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Human Robot Interaction for Teaching Robotic Assembly through an Intuitive Portable Interface

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Teaching collaborative robots to perform Assembly tasks

Problem Definition

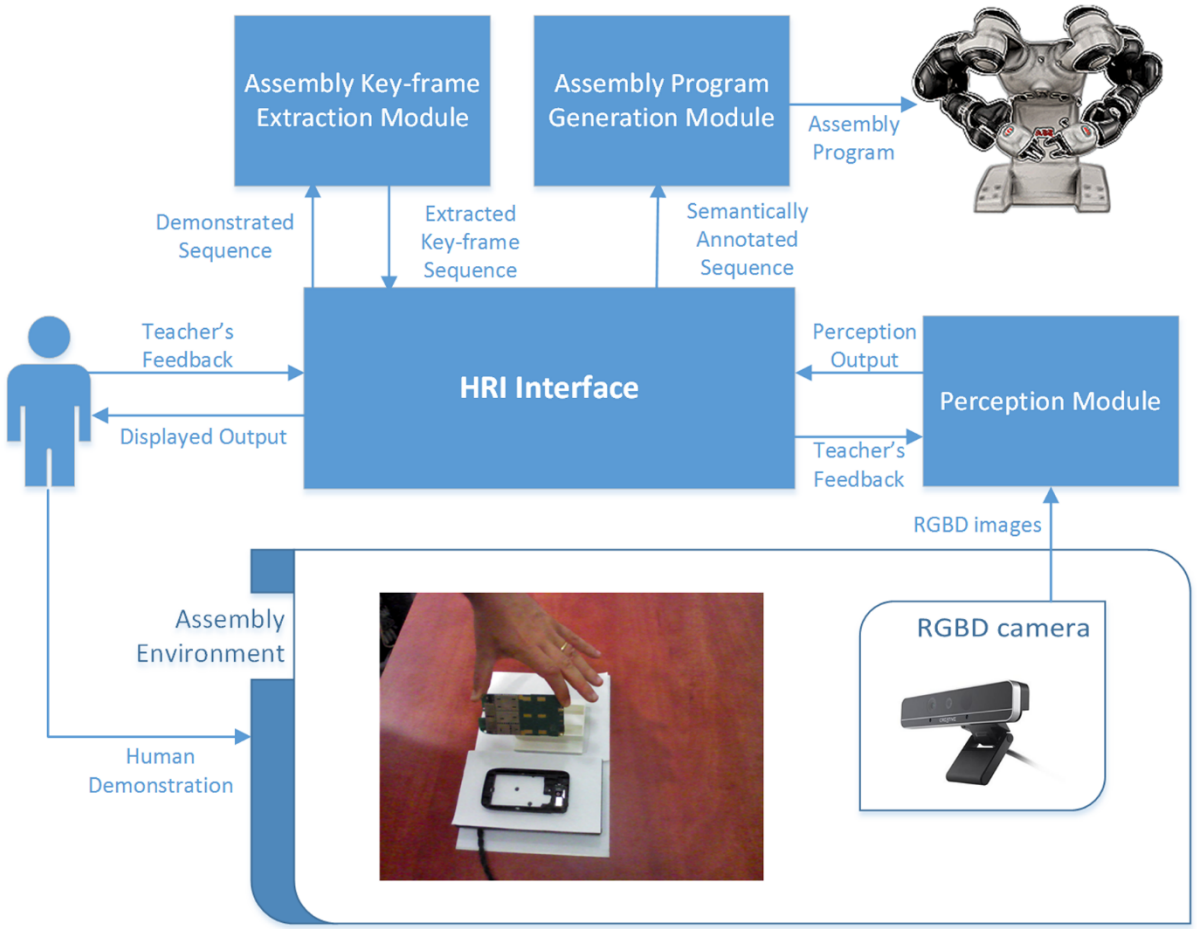
- Enable a non-expert user to ***teach*** a new ***assembly task*** to an collaborative robot in less than ***one day***
  - ***no*** explicit ***programming*** required

Motivation

- Even expensive products produced in large volumes are still assembled ***manually*** in low wage countries under ***harsh conditions***

Approach

- Extend the robotic system with advanced ***perception*** and ***cognition*** abilities
- Develop a user-friendly ***Human Robot Interaction*** (HRI) interface
  - allowing a ***human teacher*** to demonstrate an assembly task to the robot



Overview of the proposed approach

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Perception: Hand-Object Detection and Tracking in 3D

RGBD data are acquired

Object Detection (6DoF pose) is performed based on sparse auto-encoders for feature extraction and Hough Forests for classification

3D CAD models are employed for both training the object detector and performing hand-object tracking

- 6 DoF for the models of the assembly parts
- 42 DoF for the hand models

Coarse hand detection of an open configuration is performed

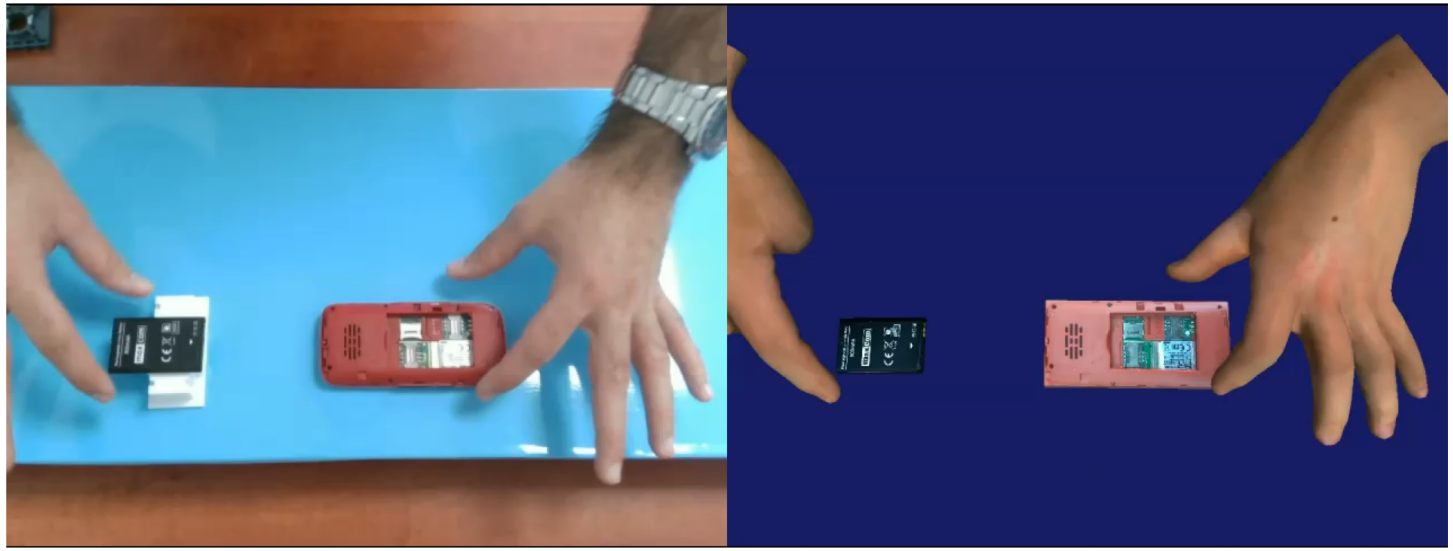
Hand-Object Tracking implementation using Particle Swarm Optimization (PSO)

- detection results are used for initializing the tracker

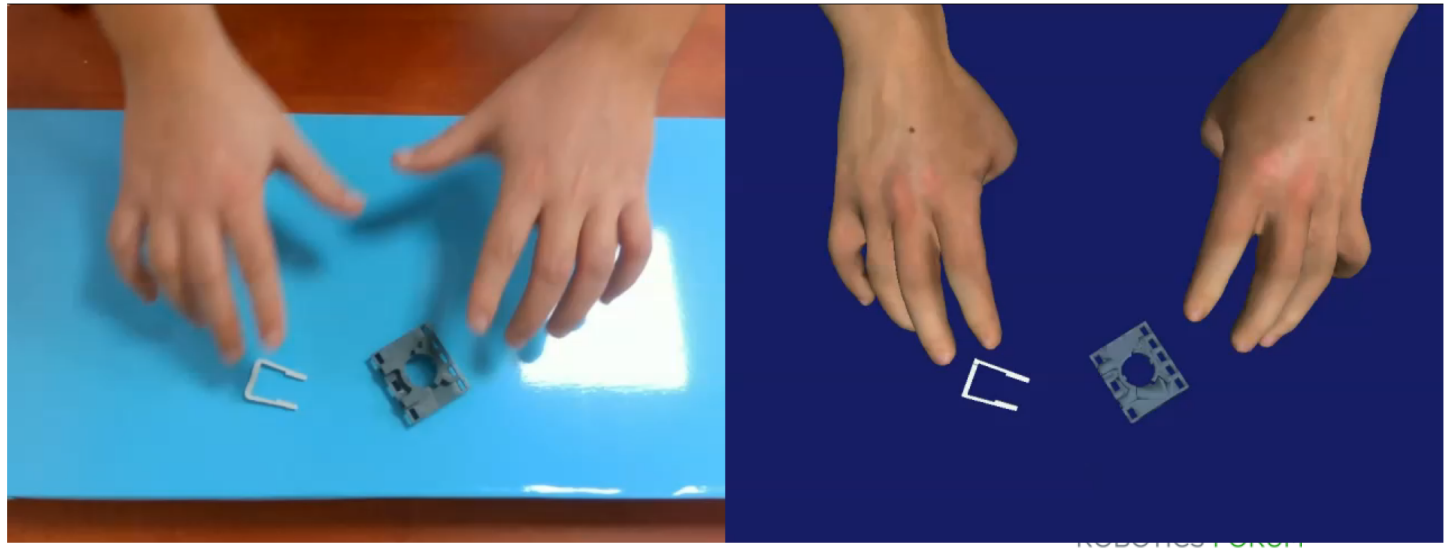
Modified existing approaches on hand tracking in order to perform ***joint*** hand – object tracking

Addressing deformable objects, as well

Optimization Time: 0.8 sec per frame



Real Data | Synthetic Data



Extracting Key-frames from the demonstrated assembly

Key-frames:
Important states of the demonstrated assembly
Folding Assembly example

Key-frame information **stored in** XML format

General information:
- Scenario id and current step
- Object(s) id involved in the demonstration phase
- Relative timestamp

Kinematics & Motion information:
- Object pose coordinates (position & orientation, 6 DOF)
- Hand pose (42 DOF)

Semantic information:
- User defined corresponding to assembly states, e.g. *grasp, align*
- Automatic system suggestions, e.g. *aligned axes*

Dynamics information:
- Forces derived from the kinesthetic learning
- Grasping contact points
- Object deformation characteristics

```
<?xml version="1.0" encoding="UTF-8" standalone="true"?>
- <KeyFrame xsi:schemaLocation="http://www.SARAFunXML.com
SARAFun_KeyFrame_XmlSpec_v02.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xmlns="http://www.SARAFunXML.com" t="25.4" idx="1" id="0">
  - <CurrentAction id="assembly.mpg">
      <Description>Putting one object over the other</Description>
    - <InvolvedObjects>
        <Object id="Obj1"/>
        <Object id="Obj2"/>
      </InvolvedObjects>
    - <VisualFeedback>
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  </CurrentAction>
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    - <PoseState>
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      </PoseState>
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    </Object>
  - <Object id="ObjB" name="Mobile Phone Case">
      <MeshFile>mobile_phone_case.obj</MeshFile>
    - <PoseState>
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        <YPR rotz="-0.0524788" roty="0.0192357" rotx="-0.723375"/>
      </PoseState>
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  </Objects>
- <Instructor>
  - <Hand id="LeftHand" name="Instructors left Hand">
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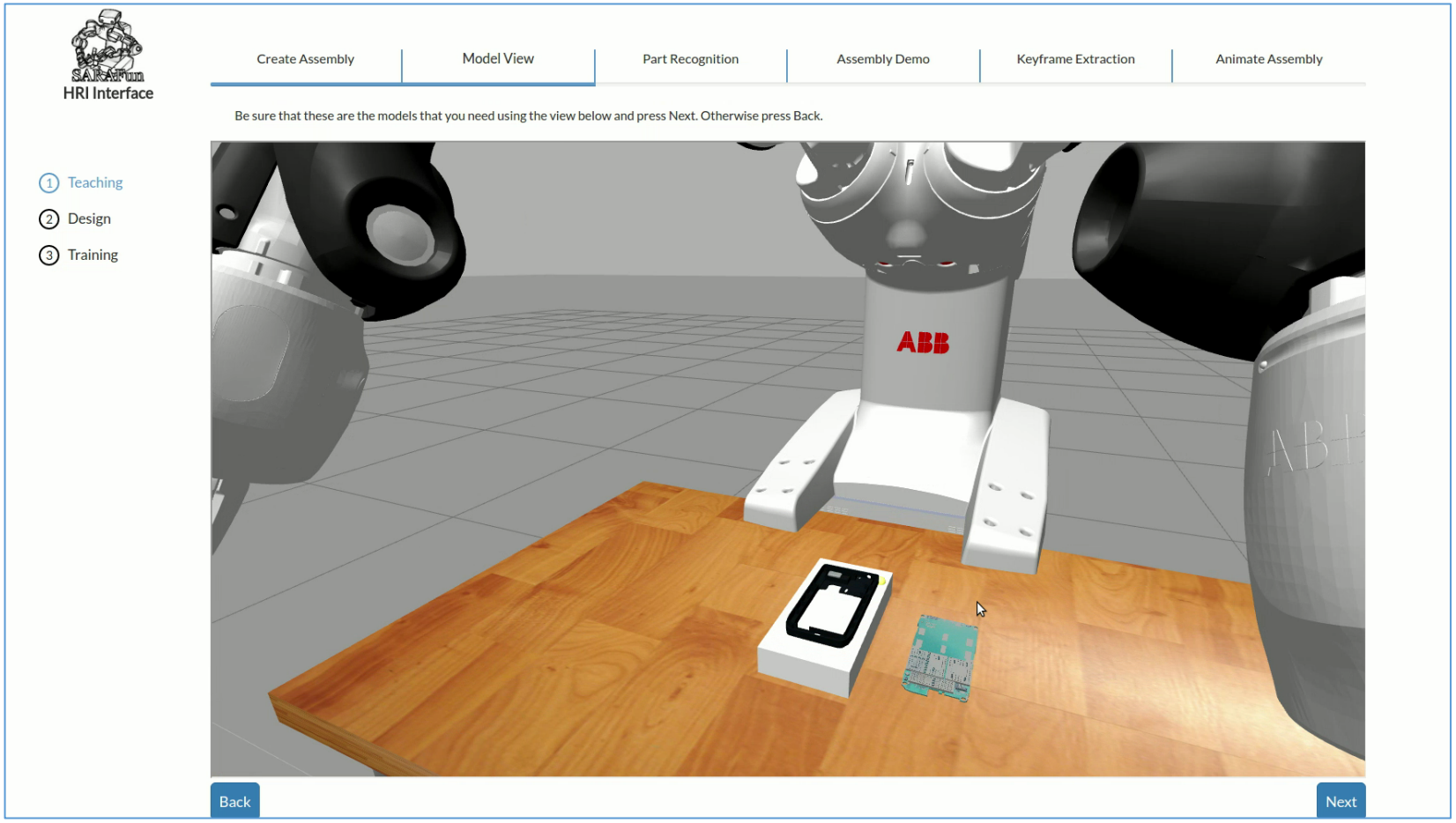
HRI Web interface for Teaching Robotic Assembly



User-friendly GUI

Intuitive Menus

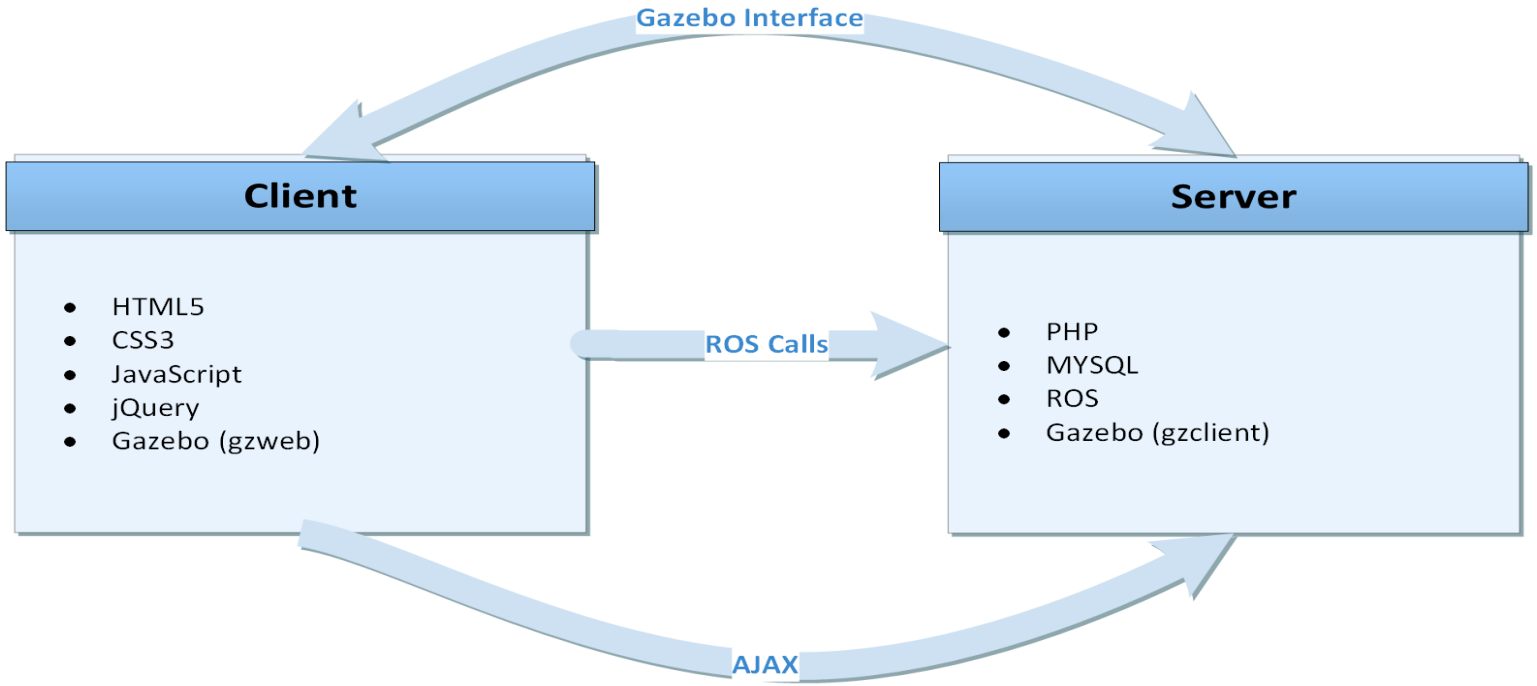
Guides the user through the assembly teaching

Deployed on the web allowing the use of portable devices (e.g. PC tablets)

Divided in 3 phases:

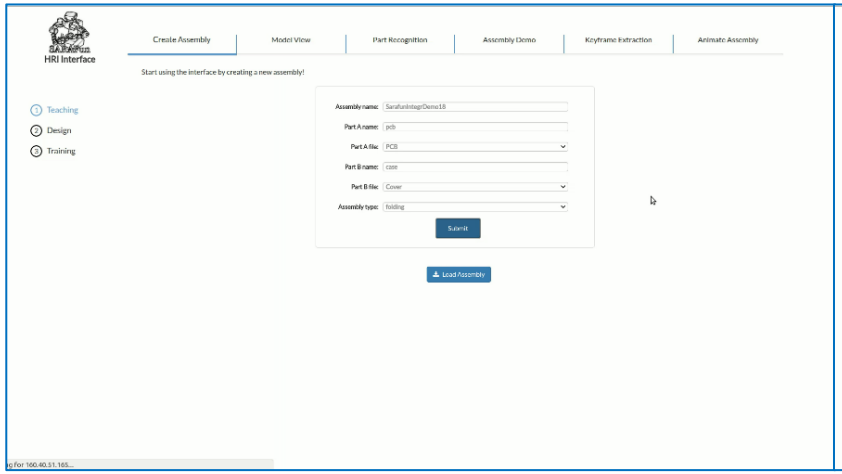
1. **Teaching**
2. **Design**
3. **Training**

HRI interface: Employed Technologies

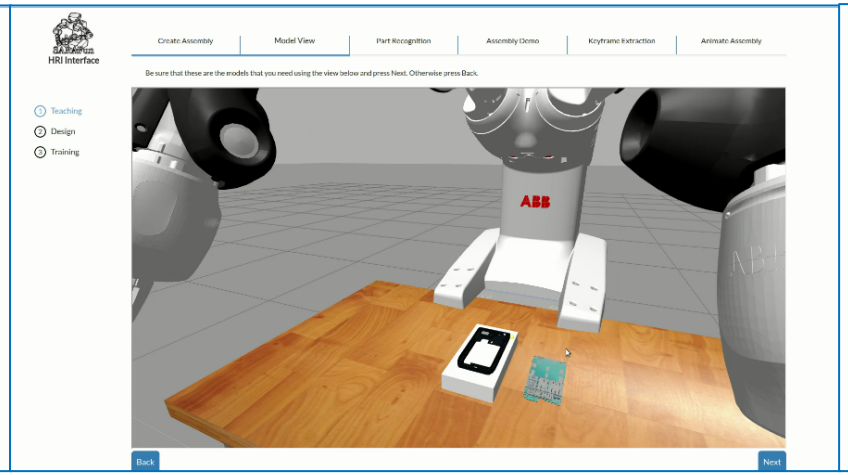


- ***Web based*** interface to increase ***portability***
- ***Client-Server*** architecture
- Different technologies in server side and client side have to work together
- *Client* view is ***lightweight*** and ***intuitive***
- ***Server*** handles the ***heavy work*** of analyzing and simulating
- Client is in ***constant communication*** with the server through Ajax, Gazebo interface and ROS calls

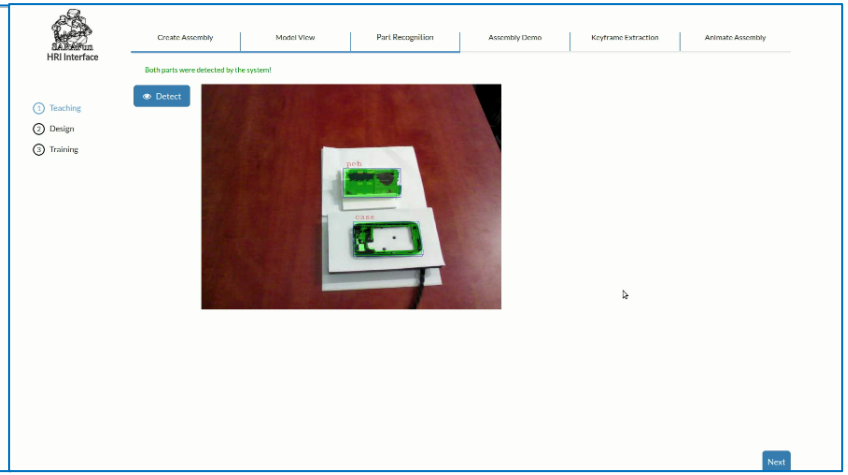
HRI interface : Teaching Example



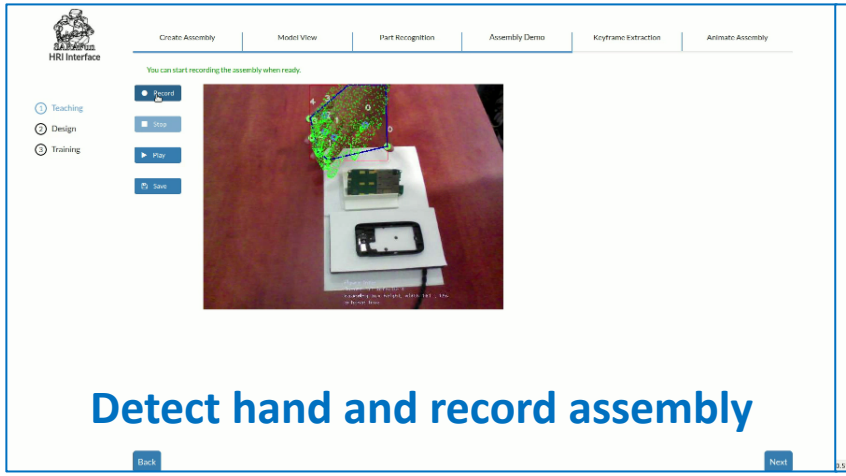
Create new Assembly



Preview CAD models

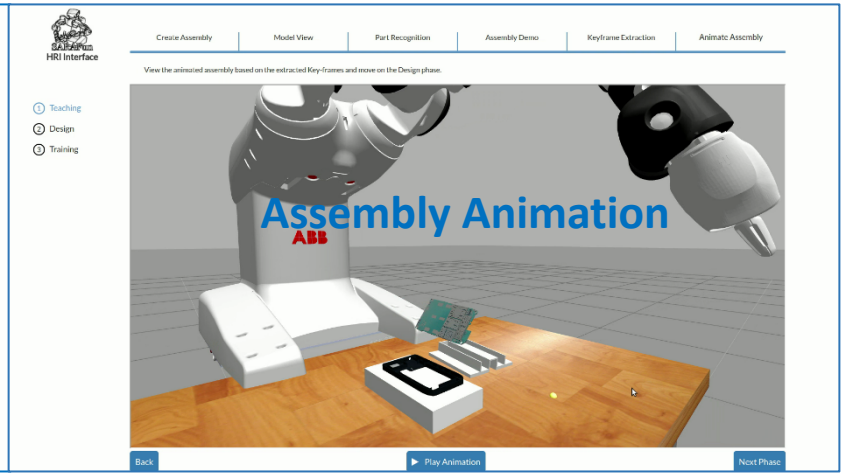


Detect parts

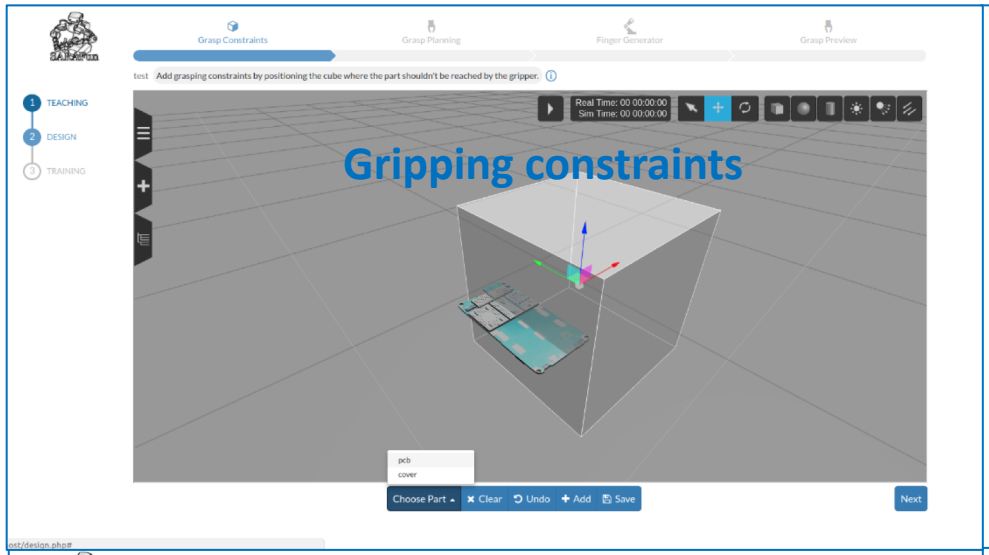


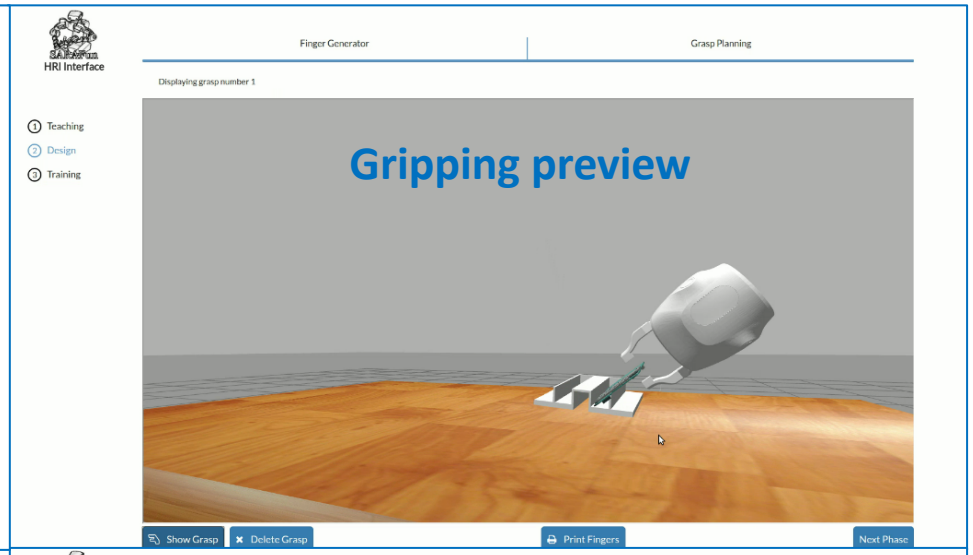
Detect hand and record assembly

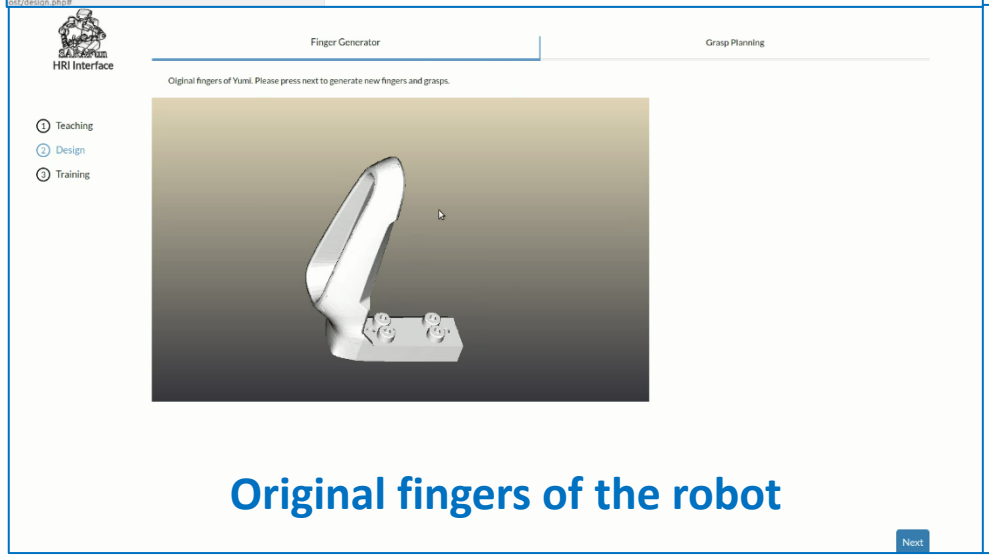
Extract Key-frames

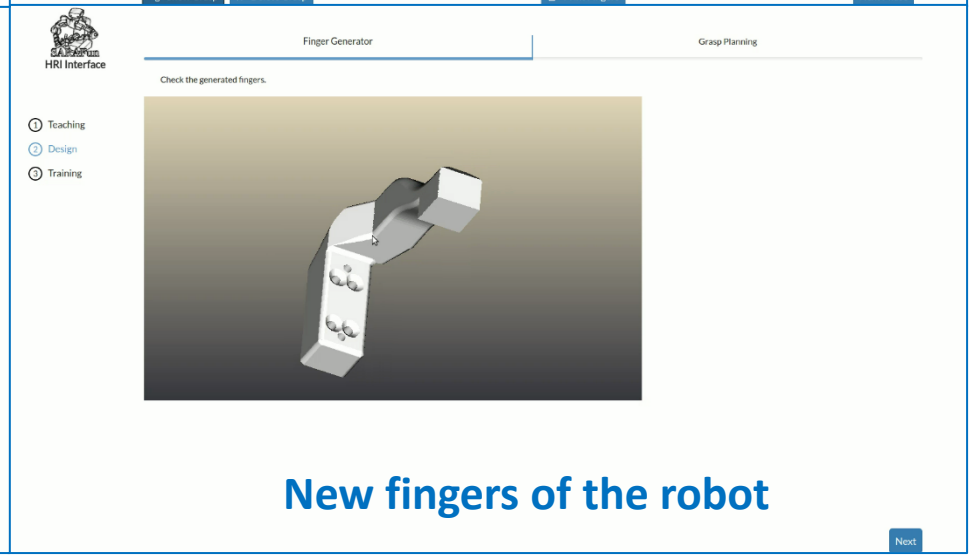


HRI interface : Design Example

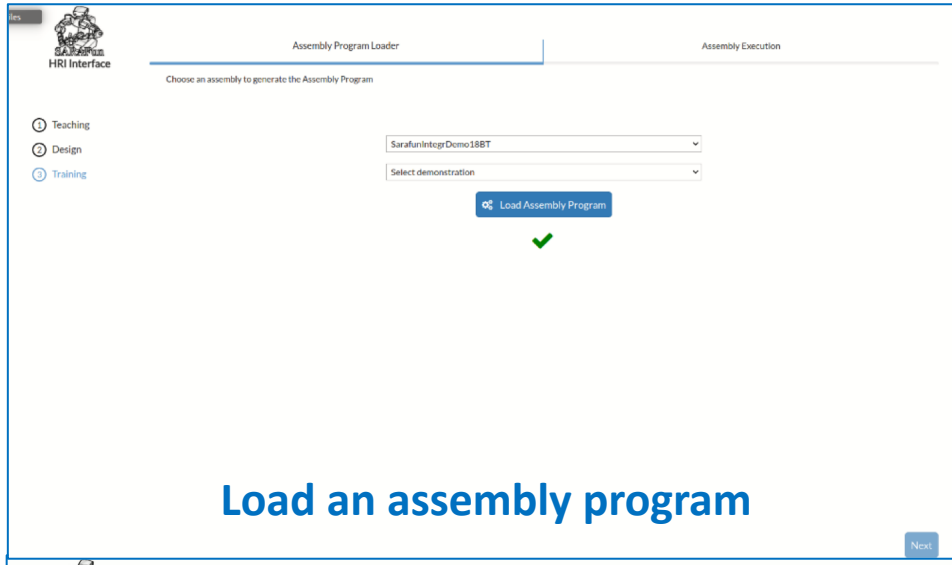




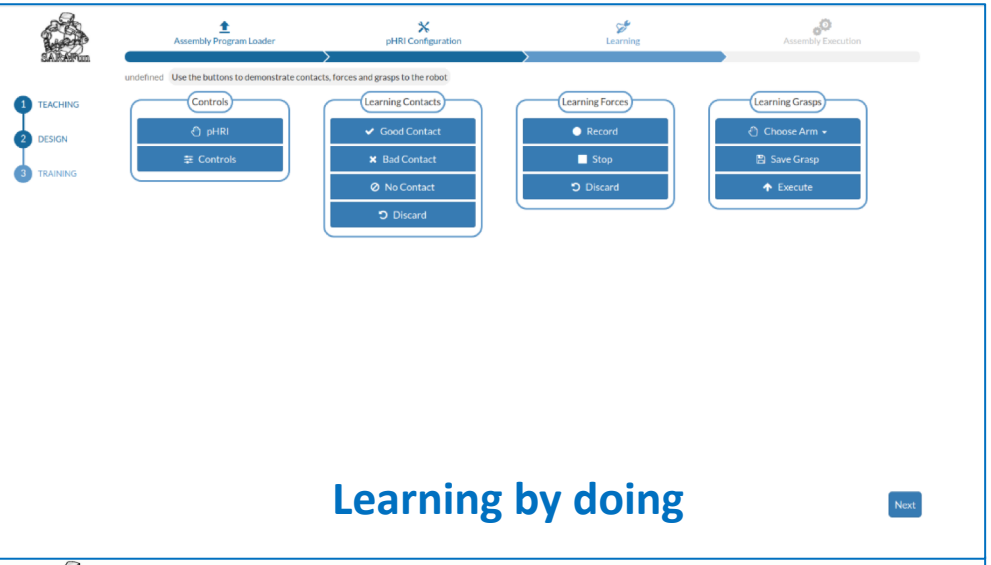




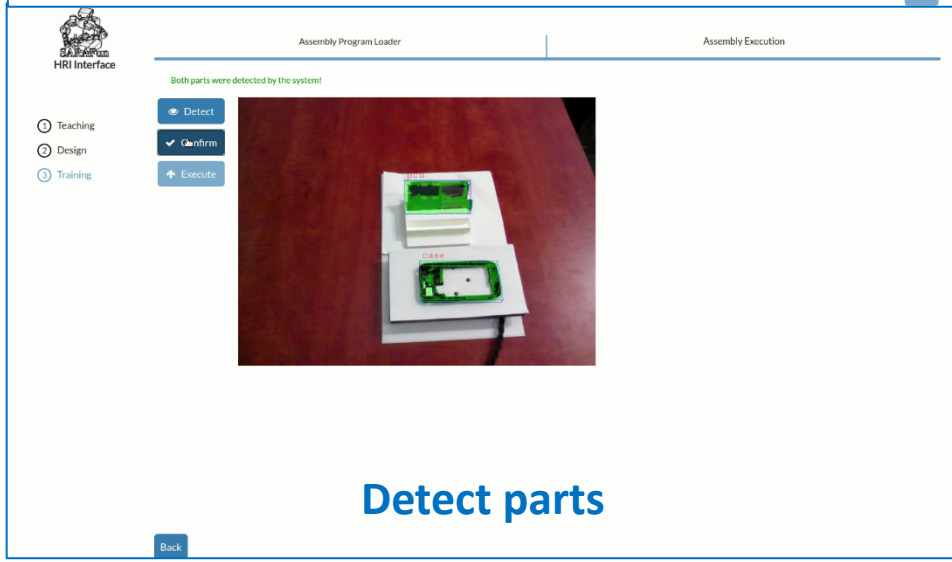
HRI interface : Training Example



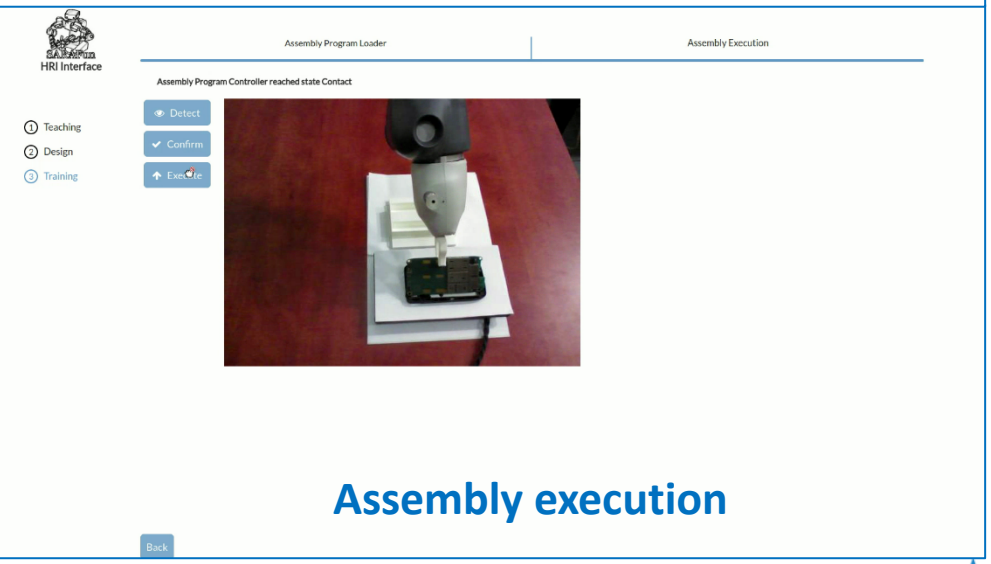
Load an assembly program



Learning by doing



Detect parts



Assembly execution

Experiment Methodology

- 13 subjects with IT background used to rate the HRI
- They were given a brief introduction of the system
- Folding assembly with mobile phone PCB and case
- A simulation of the assembly was displayed in the final phase
- Every subject completed the task in around 10 minutes

Evaluation of the HRI

Questions the subjects had to answer and the possible answers:

Questions	Median	Mean	Std
An inexperienced user can easily teach the robot an assembly task using this interface	4	4.3	0.48
I understood what buttons I needed to press to perform each action	4	4.35	0.43
I found the interface easy to use	5	4.6	0.51
The interface clearly guided me through the process	4	3.9	0.95
The interface presented a safe and effortless way to interact with the robot	4	4.38	0.51
The video streams and simulations gave a clear view of what was happening	5	4.32	0.85
Overall	**4**	**4.31**	**0.67**

The rating scale (1 to 5) corresponds to:

1	Strongly Disagree
2	Disagree
3	Neither agree or disagree
4	Agree
5	Strongly Agree

- 95% of answers were “agree” or “strongly agree”
- All the subjects found the interface very easy to use
- Experienced users needed about 10 min for completing phase 1 and 2
- New users needed on average 13 minutes for completing phase 1 and 2

Thank you!

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