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Contents

Executive summary

This deliverable contains the tasks and instructions sheets selected for the two scenarios of the ACAT project: the Industrial Assembly Scenario (IASSES) and the Chemical Laboratory Scenario (CHEMLAB), as well as motivation for choosing these specific tasks/instruction sheets for the two scenarios. For the IASSES scenario two tasks are selected: 1) a simpler one for the collection of rotor caps coming out of a production cell (a spinning machine) and 2) a more complex one for the rotor assembly. The simpler instruction sheet will be used to develop the demonstrators in year one, while the more complicated rotor assembly instruction sheet is targeted for the final demonstrator. In this deliverable only the instruction sheet for the simpler task, the collection of rotor caps coming out of a production cell, is provided. For the more complicated task we will use the instruction sheet taken from Grundfos. However, access to Grundfos materials requires signing of the Non-Disclosure Agreement (NDA) which is at the moment in the negotiation stage, thus only the general description of the task is given here. We will send the update of the deliverable when the NDA is done. However, the update will have to be “confidential” (restricted) access, only.

For the CHEMLAB scenario a DNA extraction task is selected and an instruction sheet for the task is provided. The scenario involves the handling of liquids and usage of standard laboratory equipment under the required constraints (temperature, time schedule, etc.).

1 Introduction

The ACAT project pursues two different scenarios: Industrial Assembly Scenario called IASSES and Chemical Laboratory Scenario, called CHEMLAB. This deliverable contains the short description of the tasks selected for the demonstrators of the two scenarios, motivation for choosing those specific tasks in each scenario, as well as instructions sheets for the selected tasks. The instruction sheets provided in this document will guide and motivate the development of the project. However, it is expected that the exact content and structure of the instruction sheets will be modified along the project based on the research results. This will be done in order to better reveal the achievements of the project, and, on the other hand, to avoid those complications that will be found to be un-resolvable within the scope of the ACAT project according to the research results. Hence, the instruction sheets presented in this document are only preliminary and will be continuously updated with the modified instruction sheets during the project.

The document is structured in two sections according to the two scenarios. In Chapter 2 the tasks, motivation and instruction sheets for the Industrial Assembly Scenario IASSES are presented. In Chapter 3 the task, motivation and instruction sheets for the Chemical Laboratory Scenario CHEMLAB are presented.

2 Industrial Assembly Scenario (IASSES)

2.1 Introduction and motivation

The IASSES scenario will be implemented at Aalborg University (partner AAU). It will consist of hardware components relevant for producing (or emulating the production) of various industrial components. The actual setup will depend on the selected tasks (see further).

At AAU two robot arms are available; a KUKA Lightweight Robot (LWR) and a Universal Robots 5 (UR5). Various tools are available, including a parallel gripper from Schunk and a three-finger adaptive gripper from Robotiq. Furthermore, a number of part feeders and fixtures are available. Finally, a number of production machines and machine “dummies” are available for testing the robot systems in production like environments.

The IASSES scenario will focus on manufacturing tasks in the production of rotors for electrical motors of pumps at the SQ-factory at the Danish company Grundfos. This production area called SQFlex has been the focus of research and tests in another EU Project called TAPAS funded under the Seventh Framework Program. As a partner in TAPAS, AAU has established a laboratory environment which emulates the actual production environment at Grundfos. In ACAT we will re-use some of the production emulation environment established at AAU and extend it to match the requirements of ACAT in order to demonstrate instruction sheet compilation and execution on a robot in the ACAT project.

The production emulation from Grundfos involves production activities such as: fetching parts, feeding various production machines (laser welders, hydraulic presses), quality control, assembly etc. These activities represent production activities which are typical for the general industry; hence the rotor production forms a good basis for test and research.

Two tasks have been selected from the SQFlex production:

- Collection of rotor caps coming out of a production cell (a spinning machine).
- Rotor assembly.

The rotor cap collection task, from a robotic point of view, is a fairly simple task involving a few (mainly motion control) actions. It will be used as the basis for the first demonstration and integration activities (Month 7 and Month 12 demonstrators).

The rotor assembly task is more complex, involving a number of complex motions and force controlled actions. It will be used as a point for discussion and will form the basis for the final demonstrator in the project.

Instruction sheets for the first task (collection of rotor caps coming out of a production cell), hence the Month 7 and Month 12 demonstrators, will be given in this document explicitly, whereas the second task (rotor assembly) is only explained in general terms. The actual instruction sheet for this task will be made available to the partners once a NDA is signed with Grundfos and will be non-public. The negotiations on the NDA are currently in progress.

2.2 Collection of rotor caps coming out of a production cell

2.2.1 Task description

The task here is to pick up a number of rotor caps from a conveyor belt and place them in a fixture on the robot in order to transport them. The task can be found at Grundfos (see Figure 1).

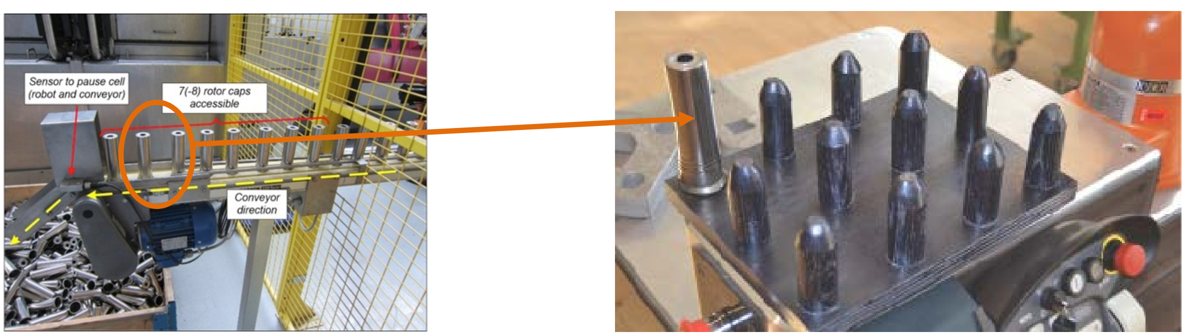


Figure 1: *Task 1 – rotor cap collection. Rotor caps are initially located on a conveyor that moves one step approx. each minute. The rotor caps have to be moved from the conveyor before they fall into a bin, and afterwards they have to be placed in a fixture.*

At AAU a test scenario will be set up as shown in Figure 2 (photo from the TAPAS project). The hardware will be changed to enable integration between the project partners.

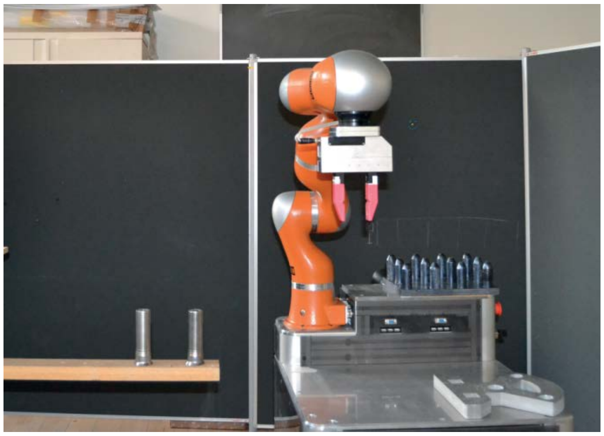
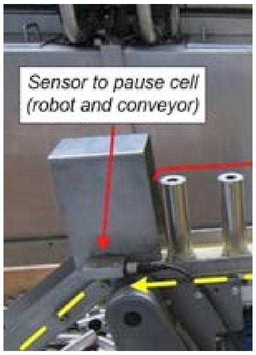
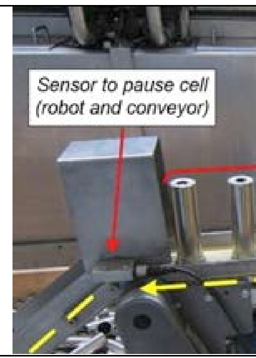


Figure 2: *Photo of a test setup at AAU from the TAPAS project. This illustrates the test setup for Task 1 – rotor cap collection for the IASSES scenario.*

2.2.2 Instruction sheet

Instruction sheets from Grundfos do not exist for this task (in the current production rotor caps fall into a bin). Hence, an instruction sheet has been written down (by AAU) for the task – see below.

Comments	Instruction sheet text	Illustration
Consists of the following sub tasks - Locate switch - Grasp switch - Pull-up switch - Release switch	Stop conveyor	
	Locate a rotor cap on conveyor	
	Pick-up a rotor cap from conveyor	

Consists of the following sub tasks: - Locate fixture - Find idle position on fixture - Place rotor cap on idle position on fixture	Place a rotor cap on fixture mounted on robot platform	
Repeat step 2-4	Pick-up until fixture is full or conveyor is empty	
Consists of the following subtasks: - Locate switch - Grasp switch - Pull-down switch	Restart conveyor	

2.3 Rotor assembly

2.3.1 Task description

In Figure 3 the parts 1x rotor shaft, 1x pressure ring, 8x magnets, and 1x rotor cap are shown. These parts are assembled into the final semi-finished good; the *SQFlex rotor* (marked "Rotor" in Figure 3).

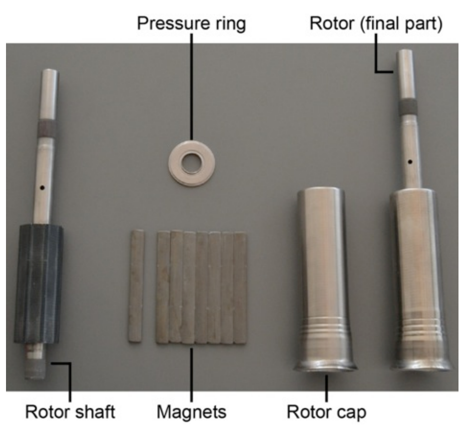


Figure 3: *Overview of the components used in the assembly of the SQFlex rotor. 1x rotor shaft, 1x pressure ring, 8x magnets, and 1x rotor cap are assembled into the SQFlex rotor.*

The rotor assembly proceeds as follows:

- The pressure ring is mounted onto the rotor shaft before it is placed into the press' fixture.
- Eight magnets are placed on the sides of the rotor shaft. These magnets must be correctly oriented and aligned with the octagonal shape of the core (part of the rotor shaft) in order to fit into the fixture.
- The rotor cap is placed on top of the fixture with the rotor axle sticking through the center hole. Due to limited clearance above the rotor axle the rotor cap must be tilted when placed on the rotor axle.
- The press is then activated.
- Afterwards the pressed rotor is removed from the press. Again the clearance above the pressed rotor is limited, and the rotor must be tilted in order to be removed.
- The pressed rotor is placed in a moveable fixture plate which holds a number of units.

Like the rotor cap collection task, a test scenario for this task has already been designed at AAU for use in the TAPAS project, see Figure 4. This or a similar setup will be used for the rotor assembly task in the ACAT project.

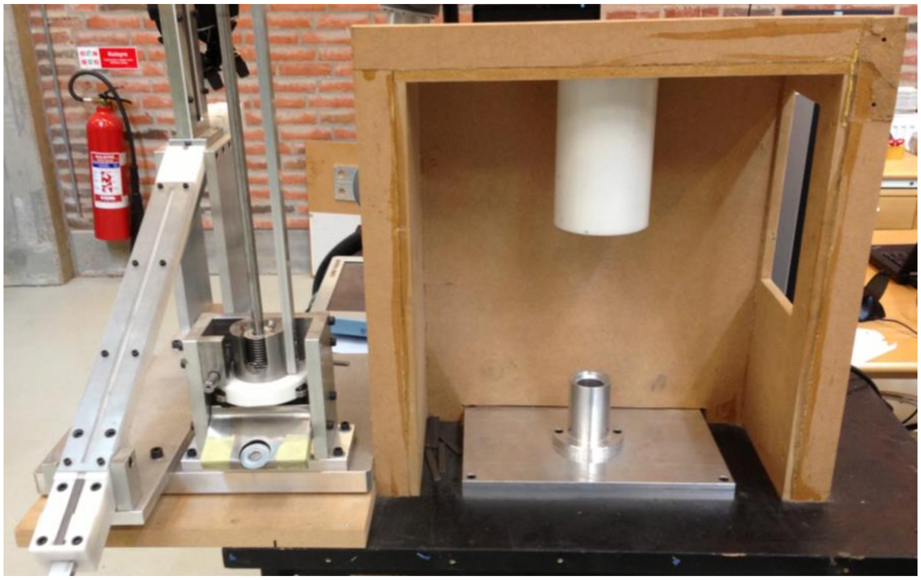


Figure 4: *Photo of a test setup at AAU from the TAPAS project. This illustrates the test setup for Task 2 – SQFlex rotor assembly for the IASSES scenario.*

2.3.2 Instruction sheets

The rotor assembly is described in a number of instruction sheets. These will be made available by Grundfos for the consortium (after an NDA has been signed and approved). The NDA process is already in progress and thus the instruction sheet will be made available in good time before the rotor assembly task becomes relevant.

Please note that the instruction sheets from Grundfos are in Danish and we will use English translation of those instruction sheets.

3. Chemical Laboratory Scenario (CHEMLAB)

3.1 Introduction and motivation

The CHEMLAB scenario will be implemented at the University of Bremen (partner UoB). The selected task for this scenario is the process of DNA extraction from a sample. The process involves the handling of liquids (pouring, decanting, etc.) and usage of standard laboratory equipment such as jars of different size and shape, filter cartridges, and a centrifuge. In order to be successful the process has to be executed under the required constraints (temperature, time schedule, etc.).

This scenario has been chosen because it combines several desired properties:

1. **Relevance**: DNA extraction is a process of high practical relevance, as it is done every day in laboratories all over the world.
2. The setting is **realistic and covers a typical workflow** in a chemical laboratory. The manipulation actions to be performed are very close to the actions a human lab assistant would perform. The basic actions, e.g., pouring and mixing, are very common in many lab processes, and not specific to the particular task of DNA extraction.
3. The success **can be evaluated easily**: the result of the successful process is a visible DNA pellet. All sub-processes involved either have an intermediate result which can be defined precisely or it can be observed directly if the sequence of actions is executed appropriately (e.g., with the required amounts of substances and according to the time constraints).
4. **Novelty**: As far as we know, a lab scenario of this level of complexity has not been successfully implemented with an autonomous robot in the past.
5. **Scalability**: The difficulty of the setting is scalable. E.g., from the point of view of manipulation complexity, we will start with very large (but yet realistic) lab equipment, but could increase the difficulty of the task by using smaller, more fragile tools and equipment.
6. I**nstruction resources**: There are many instruction resources (so-called 'lab protocols') available, both as written English text at different levels of detail and also as video, often in combination with written and/or spoken text. The combination of textual instruction and additional footage has the surplus to provide us with some 'ground truth' about how to execute the written instruction practically and gives us details usually omitted in the written instruction.

The DNA extraction shall be executed by a Willow Garage PR2 robot which has already been successfully used in related scenarios, e.g., the preparation of simple meals in a kitchen environment (see Figure 5).

Figure 5: *PR2 robot.*

3.2 Instruction sheet

As an example of a typical instruction sheet we selected the following text, taken from an instruction video by Abnova, a large antibody and protein manufacturer. This video, as well as similar instruction videos, has been distributed via different web channels, e.g., YouTube (http://www.youtube.com/watch?v=kOJfQz-G1fk) and scivee (http://www.scivee.tv/node/18111).

Transription (line breaks correspond to cuts in the video):

```
Plasmid DNA Extraction (Gigaprep)

Harvest the E.Coli by centrifugation at 6000g for 10 minutes at 4°C
Discard the supernatant
Resuspend the bacterial pellet in 15ml buffer R3 by vortex
Pour suspension together (total 75ml)
Lyse the bacterial cells by adding 75ml lysis buffer L7
Mix gently by inverting 4-6 times, and incubate at room temperature for 5
minutes
Neutralize the lysate by adding 75ml precipitation buffer N3
Mix gently by inverting 4-6 times
Centrifuge at 20,000g for 15 minutes at 4°C
Pour the supernatant into the gigaprep lysate filtration cartridge
Apply vacuum until all liquid has drained
Add 200ml equilibration buffer EQ1 to the DNA binding cartridge
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Apply vacuum until all liquid has drained; Discard the flow-through
Add the filtered lysate into the equilibrated DNA binding cartridge
Add 550ml wash buffer W8
Transfer the binding cartridge onto a clean bottle
Add 120ml of elution buffer E4
Transfer the flow-through to a new centrifuge bottle
Add 85ml isopropanol
Centrifuge at 13,000g for 30 minutes at 4°C
Carefully decant the supernatant
Wash DNA pellet with 1ml 70% ethanol twice
Centrifuge at 15,000g for 10 minutes at 4°C
Carefully remove the supernatant
Air-dry the DNA pellet for 10 minutes
Redissolve in 1ml TE buffer
Purified plasmid DNA is ready for the downstream application
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Although this instruction text is precise in some respects (e.g., exact quantities), it also exhibits many of the challenges we expected, including vague modal adverbs ('gently', 'carefully'), descriptions of actions in terms of their effects ('until all liquid has drained'), underspecified verb frames (e.g., missing direct object in 'Redissolve in 1 ml TE buffer'), and many missing details (e.g., after adding isopropanol the lab assistant inverts the sample several times, which isn't reflected in the written instruction at that point, though the same step had been mentioned explicitly in the description when it had been executed, before).

4 Conclusions

The instruction sheets for the IASSES and CHEMLAB scenarios presented in this document will guide collection of the text corpora and other data repositories for further development of the action categories (A-cats) as well as preparation of the actual robot setups at partner institutions. The actions involved in the presented instruction sheets will serve as the basis for selecting about 20 action verbs which will be used as the starting set and for which the first action categories will be developed. The actions, objects and properties mentioned in the instruction sheets will allow evaluating the suitability of the ontologies (which already started to emerge through the work of the ACAT partner institutions) for the project needs. Also, based on the presented instruction sheets the designed structures for the A-cat library will be evaluated as well as benchmarks for the ACAT project will be designed.