



# Trust and Interaction in Industrial Human-Robot Collaborative applications

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#### Highly customizable robotic solutions for effective and safe human robot collaboration in manufacturing applications

- FourByThree proposes the development of a new generation of <u>modular</u> industrial robotic solutions that are suitable for <u>efficient</u> task execution in collaboration with humans in a <u>safe</u> way and are <u>easy</u> to use and program by the factory worker
- 3 Industrial settings + 1 Permanent lab
  - Welding, assembling, riveting, machine tending



#### www.fourbythree.eu

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# **CONTEXT: X-ACT**

- Expert cooperative robots for highly skilled operations for the factory of the future
  - Dual-arm based fenceless disassembly cell
  - Disassembly of electrical appliances
  - No fixtures
  - High flexibility







#### **CONTEXT: SMERobotics**

- The European Robotics Initiative for Strengthening the Competitiveness of SMEs in manufacturing by Integrating aspects of Cognitive Systems
- FLEXAS: Aeronautic components assembly using flexible dual-arm robotic in close collaboration with human operators







#### **CONTEXT: Need of collaboration**



#### X-ACT

#### **SMERobotics**





## **CONTEXT: Safety Strategy**





- Human Detection and tracking
- SSM 🔪
- Other Means
  - Safety devices
  - Feedback
  - Working procedure





The objective is to create a two-arm robot







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# **CONTEXT: Interaction mechanisms**

- Pushbutton
- Voice based
- Gestures
- Implicit







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- Safety. How do workers perceive the safety aspects when working in the vicinity of an industrial robot without physical barriers
- Interaction. What is the workers' feedback about different interaction mechanisms? How do they influence the level of trust?







- 17 workers
  - Experience: 16 industrial, 6 working with robots
  - Knowledge about accidents: 11 machinery, 4 robots





# **EXPERIMENT: Task (1)**



- 5 Iterations per session
  - 4 according to experimenter's request
    - Voice, gesture, button, implicit
  - 5<sup>th</sup> free choice







## **EXPERIMENT: Task (2)**



- Non programed entrance into the working space of the robot
  - The worker had to take an object from the workbench
  - The robot was moving at high speed







- Standard pushbutton is the preferred option 38%
  - Gestures 26% and voice 21%. Implicit 15%
  - It is the only one that did not confuse the participants
- Feedback on command recognition is suggested by 41% of participants
  - Lighting (41%) and screen message (35%)Speech (12%) or sound (18%)
- 100% considered the system easy (35%) or very easy (65%) to use



#### **RESULTS: Interaction-Screen**



- Only 2 participants complaint about the position of the screen.
  - But it should be considered (worker height and possible occlusions)
- 71% of the participants would appreciate a task guiding message on the screen
  - 6% feel the screen distracting
  - 64% paid attention always vs 6% that did not pay attention ever
- Most participants (82%) considered that the information on the screen contributed to do the task safer
- 10 knew HMD: 7 thought they could be useful





- 2 participants felt ridiculous using voice commands
- 59% participants preferred predefined commands instead of natural language (1 participant)
- Only one participant doubt about the Command to be used (second session)
- But in case of having more commands 65% considered a possible **source of confusion**
- 24% 'shouted'





- Nobody felt ridiculous
- The number of participants that thought that gestures can be confusing increased from the first session to the second (2 / 4)
   – Only 2 gestures
- In case of having more commands 76% considered a possible source of confusion





- 18% felt that they lost control
- Only 3 participants would like this form of interaction
- 53% doubt whether the robot had identified the end of the task or not





- The beep sound used to warn the approach to the risky zone was not considered annoying (100%)
- It was considered helpful even in the collaboration area (very low speed) by 71%





- After the experiment 53% felt that their perception on safety had improved
- 76% felt completely safe; 24% felt safe
- The marks on the floor
  - The Warning zone was appreciated by most participants (82%)
  - The collaborative zone was appreciated by 24% (35% placed inside it during the collaboration)
- All safety measures contributed in a similar way to the safety perception







- An emergency pushbutton would be convenient (53%) or should be mandatory (47%)
- The interlock key would be convenient (53%) or should be mandatory (47%)
- In the experiment:
  - (29% / 18%) used it and took the key
  - (18% / 18%) used it but they didn't remove it
    (53% / 65%) did not use it
- The interlock key would be used always by 18% of the participants







- The **pose** during collaboration was appreciated by most participants (65%)
- The metallic nature and overhead position was not considered relevant
- 41% would prefer an **smaller** robot
- Perception on robot speed changed from 1<sup>st</sup> to 2<sup>nd</sup> session
  - 24% / 41% too slow
  - 65% / 47% slow (it contributed to feel safer even if it is slow)
  - 12% / 12% considered it right
- 7 participants suggested the use of a helmet







- In case of collision the robot should stop immediately (100%)
  - Instead of moving in the opposite direction
- In case of collision nobody considered that a serious injury might happen
- 29% started the task even before the robot finished the part turning
- 29% moved back before the robot start turning





#### **Good news!**





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#### FourByThree

- Safety strategy
  - SSM (different technologies)
  - Force and Torque monitoring
  - Variable stiffness
- Multichannel input
  - Voice, gestures, remote control
  - Projection system
    - Virtual buttons
    - Guiding information
  - Manual guidance









- More information:
  - www.fourbythree.eu
  - www.smerobotics.org
  - www.xact-project.eu

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