University of Ljubljana
Faculty of Electrical Engineering

robolab

Caretoy signal processing

Matjaž Mihelj

CareToy

Workshop on new multi-sensor devices for remote management of disease
IEEE International Conference on Multisensor Fusion and Information Integration,
Hamburg, September 15, 2012

Objective

- **Customized training and objective assessment** based on
  - Acquisition of postural, movement, grasping and gaze information,
  - Implementation of sensor data processing and sensor fusion algorithms,
  - Derivation of methods for data segmentation,
  - Classification of performed actions and adopted behaviors,
  - Adaptation of training protocol based on progress resulting from previous therapy sessions,
  - Clinical interpretation of results.

Sensors

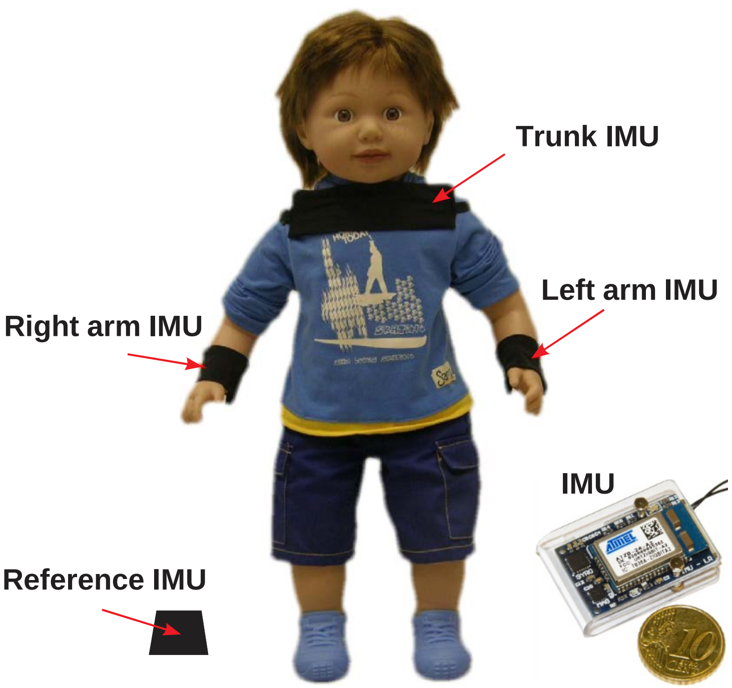
Senzorized Mat module

Toy sensors

Force resistive sensors

Pressure sensors

Orientation sensor



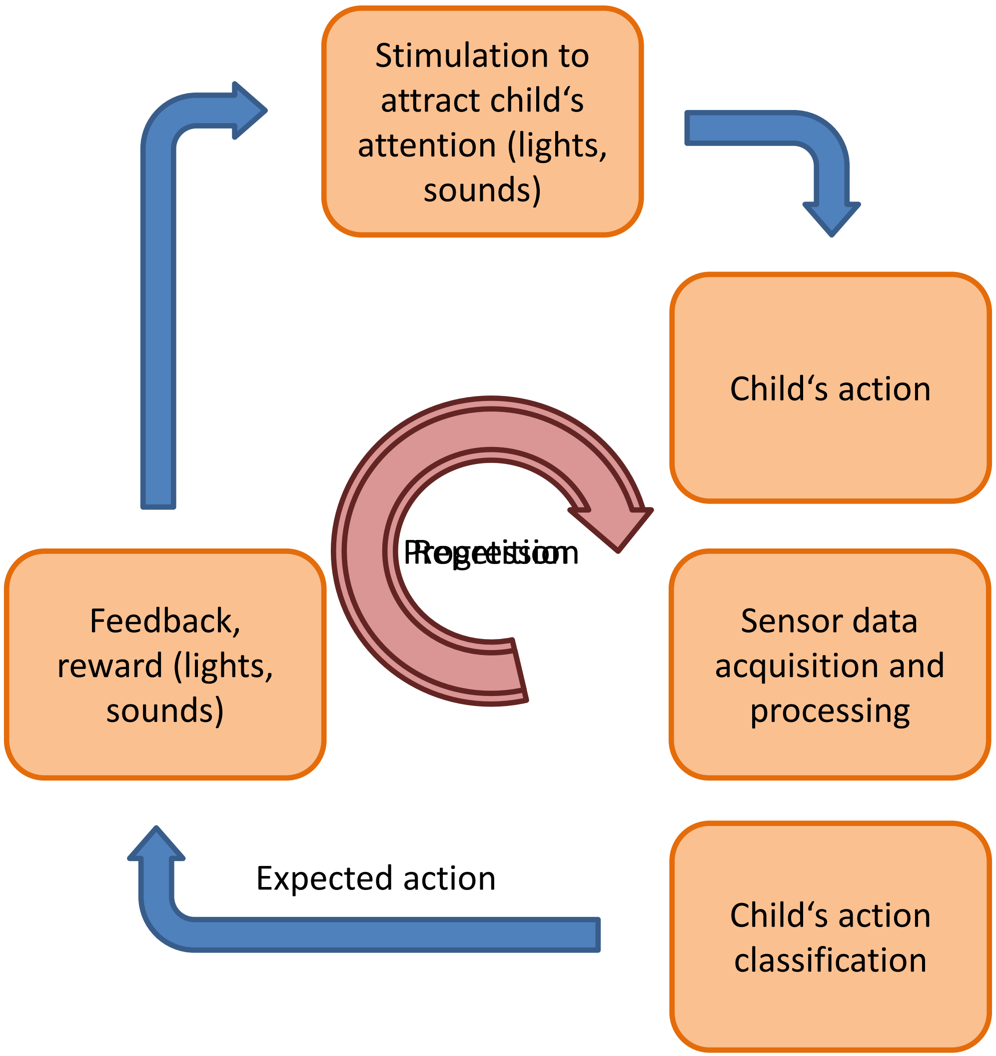
Sidewall buttons and switches

Posture sensors

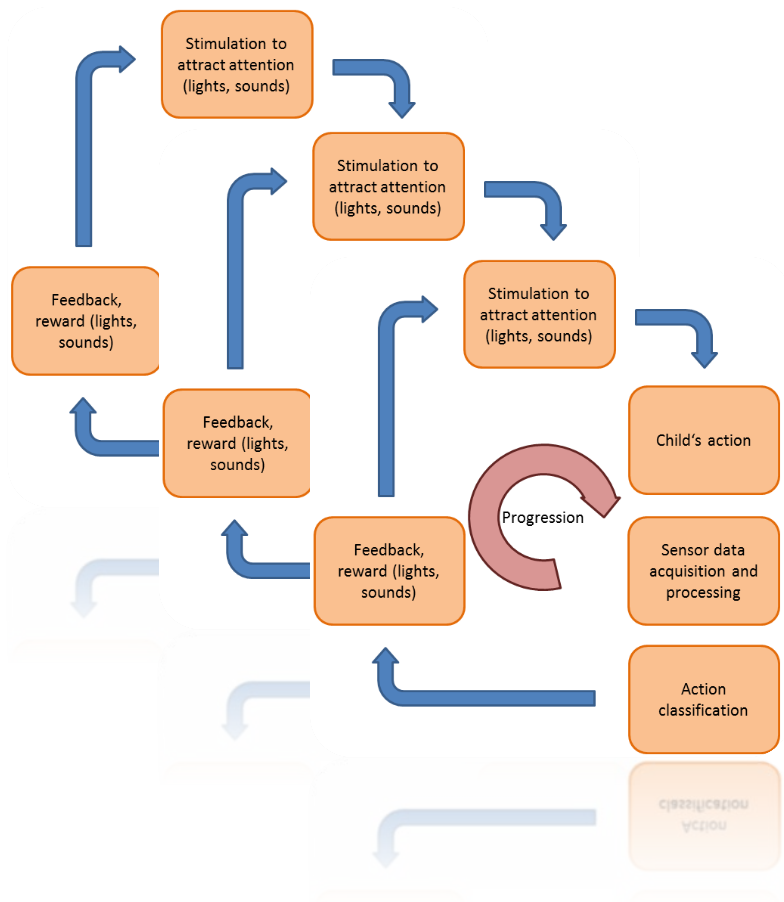
Trunk orientation sensor

Bracelets

Training concept



Next tasks



Signal processing and interpretation

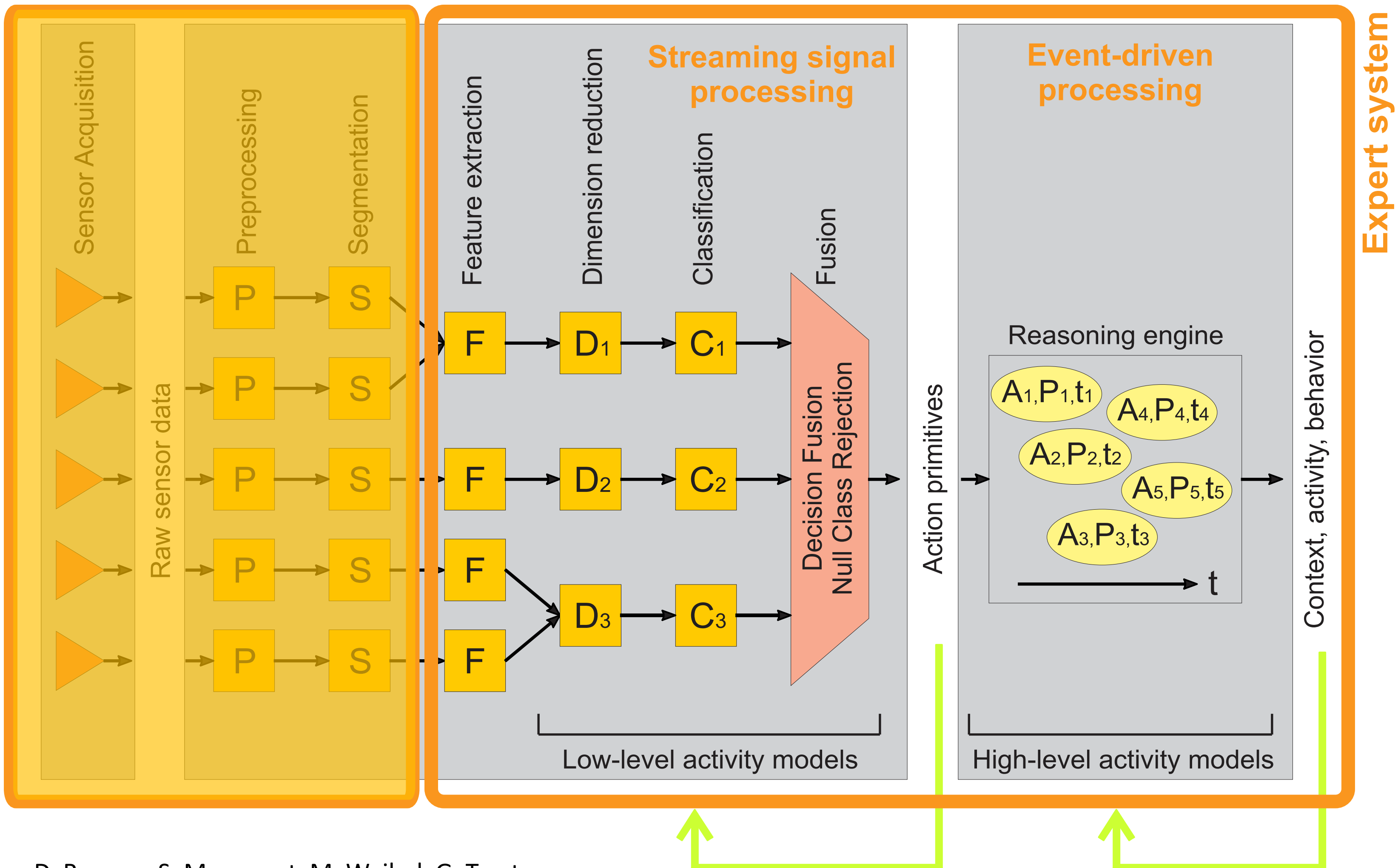


Figure based on: D. Roggen, S. Magnenat, M. Waibel, G. Troster, „Wearable Computing“, *IEEE Robotics & Automation Magazine*, 2011

Sensor level data processing and fusion

- **Movement analysis** (inertial measurement units and mat module)
  - Inertial measurement units
    - child's body posture (arms and trunk),
    - posture changes,
    - movement dynamics
  - Sensorized MAT module
    - pressure distribution map,
    - support polygon
- **Grasp analysis** (force and pressure sensors embedded in the toy)
  - grasp force (average grasp force, grasp dynamics)
  - spatial distribution of grasp
- **Gaze tracking**
  - gaze direction – to determine if the infant is looking toward the region of interest (a toy, parents face, moving object),
  - timing of fixations and saccades – analysis of cognitive behavior.

Action and behavior classification

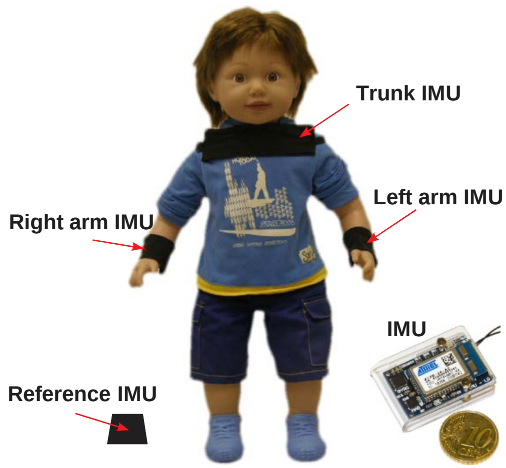
- *Motor actions* – analysis of child‘s motor action primitives (reaching motion, dexterous manipulation, uncoordinated movements, slow or fast motion),
- *Postural control* – analysis of child posture (supine, prone, lateral, sitting, symmetrical or non-symmetrical weight distribution, preferred posture, change of posture),
- **Grasping behavior** – type and strength of grasp (power grasp, precision grasp, number of repetitions),
- *Visual capabilities* – analysis of child‘s gaze action primitives,
- Extract parameters, which describe **temporal and spatial properties** of child’s actions

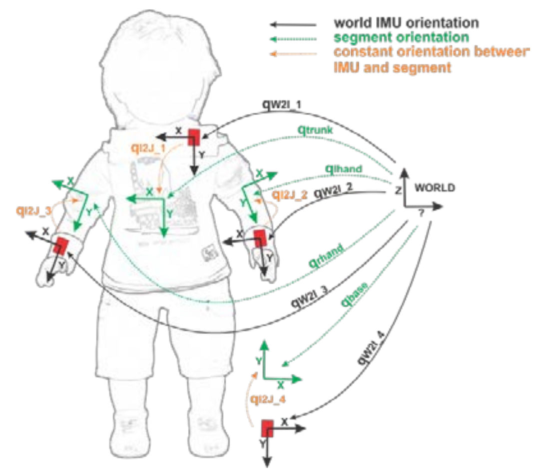
Model for user progress assessment

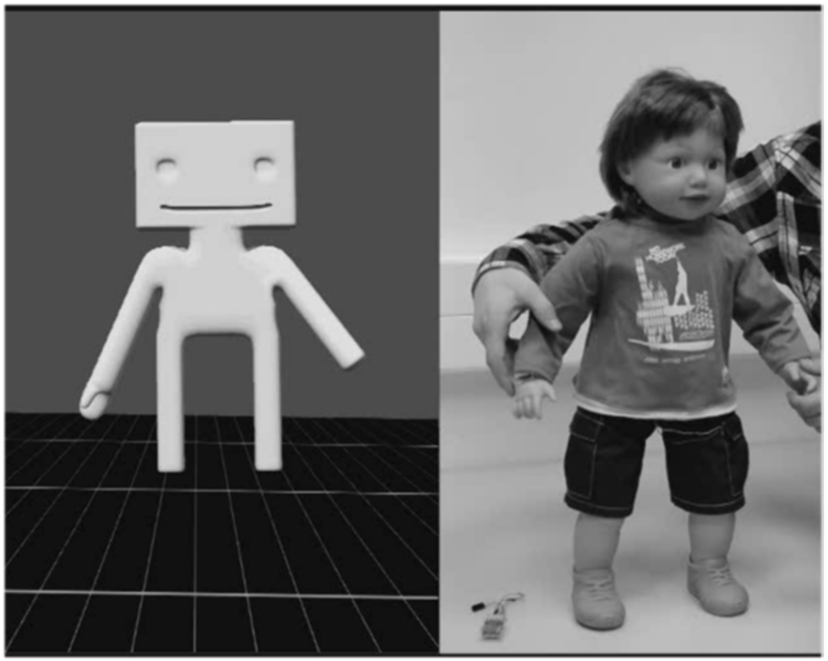
- **Purpose** – to assess child's performance in the current session and suggest the intensity of the next session, analysis of child's progression
- **Model development** – statistical analysis of clinical trial results (machine learning approach)
  - Kalman Adaptive Linear Discriminant Analysis,
  - Hidden Markov model,
  - Support Vector Machine,
  - Neural Network
- **Model adaptation**
  - based on results of multiple consecutive sessions,
  - model updated and customized for a specific person.

PRELIMINARY SINGLE CASE STUDY

Arm bracelets and trunk IMU

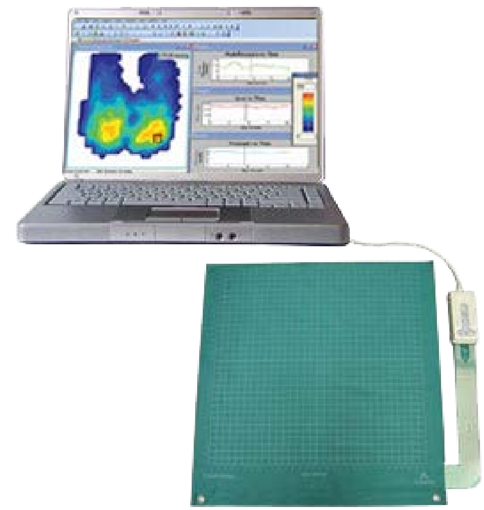




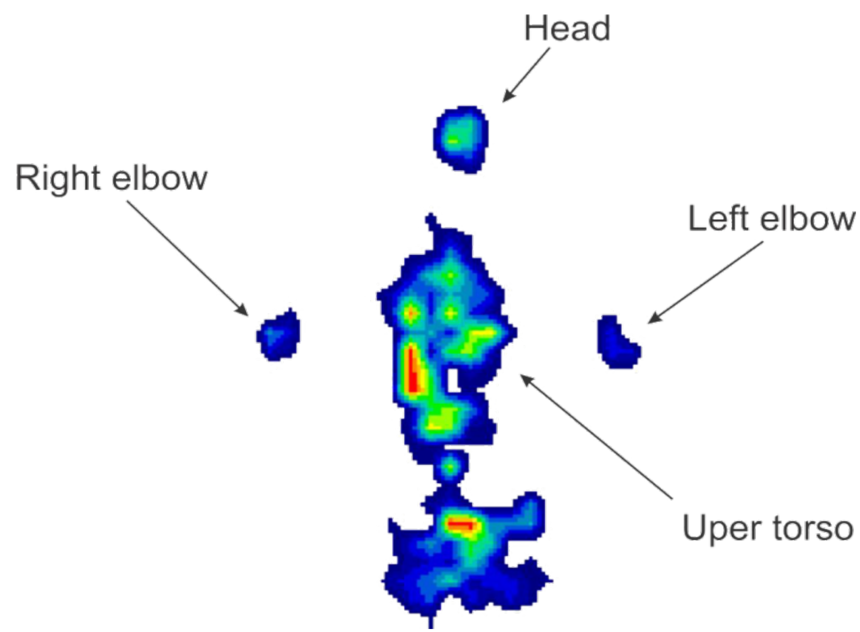


- Inertial measurement unit (IMU)
  - Gyroscope, accelerometer, magnetometer
  - Wireless
  - Small to fit on infants forearms
- Mounted on chest, forearms and base

Mat module

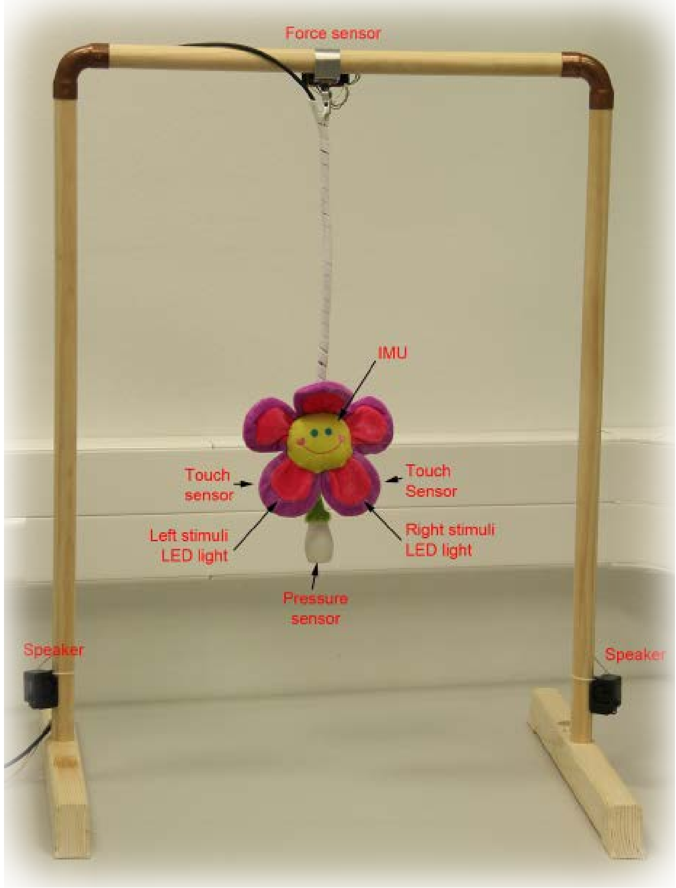


- Sensorized mat module (Tekscan)
- 471mm x 471mm, 32 x 32 sensors
- Output is a pressure distribution matrix
- Child's support polygon computation



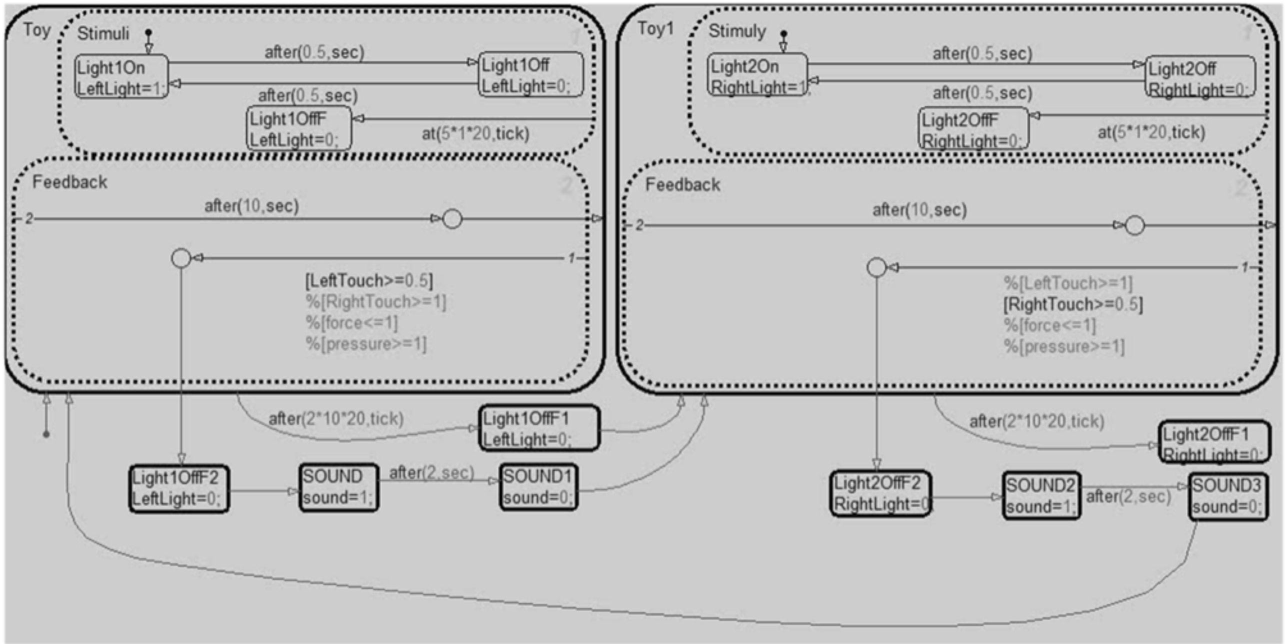
Experimental setup

- Wooden arch, Tekscan mat module, bracelets, toy with sensors and stimuli
- Flowchart based feedback control



Control flowchart

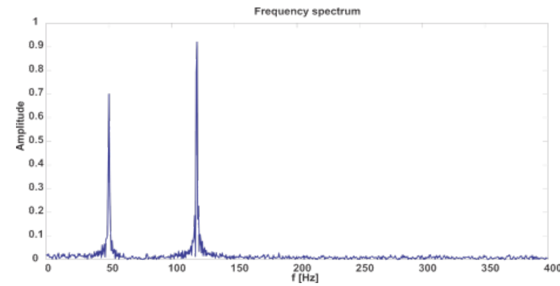
- Light stimulation
  - Left and right petal
- Measured response
  - Left/right petal force sensor and middle pressure sensor
- Reward feedback
  - Sound



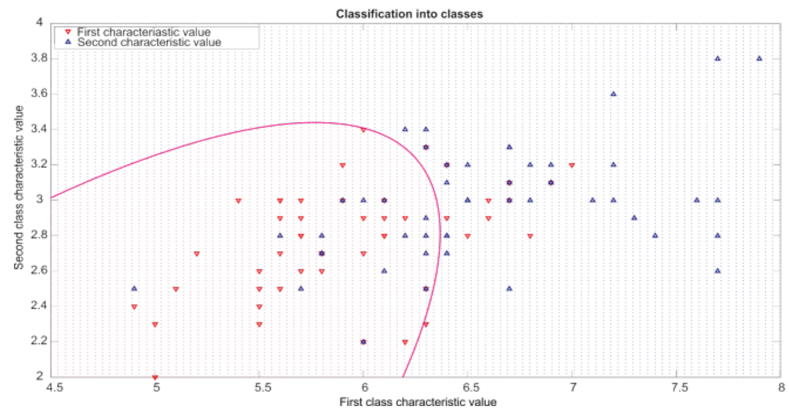
Signal processing methodology

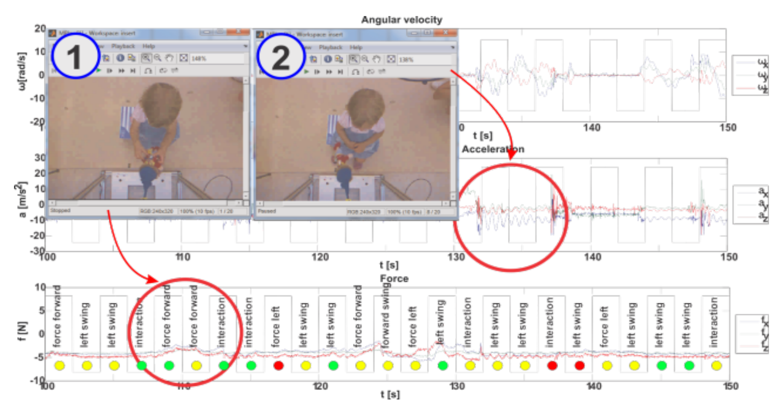
$$F(\omega) = \int_{-\inf}^{+\inf} f(t) e^{-j\omega t} dt$$

$$f(t) = \frac{1}{2\pi} \int_{-\inf}^{+\inf} F(\omega) e^{j\omega t} d\omega$$



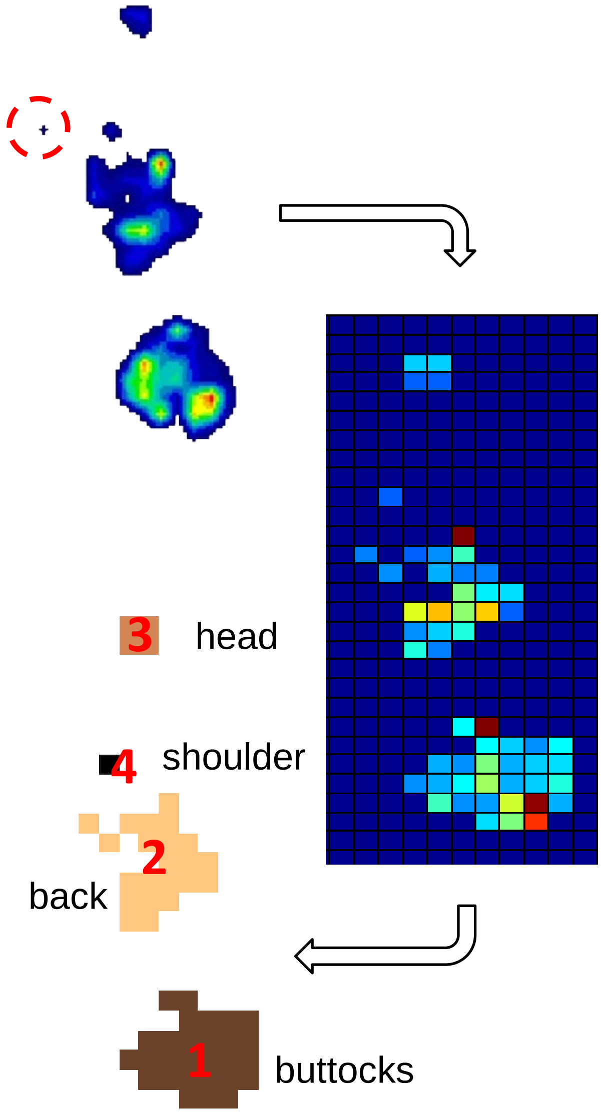
- Lowpass filtering, thresholding
- Frequency and power spectrum analysis
- Linear discriminant analysis
- Fuzzy logic
- Hidden Markov model
- Clinical description





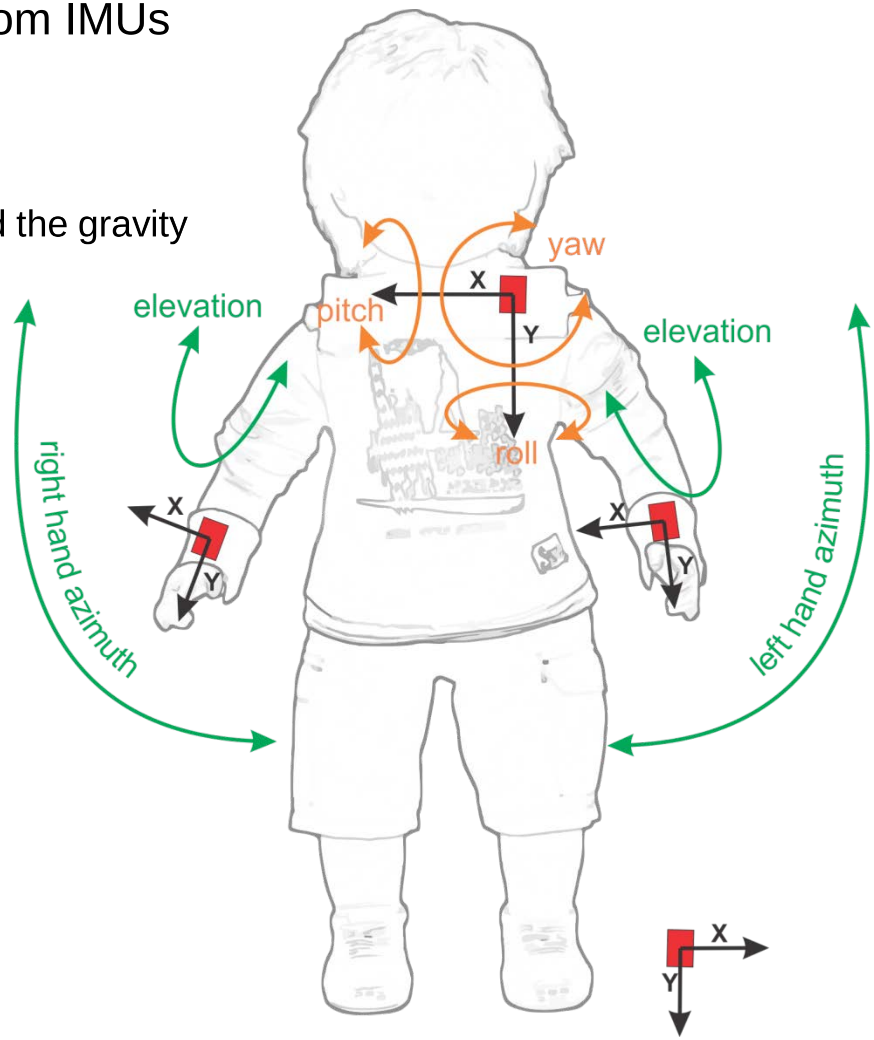
Mat module processing

- Artifacts removal
- Segmentation of major pressure patches
- Fusion with child‘s IMU pose data can assist
  - attribution of labels to pressure distribution matrix patches (head, arms, legs, back)
  - detection of body posture (relative to mat)
  - detection of arms posture (relative to mat and body)



Body and arms posture estimation

- Computation of body and arms angles from IMUs
  - Trunk
    - **roll** – prone, lateral, supine
    - **pitch** – trunk elevation, sitting ↔ lying
    - **jaw** – counter-clockwise rotation around the gravity vector
  - Arms
    - **azimuth** – abduction ↔ adduction
    - **elevation** – flexion ↔ extension



Posture results

Child age: 6.5 months old
Session duration: 15 min

Change of body posture

- **Roll** (prone, lateral, supine)
  - from supine to right lateral 14 times
- **Pitch** (trunk elevation, sitting ↔ lying)
  - no activity
- **Yaw** (counter-clockwise rotation)
  - from initial to 20 degrees right position and back 5 times

Average posture duration

- **Roll** (prone, lateral, supine)
  - 3.5 s on supine
  - 3 s on right lateral
- **Pitch** (trunk elevation, sitting ↔ lying)
  - no activity
- **Yaw** (counter-clockwise rotation)
  - 14 s initial position
  - 10 s right position

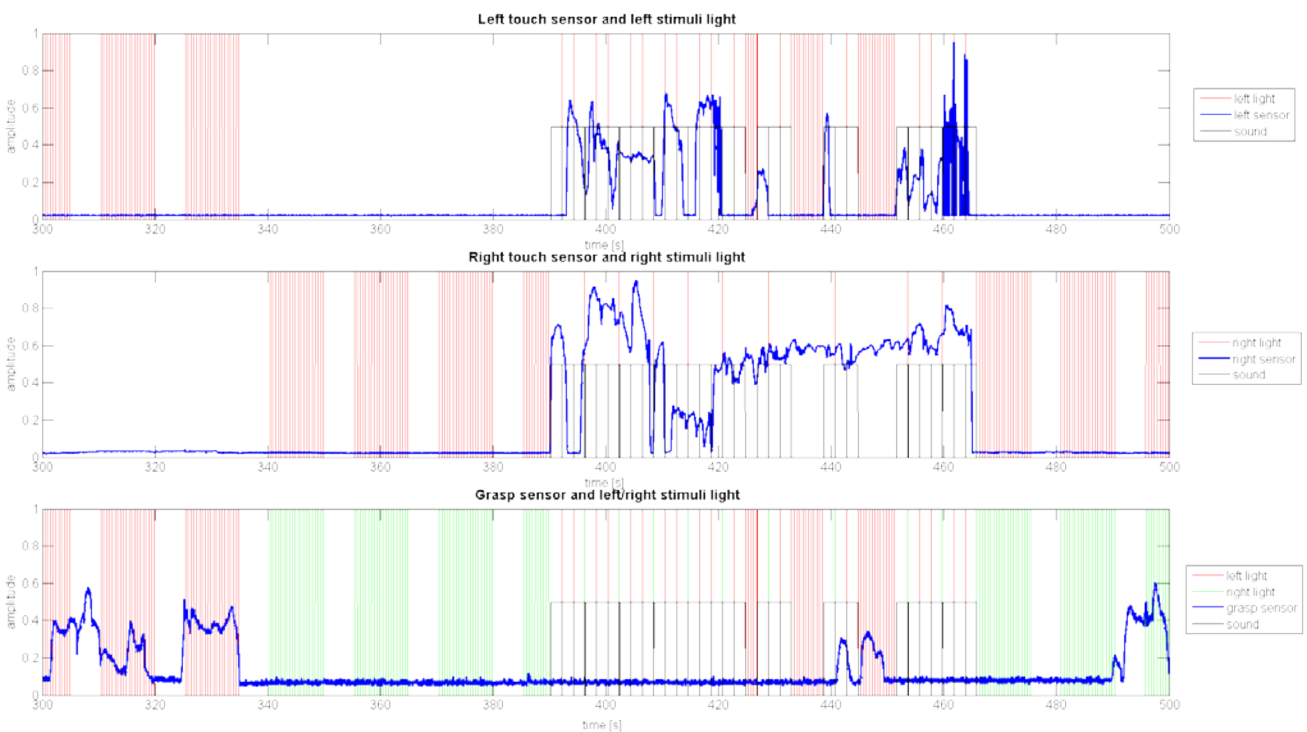
Grasping results summary

Grasping

- Pressure sensor 50 times
- Left petal sensor 42 times
- Right petal sensor 35 times

Max duration of grasp

- Pressure sensor 40 seconds
- Left petal sensor 30 seconds
- Right petal sensor 45 seconds



- Average grasp force
- Maximal grasp force

Arm posture assessment

- In 80% of the session hands in front (in contact with the toy) with slight movements in all directions
- The rest of time just waiting or catching the toy
- Longest period with hands in front - 350 s

- The younger the child the more random are the arm movements

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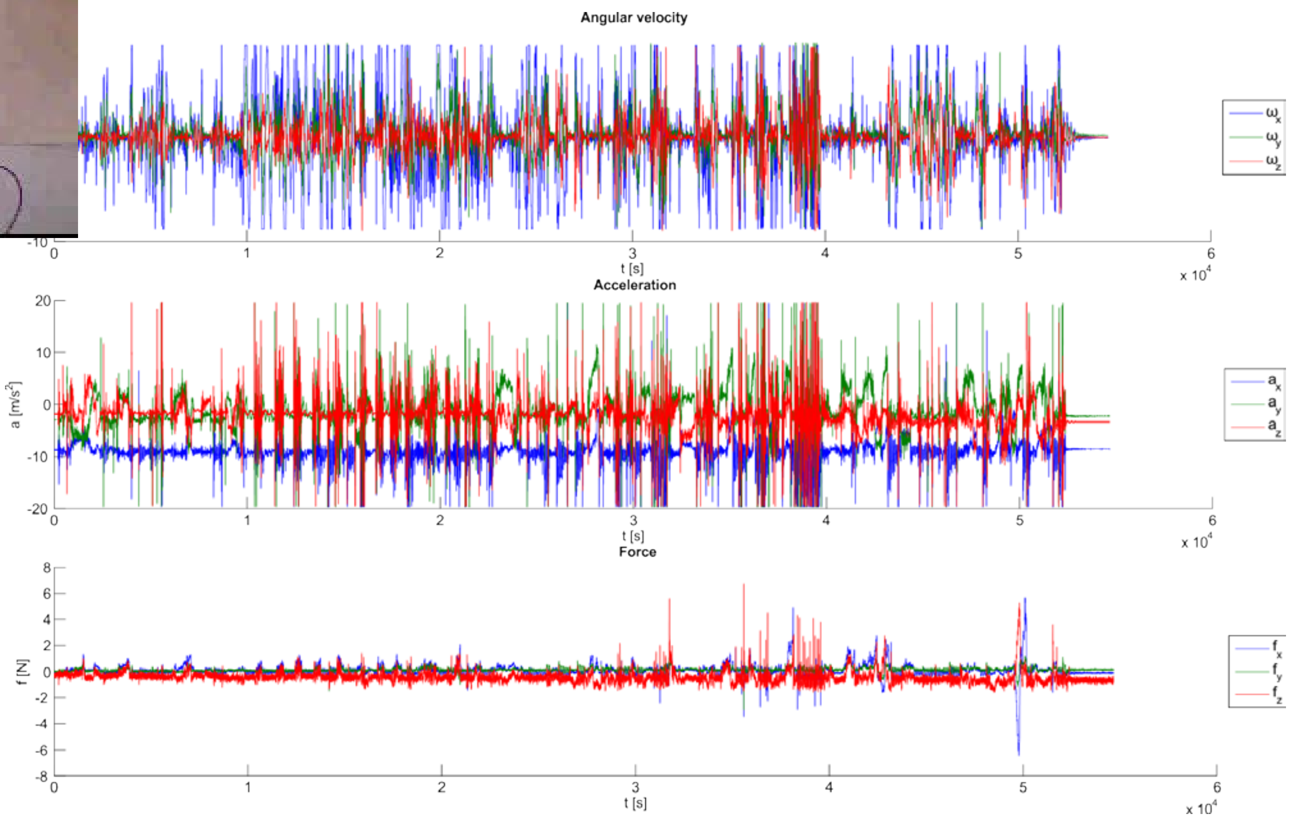
ACTION CLASSIFICATION BASED ON TOY SENSORS

Segmentation and interaction classification

- Frequency domain analysis
- Linear discriminant analysis
- Hidden Markov models (HMM)

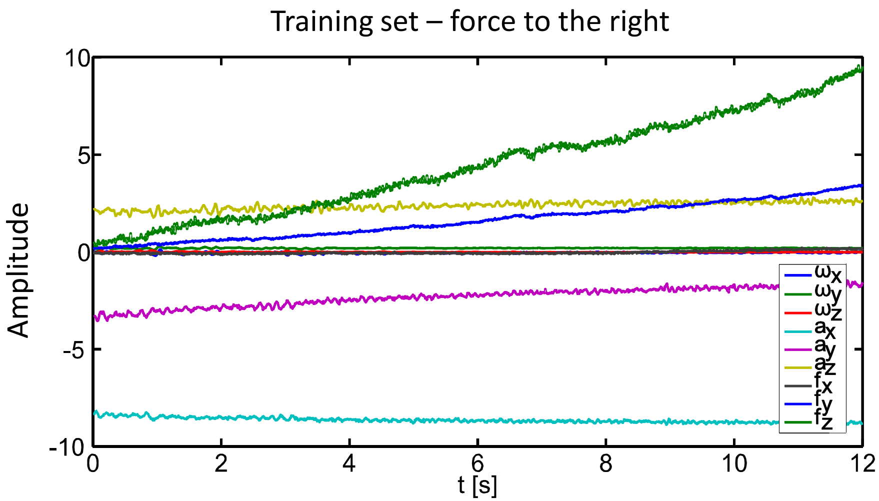


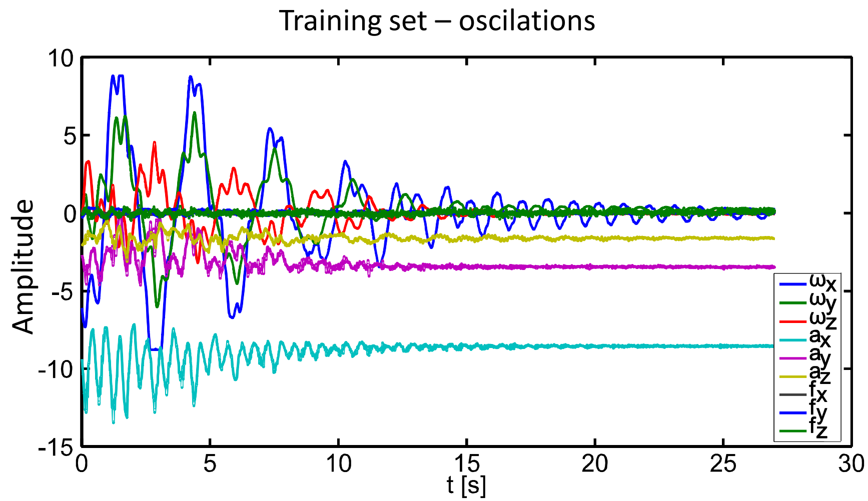
Possible (11) events

- Toy standstill
- Strong interaction
  - hitting, shaking
- Passive toy oscillation
  - frontal, lateral
- Pulling force
  - left, right, down, forward
- Toy orientation
  - left, right, forward

Hidden Markov model approach

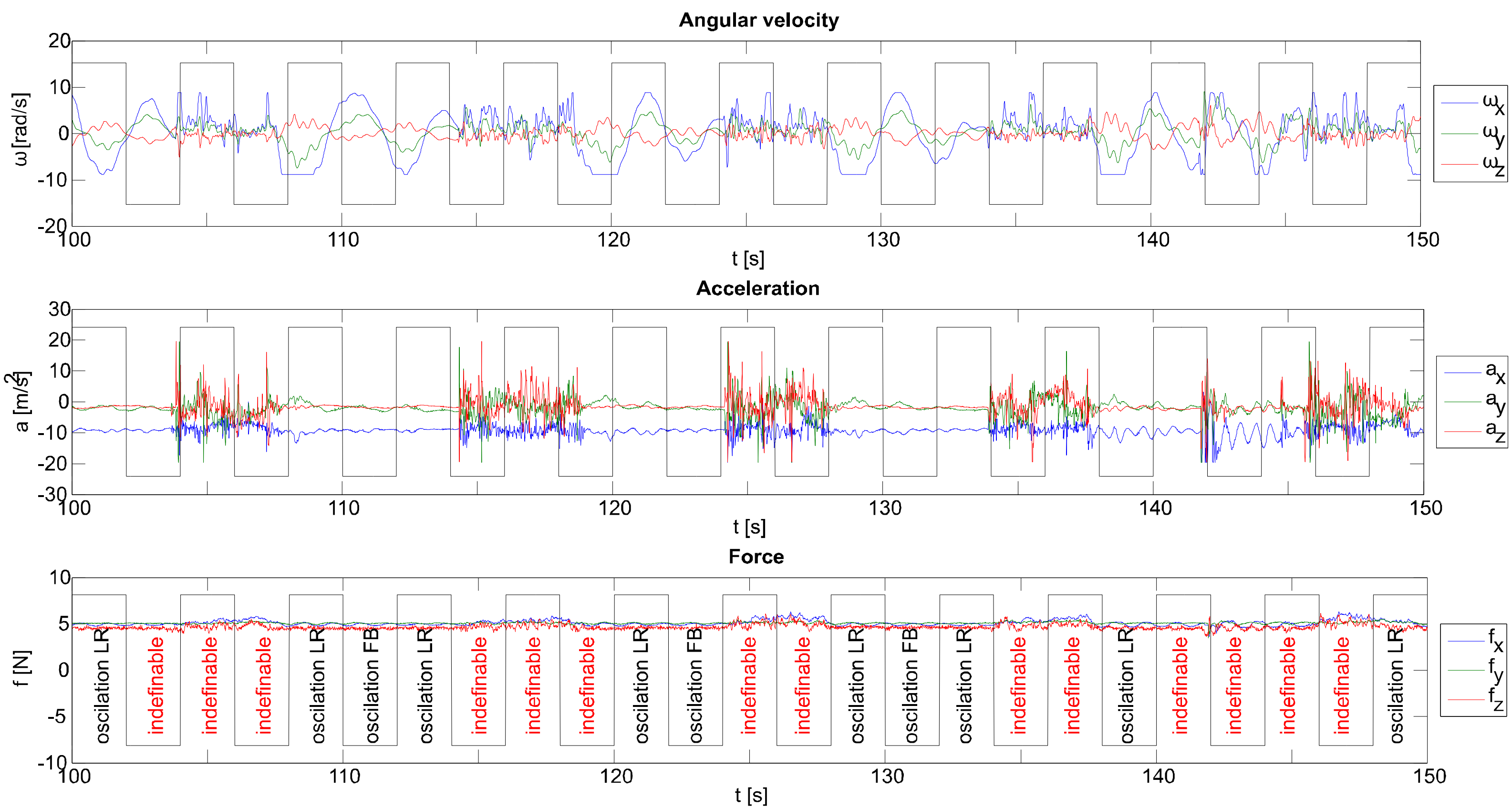
- Creation of a training set
- Construction of a HMM model
- Segmentation of signals and classification of different events
- Combinining HMM with min-max operator



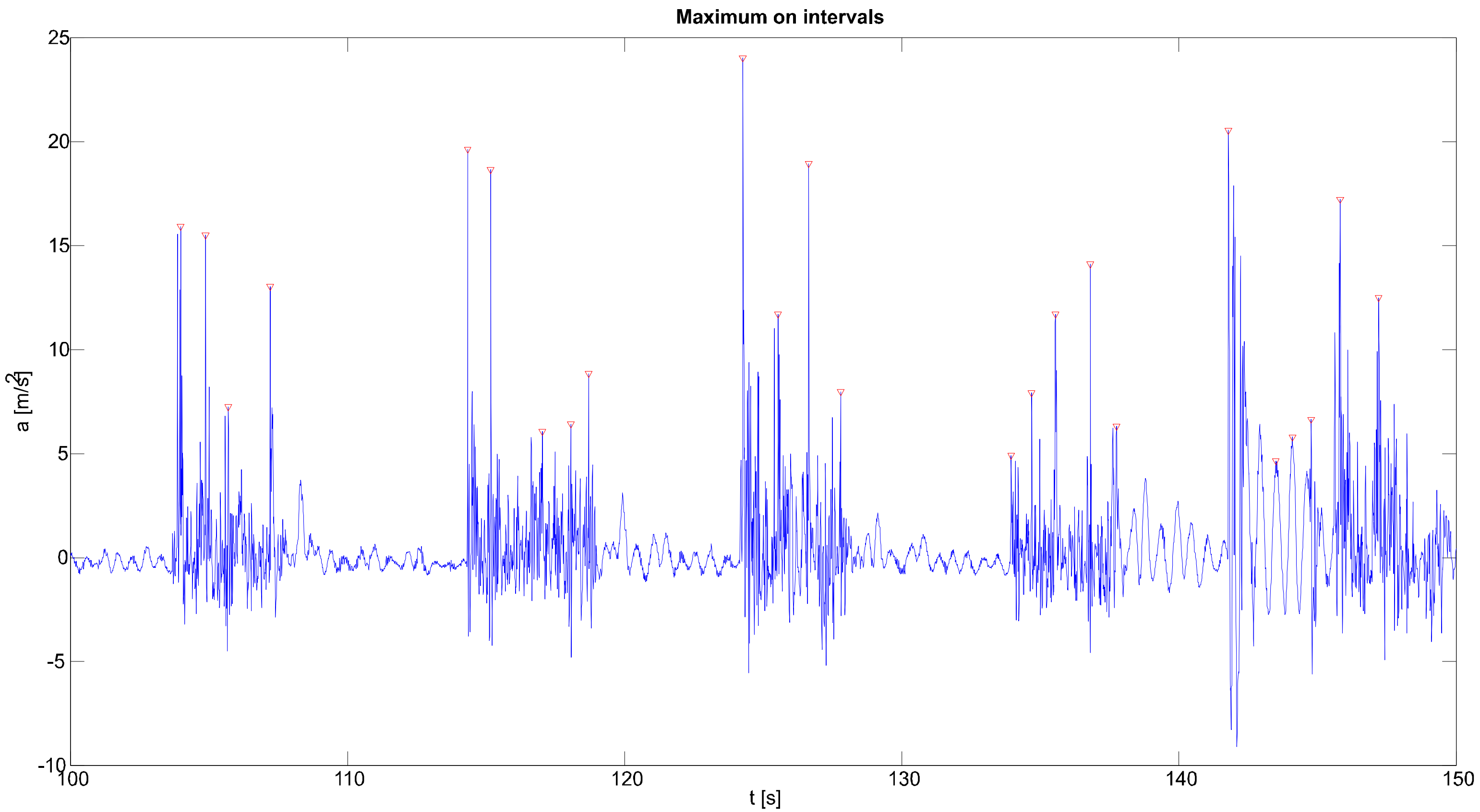


Classification based on HMM

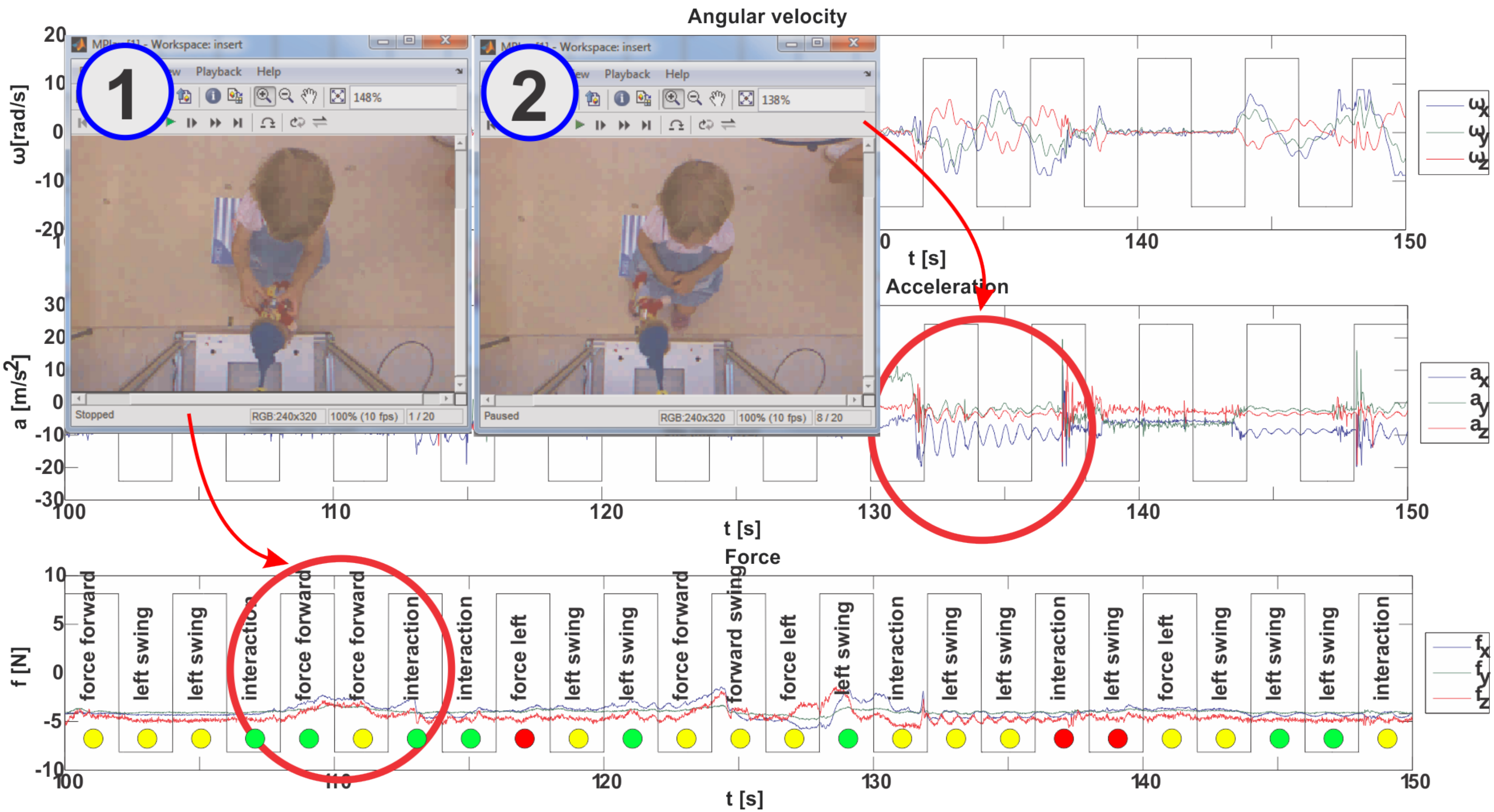
- window width 2 seconds,
- classified 52% of signal



Min-max operator



Classification based on HMM and min-max



The CareTOY team

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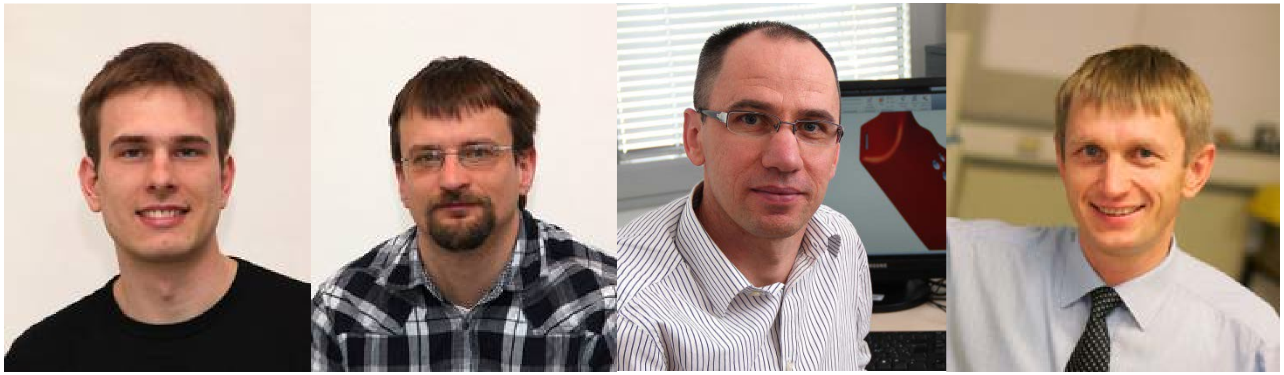
Slovenian Technology Agency

EC:

SEVENTH FRAMEWORK PROGRAMME

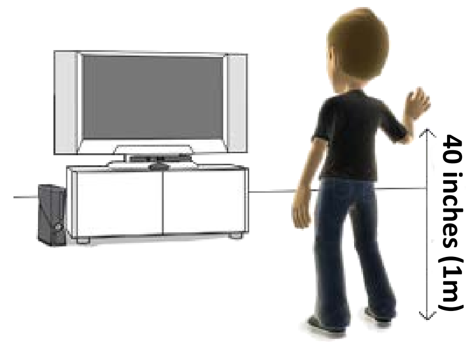
CareTOY members:
- Marko Munih
- Matjaž Mihelj
- Janko Kolar
- Jure Pašič



Few words about Kinect

PLAYER CONSIDERATIONS

PLAYERS NEED TO BE AT LEAST 40 INCHES TALL (1 M).



- Motion tracking device
  - simple,
  - easy setup,
  - contactless,
  - cheap
- Not appropriate for motion tracking of infants due to height limitation