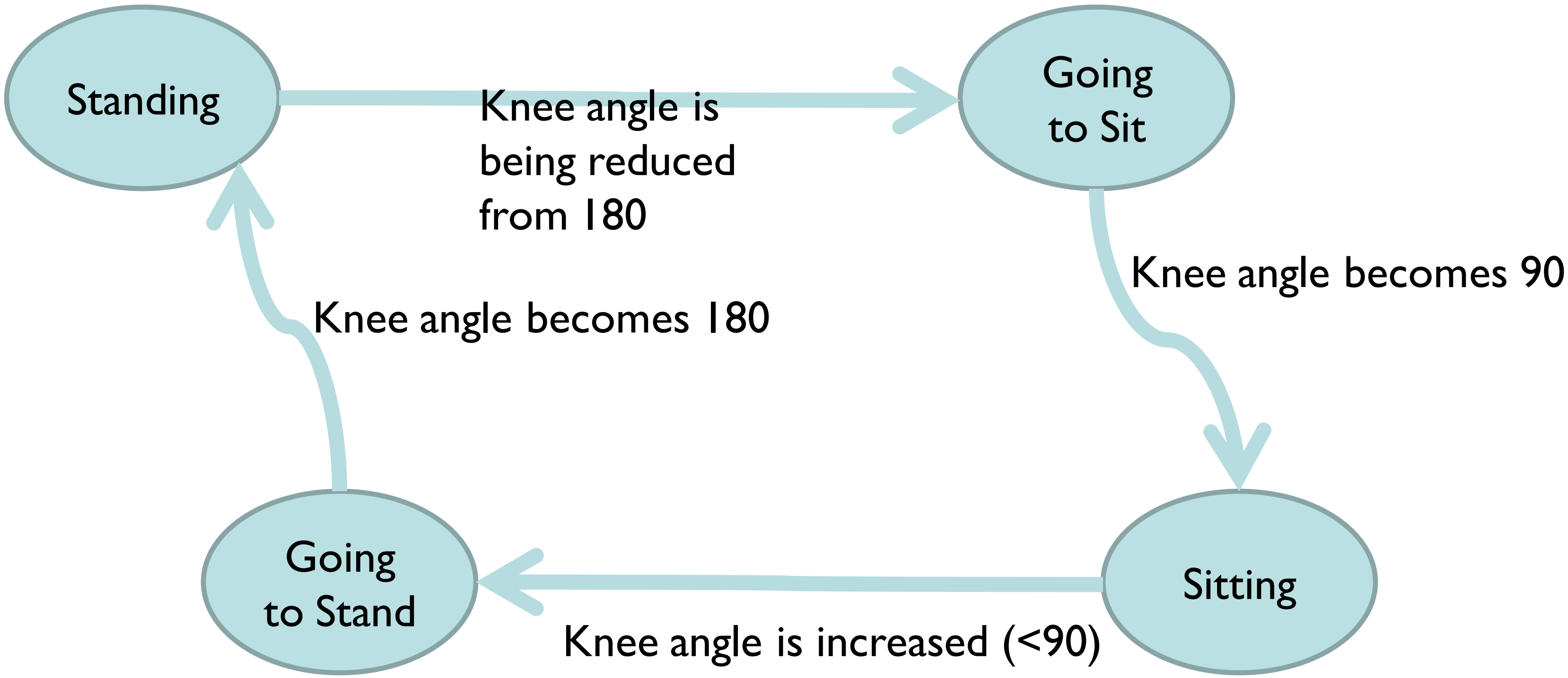
  70-79 y/o 12.6 sec

  80-89 y/o 14.8 sec.

- E.g. 11.4 seconds => score of 100. This approach requires measuring exactly 5 times

(*) [http://web.missouri.edu/~proste/tool/5x-STS.rtf]

Sit-Stand Regular Automaton



Sit-Stand Test

- Demo:

https://www.dropbox.com/s/tuyfu8688dqpw7h/Rehab%40Home.mov

- Start session: touch your head ONCE until you hear the tin sound ONCE.
- Stop session: touch your head again ONCE until you hear the tin sound TWICE.

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Challenges

- OpenNI C++ and Kinect for Windows SDK (C#): different skeletons
- Bone joint path-based learning machine: not accurate enough, ++ false positives.
- -> We add angle-based Learning Machine, for pose independent gesture recognition
  - Increments computational complexity and recognition speed.

Challenges

- Training: Recorded depth video of ~1min: ~5GBs!!
- In general, hard to make it robust (+ sensors would be helpful)
- *Sitting mode*: ignores lower limbs. [Knee extension in standing mode: computationally more complex but not impossible].
- Voice commands (to start/stop recording) work sometimes.

Conclusions

- Software allows
  - Recording new patterns from different users to train the system.
  - Recognize simple exercises
    - *Hip Extension*
    - *Hip Abduction*
    - *Sit-Stand*
    - *Knee Extension*
    - *Knee Abduction*
  - Insert data into M3 for further annotation, tracking and inference

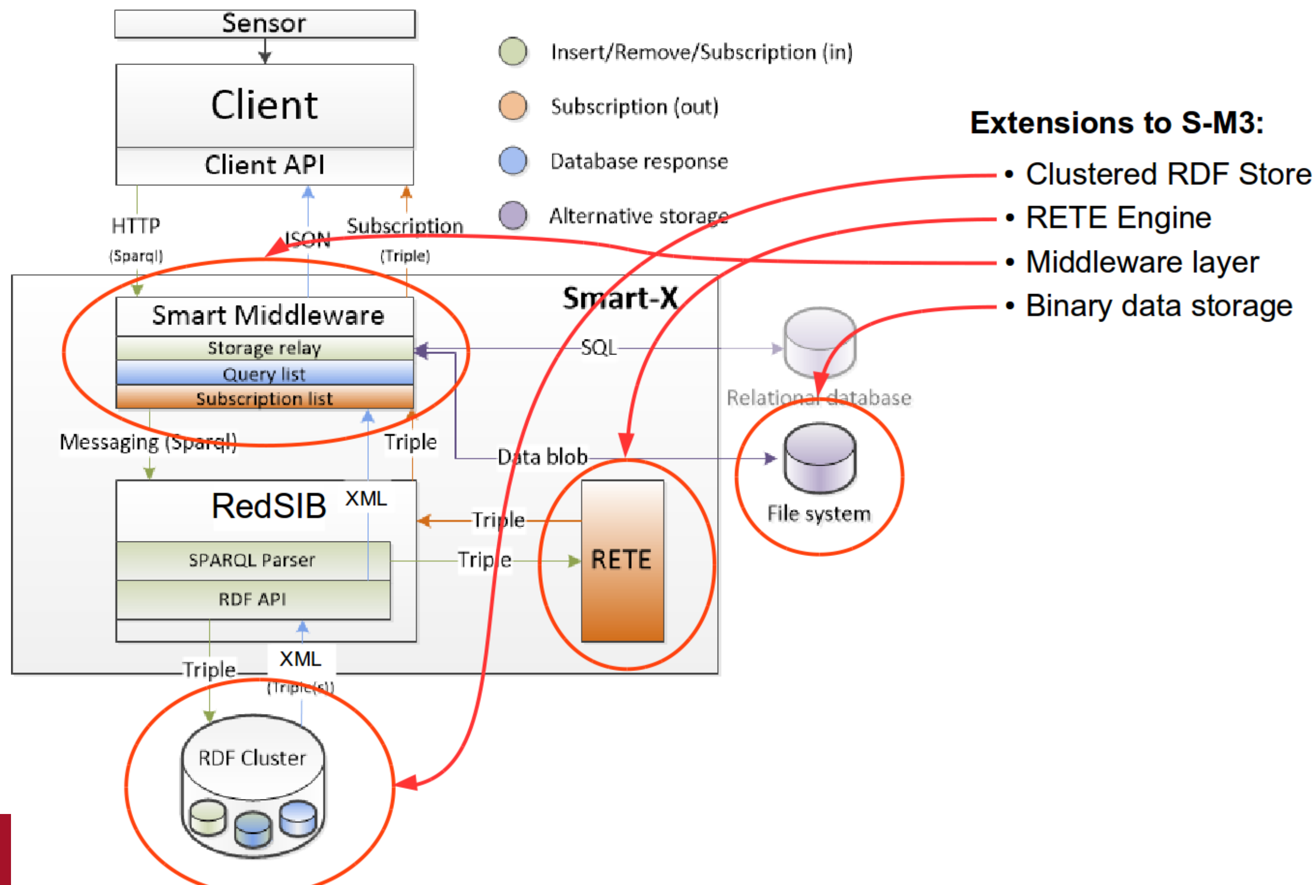
Future Directions

- Integration into new M3 distributed architecture to provide low power distributed processing

(Atom board at the moment,

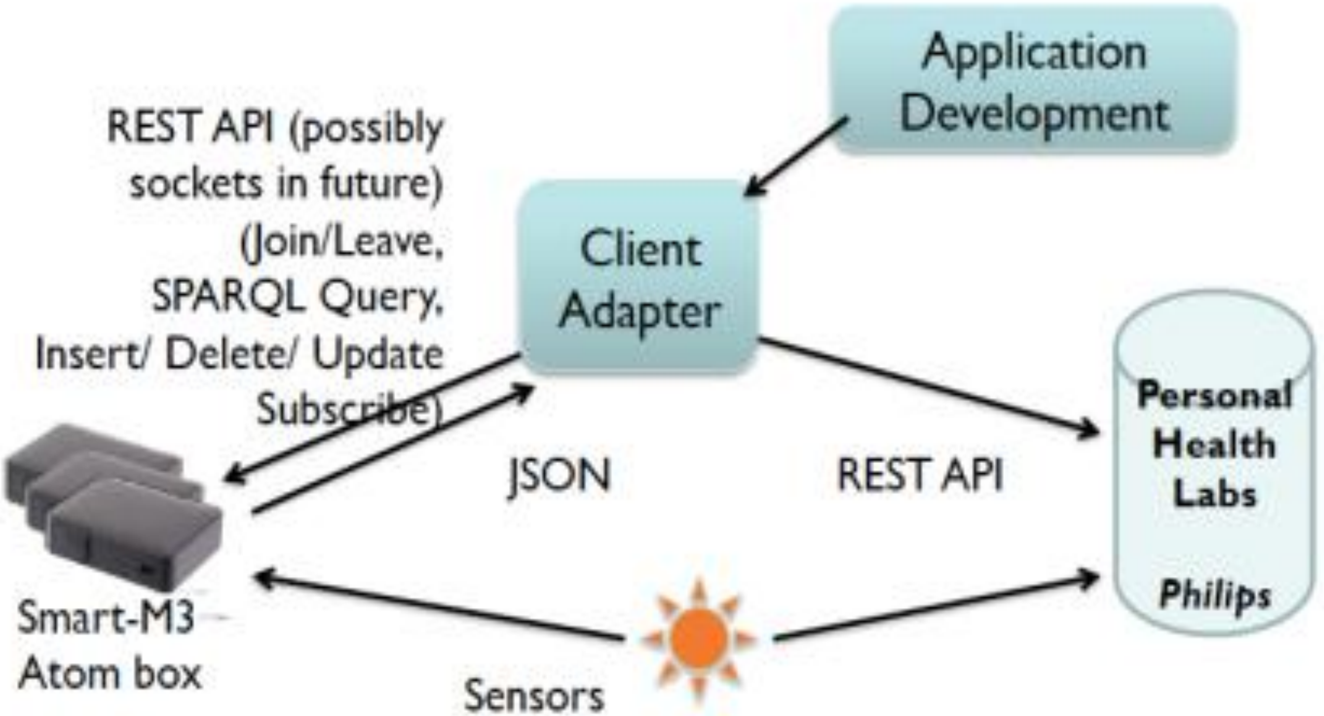
Future aim:

ARM)



Future Directions

- Integration into Philips PHL (Personal Health Labs) platform



Future Directions

- Tackling feedback
- Person (face/height/width) recognition for work-out session logging
- Ontologies refinement (with Philips, Fraunhofer and INRIA Grenoble and DFKI)
- Scalability + performance experiments (reasoning, querying/updating/ subscribing VS ontology size)
- Fuzzy rules to tackle imprecision, vagueness & uncertainty in knowledge representation
- Development of a *Gesture Definition Markup Language (GDML)* to specify exercises formally.

Thank you for your attention!

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