Robot Competitions Kick Innovation
in Cognitive Systems and Robotics
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RoCKIn@Home

– A Competition for Domestic Service Robots –
Competition Design, Rule Book, and Scenario Construction

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Abstract

RoCKIn is a EU-funded project aiming to foster scientific progress and innovation in cognitive systems and robotics through the design and implementation of competitions. An additional objective of RoCKIn is to increase public awareness of the current state-of-the-art in robotics in Europe and to demonstrate the innovation potential of robotics applications for solving societal challenges and improving the competitiveness of Europe in the global markets.

In order to achieve these objectives, RoCKIn develops two competitions, one for domestic service robots (RoCKIn@Home) and one for industrial robots in factories (RoCKIn-@Work). These competitions are designed around challenges that are based on easy-to-communicate and convincing user stories, which catch the interest of both the general public and the scientifc community. The latter is in particular interested in solving open scientific challenges and to thoroughly assess, compare, and evaluate the developed approaches with competing ones. To allow this to happen, the competitions are designed to meet the requirements of benchmarking procedures and good experimental methods. The integration of benchmarking technology with the competition concept is one of the main objectives of RoCKIn.

This document describes the first version of the RoCKIn@Home competition, which will be held for the first time in 2014. The first chapter of the document gives a brief overview, outlining the purpose and objective of the competition, the methodological approach taken by the RoCKIn project, the user story upon which the competition is based, the structure and organization of the competition, and the commonalities and differences with the RoboCup@Home competition, which served as inspiration for RoCKIn@Home. The second chapter provides details on the user story and analyzes the scientific and technical challenges it poses. Consecutive chapters detail the competition scenario, the competition design, and the organization of the competition. The appendices contain information on a library of functionalities, which we believe are needed, or at least useful, for building competition entries, details on the scenario construction, and a detailed account of the benchmarking infrastructure needed — and provided by RoCKIn.

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Chapter 1

Brief Overview on RoCKIn@Home

This chapter gives a brief overview on RoCKIn@Home. It is a quick guide to anyone who wants to learn what RoCKIn@Home is about, and it should raise the interest of anyone working on indoor service robotics. Ideally, researchers should recognize the opportunity to evaluate and assess their robots and their research approaches in an independent, but well-defined setting. Developers, manufacturers and investors in the domestic service robotics area should recognize the opportunity to objectively assess and compare different engineering solutions for robot hardware and software design problems in an independent and objective manner, or to use the results obtained by third parties performing such assessments.

1.1 Purpose and Objectives of RoCKIn@Home

The main purpose of RoCKIn@Home is to *foster research in domestic service robotics*.

One of the most challenging societal problems in Europe is centered around *healthy aging* and allowing a *better living for elderly people* in an aging society. Service robots have been seen as a technology that could play an important, if not essential, role in providing technological support for healthy aging. However, progress in the past decade has been less than expected by many, and most products currently offered or being developed for healthy aging are not based on robots. In this situation it is necessary to foster and accelerate research efforts and to provide incentives to researchers for developing technologies needed for building robot applications for healthy aging.

A commonly agreed-on deficit by the robotics community is its sub-par use of rigid evaluation and assessment procedures in order to compare alternative methods and approaches and to effectively find out which ones are advanced and robust enough for use in developing applications. Benchmarking is one element to improve evaluation and assessment, competitions are another. While benchmarking focuses on the rigidity and validity of the results, competitions can do a great job to raise the interest in solving particular problems and to create more research and development activity in an area. RoCKIn strives to combine both elements in the competitions it designs and organizes.

Another barrier for higher market penetration of domestic service robots is commonly seen in the lack of standards. While it is not an immediate objective of RoCKIn to work on standardisation in robotics, the project still makes significant contributions towards this effect. This is achieved e.g. by identifying *typical scenarios* and *typical tasks* relevant for domestic service robotics, and by developing *methods and techniques to evaluate and assess various abilities* of such robots. This is an essential step towards standardization.

1.2 The RoCKIn Approach

The RoCKIn project uses a systematic approach to achieve its goals. This approach is illustrated in Figure 1.1 and briefly explained the following five paragraphs. For more details, please refer to Deliverable D-1.1 [1].

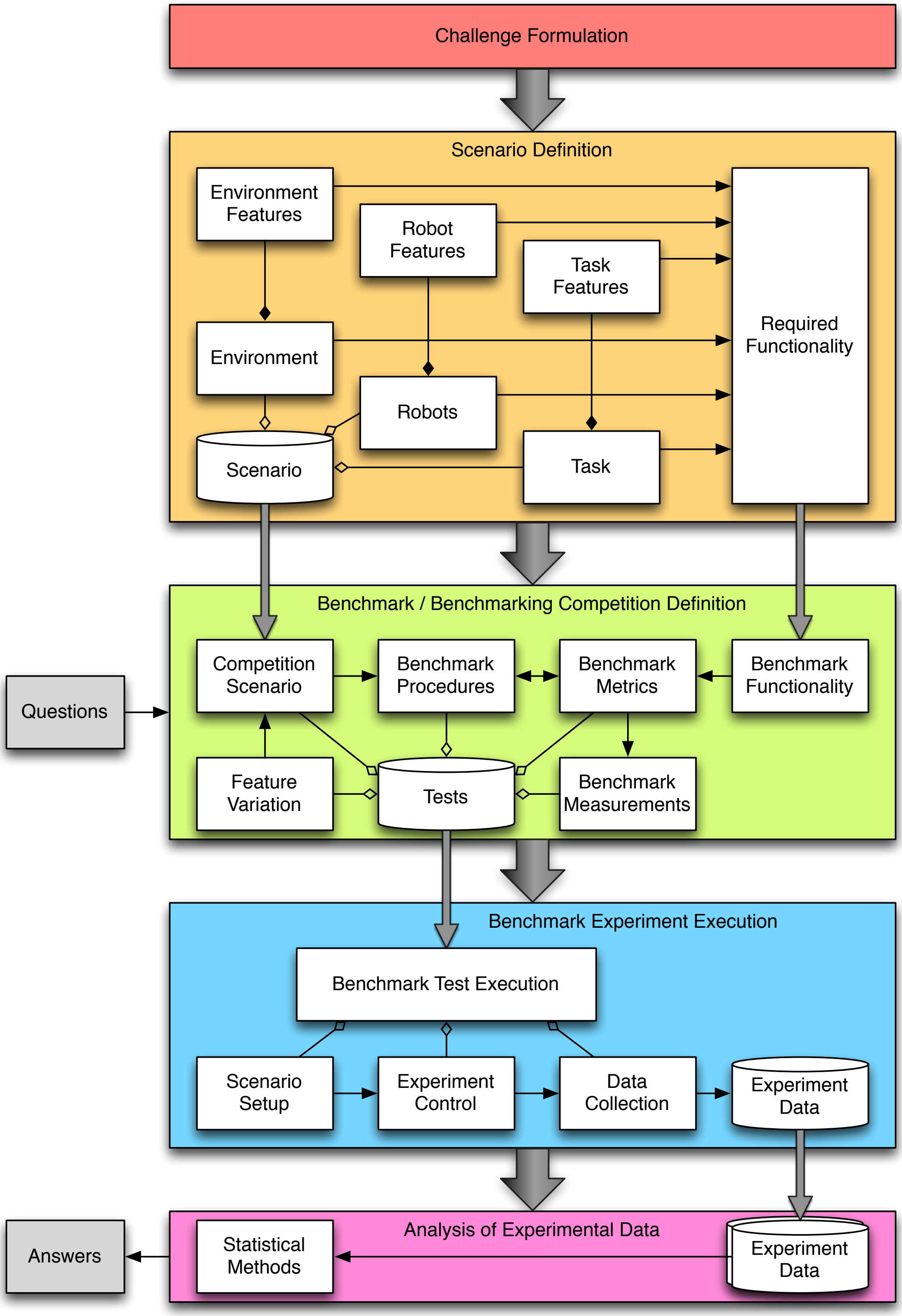


Figure 1.1: Overview of the RoCKIn approach.

(1) Formulation of challenge problems: As a first step, challenge problems need to be formulated. This is a difficult yet critical step, because the challenge problems need to satisfy various constraints, such as being new and interesting enough to raise the interest of the general public, the media, and relevant societal and political stakeholders. Furthermore, the challenge problems should have an interesting application potential in domains with significant market potential to raise the interest of industry. The challenge problems should pose interesting and new research questions to raise the interest of the research community, but solutions need to be within reach in a foreseeable period of two to five years.

(2) Definition of a scenario: Once a challenge problem has been identified and described, we need to define a scenario for it. A scenario description includes all relevant aspects of the *task* to be performed, of the *environment* in which the task is to be performed, and of the *robots* to be used.

For each of these three major aspect categories, a set of relevant features[1] are identified. For each feature, a feature domain, i.e. a range of possible instances of the feature, is defined. Features can be mandatory or optional in a scenario. Thus, while the set of features describes the *structure of a scenario*, the feature domains span a space of possible parameter values and thereby define the *variability of the scenario.*

An interesting aspect of scenario definitions is their relationship with the functionalities that the robots are required to have. One of the major objectives of the RoCKIn project is to better understand how the performance of particular functional subsystems, e.g. for mapping, navigation, grasping, taking orders from humans, etc. correlates with the overall performance of the robot executing a particular non-trivial task, e.g. "*Deliver this parcel to the post office!*". To that extent the scenario definition should include a list of *abstract* functionalities which appear to be implied by the specification of the scenario and its major subcategories task, environment, and robot.

(3) Definition of a benchmarking competition: While scenario definitions are an excellent means to characterise a particular application domain, they usually leave an immense variability in various aspects of task, environment, and robot. When performing a benchmark or scientific competition we like to make it as much a scientific experiment as we can.

Aside of identifying the functionalities, defining measures and metrics, and suitably constraining the scenario, we need to specify precisely the procedures for executing the experiments. In scientific competitions this includes timing, setup of the scenario, initiation of a test run, any kind of interaction with the robots during a run, controlling any environment or task features (e.g. supplying an object at a particular instant of time), scoring, measuring and recording of data, and so on.

(4) Execution of the benchmarking competition: After a benchmark or scientific competition has been defined and a well-specified set of tests is provided, the tests need to be executed. This requires the actual setup of the scenarios specified in the tests, carefully executing the procedures for experiment control, and diligently recording all required data.

[1] Most of the features can be viewed as parameters in a scientific experiment.

(5) Analysis of the results: After execution of the experiments, the recorded data can be analysed by applying the appropriate statistical methods in order to provide the answers that motivated the benchmark or competition.

1.3 Brief Outline of the RoCKIn@Home User Story

This section provides a brief overview of the competition scenario and will describe – in general terms – the kind of robots targeted and the tasks the robots are expected to perform. Further details on the scenario are deferred to Chapter 2.

The basic idea is that we have *an elderly person, named "Granny Annie", who lives in an apartment together with some pets. Granny Annie is suffering from typical problems of aging people: She has some mobility constraints. She tires fast. She needs to have some physical exercise, though. She needs to take her medicine regularly. She must drink enough. She must obey her diet. She needs to observe her blood pressure and blood sugar regularly. She needs to take care of her pets. She wants to have a social life, and welcome friends in her apartment occasionally, but regularly. Sometimes she has days not feeling so well and needs to stay in bed. She still enjoys intellectual challenges and reads books, solves puzzles, and socializes well.* For all these activities[2], RoCKIn@Home is looking into ways to support Granny Annie in mastering her life.

We would like to point out here that we do not expect a single, very complex robot to solve all of the above tasks. Rather, we would like to open the arena for more flexible solution concepts, which may make use e.g. of other mobile devices, such as smartphones and touchpads, integrate various means of communication between the human user and the technology platform, might employ and interact with intelligent devices in an ambient environment, and are able to tap into the Internet to provide simpler and richer solutions in a more flexible and cost-efficient manner.

In particular, the competition will be designed such that at least non-trivial parts of it can be solved using robots without a dexterous manipulator, because such robots are not yet as widely-spread in research labs and meaningful sub-parts of the scenario can be solved without a dexterous manipulation ability. Many more advanced tasks, however, do require such a manipulation ability, and the competition also foresees tasks that hopefully drive research in that area.

1.4 The RoCKIn@Home Competition

The RoCKIn project runs from 2013 through the end of 2015. The RoCKIn competitions will be held twice, in Fall 2014 and Fall 2015. Both RoCKIn and RoboCup have the intention to eventually merge the competitions in a joint event for the years beyond 2015.

The first RoCKIn event including the RoCKIn@Home competition will be held end of November 2014 at LAAS, Toulouse, France. Details on this competition will be supplied as they become known. Please refer to the web site of the RoCKIn project (`www.rockinrobotchallenge.eu`) and the web pages on RoCKIn@Home.

[2] Much more detail on the user story is provided in Chapter 2.

1.5 Commonalities and Differences with RoboCup

It is not a secret that RoCKIn@Home is inspired by RoboCup@Home, and the RoCKIn-@Home organizers hope that many if not all of the concepts and methods developed for RoCKIn@Home will eventually be picked up and integrated in RoboCup@Home. Nevertheless, it may be illustrative to briefly outline some commonalities and differences between RoCKIn@Home and RoboCup@Home, based on the list of *"Concepts behind the competition"* in the 2013 rule book of RoboCup@Home:

- Both RoCKIn@Home and RoboCup@Home aim for *applications*, *social relevance*, *scientific value*, and *attractiveness*.
- RoCKIn adopts the concepts of *lean set of rules* and *community* in a modified form, due to its different structure and objectives.
- RoCKIn@Home differes from RoboCup@Home with respect to the concepts of *desired abilities*, *autonomy and mobility*, *time constraints*, and *no standard scenario*.

Chapter 2

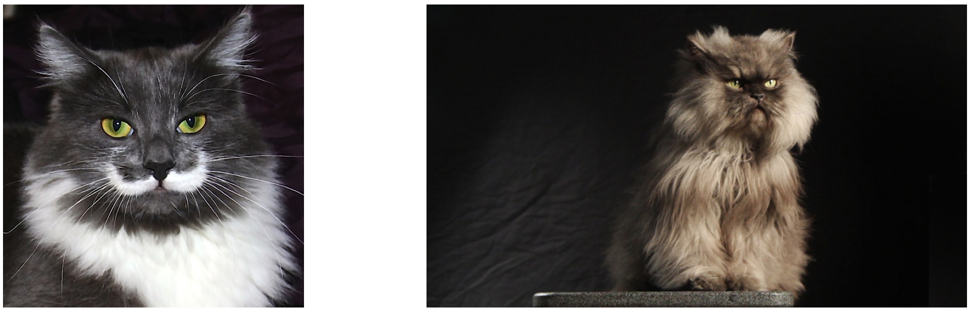
The RoCKIn@Home Challenge

This chapter first sets the stage for RoCKIn@Home by describing the user story, which serves as a basis to derive specific scenarios and tasks for the competition, in more detail. The user story has a general part and a sequence of episodes, each of which requires several tasks to be performed. Subsequent sections present the concepts and objectives behind RoCKIn@Home, and describe the differences and commonalities with RoboCup@Home in more detail.

2.1 The RoCKIn@Home User Story

The common background for the RoCKIn@Home user story is as follows:

Granny Annie is a nice but slightly seasoned lady. After a fulfilled work life she is already in retirement for well over ten years. Sadly, she has lost her husband a few years ago and now shares her apartment only with her two cats Hamilton *and* Colonel Meow *(see Figure 2.1). The apartment (see Figure 2.2) features a kitchen, a large combined dining and living room, a bedroom, a bathroom and a toilet, all connected by a hallway. Age is slowly taking its toll, and is recently showing in various situations. Getting out of bed or sitting down in the couch is getting harder, her eyesight is suffering a bit more than it used to, and she sometimes forgets to take her medicine timely. Many household chores are now a lot more difficult for her to do.*



(a) Hamilton (b) Colonel Meow

Figure 2.1: Granny Annie's cats

Luckily, Granny Annie could get into a new program sponsored by her health and social security insurances. In this program, elderly people are supplied with household and elderly

Figure 2.2: Granny Annie's appartment.

care robots and other helpful electronic appliances. The robots and electronic devices are to assist the elderly people to manage and master their daily lives, to longer live an independent life in their known surroundings, and to better maintain social contacts, which is known to have a very positive influence on the mental and bodily health of elderly people.

A list of tasks these robots are supposed to perform includes the following activities:

1. **Meal Service:** Planning, preparing, and serving meals thoughout the day, including setting the table before the meal and cleaning it up afterwards, including serving accompanying drinks, and covering both private meals as well as serving food and drinks for a small number of guests.

2. **Mobility Assistance:** Helping the user to sit down or stand up from chairs, sofas, or bed, by "lending them an arm", and guiding the user through the appartment.

3. **Medical Therapy Support:** Ensuring the user is reminded of taking prescribed medicine, serving the medicine, and observing correct intake or application of the medicine (like injection of insuline), support in performing observation functions (like measuring pulse, blood pressure, or blood sugar), maintaining a record of the intake of liquids and food, and animating the user to perform physical exercise and recording the actual activities.

4. **Social Contact Support:** Assisting the user in maintaining social contact with friends and family, using a range of media for doing so, like phone, email, chats, video calls, and video conferences, and social media.

5. **Visitors Handling Support:** Assisting the user in receiving visitors and guests by welcoming them at the door, guiding them through the appartment, interacting

with them directly or serving as a communication relay to the visitor, ensuring personal safety by not admitting anyone unknown to the appartment.

6. **Entertainment and Mental Health Support:** Assisting the user in using media of all kinds for entertainment (reading books, listening radio, watching television, playing digital music, solving puzzles, using Internet entertainment services), and playing card games and board games with the user.

7. **Personal Comfort Support:** Ensuring the personal comfort of the user at all times, e.g. by adjusting light settings, operating window shutters and blinds, opening and closing windows and doors, and controlling room temperature.

8. **Pet Care Support:** Taking care of the user's pets, including knowing or finding out about their whereabouts and activities, ensuring a sufficient supply of food and water, and possibly mucking out the litter pan.

9. **Emergencies Handling Support:** Finding lost items the user cannot remember where she/he put it, collecting and replacing dropped items, detecting spilled liquids and cleaning them, detecting when the user has fallen, and activating emergency help if necessary.

10. **Private Inventory Management:** Assisting the user in maintaining the private stock of household items (food ingredients, drinks, toiletries, personal care products, and medicine supplies), ordering them when necessary, potentially after confirmation by the user, stocking delivered items, disposing emptied supplies, replacing towels in the bathroom, and tidying clothes.

11. **Cleaning Support:** Assisting the user to keep things in their place, cleaning the table after meals, wiping surfaces, vacuuming floors.

This list could be easily extended, but the reader should be able to get the general idea. Most of these services would involve the use of a mobile robot, which is able to roam around Granny Annie's apartment. For some services, the robot does not need a dexterous manipulator, for others such a device may be indispensable. For our story, we assume a home robot called *Jenny* has been delivered to Grannie Annie. Needless to say, any technology used must be absolutely safe for operation in Annie's apartment without supervision by an operator, and Granny Annie must be able to use it in very intuitive and simple ways.

In addition to the use of a mobile robot, Granny Annie's apartment may be equipped with additional electronic devices. For example, a camera observing the kitchen may have been installed, small devices which can be remotely activated by the robot may help the robot to open and close doors and drawers, and a remotely activatable dispenser for water and food for the pets may be present. Granny Annie can communicate with the robot either directly through speech and gestures, when the robot is near her, or through a touchpad device, which aside of using the haptic capabilities also allows for voice communication and video streaming from a robot camera.

We outline below a couple of specific episodes involving tasks that are believed to be within reach by state-of-the-art robotic devices.

2.1.1 Episode 1: Wake-Up Procedures

It is 7am. Granny Annie is waking up and today she feels a bit tired because she has not slept very well. Still a number of tasks need to be taken care of. The home robot will help her in all these tasks. She can communicate with it through a tablet device allowing voice communication and video streaming from a robot camera.

First she asks the robot to come to her bedroom for taking her orders. She wants the robot to lift the rolling shutters, switch off the ceiling light, and tilt a window.

Next, she worries about the cats. Are Hamilton and Colonel Meow at home? If not, the door that allows the cats to enter must be opened. Do they have food and water? Better supply them before hearing their complaints. She would like also to see the cats on the screen, if they are around. She asks the home robot to take care of these activities.

Then, Granny Annie wants to read a book, but she realizes she has forgotten her reading glasses somewhere in the home. She asks the robot to check whether they are on the sofa in the living room, or else maybe in the bathroom. In any case she needs the robot to find them and bring them to her. During the search she might remember and tell the robot other places the glasses might be.

Just as the robot has found and delivered the reading glasses, she hears the bell ringing. The robot needs to check who is at the entrance. Hopefully, the breakfast service is coming, or possibly the doctor, the mailman, or the newspaper just being delivered. The robot must open the door, welcome the visitor and tell him/her that Annie is ok and wants to stay in bed for a little more time. The robot must then understand the aim of the visitor and handle it accordingly.

2.1.1.1 User Task "*Cater for bedroom comforts*"

A possible execution of the wake-up-scenario would requests some service ensuring the personal comfort of Granny Annie and may proceed as follows:

1. Granny Annie activates her touchpad by swiping over it.
2. By touching a big icon for the home robot Jenny she initiates a dialog with the robot.
3. Jenny reacts by greeting Granny Annie and saying "*Good morning, Annie! Did you sleep well? What can I do for you?*"
4. Granny Annie: "*Please come to the bedroom.*"
5. Jenny: "*Okay. Just a minute.*"
6. The robot moves from wherever it had been to the bedroom and positions itself at the footside of the bed.
7. Granny Annie: "*Lift the shutters, please. And switch off the light. I want to stay in bed a little longer and read.*"
8. Jenny: "*Okay, will do.*"
9. The robot moves to the left side of the window, where it knows the switch for operating the rolling shutters is located.
10. The robot uses its arm to operate the switch accordingly. (Possible difficulty: The switch is occluded by a curtain.)
11. Granny Annie: "*Ah, I forgot. Please tilt the window, too.*"

12. Jenny: "*Okay, no problem.*"
13. The robot reaches to the window handle, turns it upwards (counterclockwise), and tilts the window by pulling it a little.
14. Then the robot moves towards the door, next to which the switch for the ceiling lights is located, and switches off the lights. (The lights had been switched on by Annie herself using an intermediate switch located next to her bedside.)
15. Jenny: "*Okay, window tilted, shutters lifted, lights off. Is it okay this way?*"
16. Granny Annie: "*Thanks, Jenny, marvelous job.*"
17. The robot starts moving out of the bedroom to leave Granny Annie undisturbed. Just before the robot leaves the room, ...
18. Granny Annie: "*By the way, Jenny, where are my cats?*" (see next)

Discussion of variations: Despite appearing as if everything in this little episode is fixed and set, there is quite a bit of variability hidden in it. We will discuss these eventually in greater detail in later chapters and later versions of this document, but some variations coming easily to our mind include:

- ***More flexible human-robot interaction:*** Looking into more detail into the interaction between the robot and the human, especially into the role of the touchpad device. While probably neither solving this communication problem completely without a touchpad (how would the human call the robot on duty if the robot is in another room or far away, making direct interaction impossible?) nor performing all communication via the touchpad is desirable, the question arises, when and how to properly switch between these two modes, or better, how to integrate them seamlessly such that the human would not even notice whether the robot got a command via the microphone or via the touchpad. However, solving this dilemma poses challenging problems for the integration of GUI-based and speech-based communication.

- ***Dealing with linguistic challenges:*** The dialog itself contains several examples of phenomena in human speech which present challenges for speech processing and natural language interaction, such as resolving referents, ellipsis, colloquial expressions, etc.

- ***Manipulating a variety of electric switches and knobs:*** Assuming the rolling shutters are electrically operated, there are several variants of push-button or switch devices that could be used; some examples are depicted in Figure 2.3. An option would be to replace manually operated switches by devices that can be remotely activated. This option would, however, incur additional cost.

- ***Handling ad hoc plan changes and continuous state:*** Another variation for operating the shutter would be that Granny Annie finds out – as the shutters are receding – that the Sun is shining in too strongly and blinding her. As a consequence, she requests the robot to put the shutters in some intermediate state, e.g. 1/3rd down.

- ***Interacting with handles:*** Great variation also exists for window opening/tilting handles and associated mechanisms (similar, if not exceeding the variation for door openers). The challenges here include representing the different concepts, providing the required perceptual abilities to enable the robot detect the current state of a window or door, and the manipulative abilities to perform the correct actions in order to achieve a different state.

Figure 2.3: Examples of switches operating shutters.

2.1.1.2 User Task "*Handle the home pets*"

After getting some comfort, Granny Annie is worried about her pets:

1. Granny Annie: "*By the way, Jenny, where are my cats?*"
2. Jenny: "*Okay, I will look for them.*"
3. The robot moves to the place in the living room known as the cats' corner, which has two cat baskets, a litter box. a scratching post, and bowls for water and cat food. The cats are not there.
4. The robot moves to the front door, which features a cat flap. The robot detects that the flap is locked and unlocks it. The cats, who were already waiting in front of the door, are coming in and walk to the cats' corner.
5. When the robot has detected the cats, it is directing its camera towards them and sends the video stream to Granny Annie's touchpad. Jenny is tracking the cats while they walk to their home place in the living room.
6. Granny Annie: "*Oh great, my darlings are back from their night walk! Jenny, let's check their water and food supply.*"
7. Jenny: "*Okay.*"
8. The robot moves close enough to the cats' corner such that Granny Annie can have – via the robot's camera – a good look at the bowls with water and cat food. The water bowls are empty, as is Hamilton's food bowl. Colonel Meow's food bowl has some leftover food from yesterday.
9. Granny Annie: "*Jenny, fill both water bowls with water. Then dispose the leftovers in Colonel Meow's bowl and serve both cats with 60 grams of Chicken Brekkies.*"
10. Jenny: "*Okay.*"
11. The robot picks up Colonel Meow's bowl and carries it to the kitchen.
12. The robot pulls the closet with the trash can and disposes the remains.
13. The robot leaves the bowl in the kitchen, and picks up a water can, which is already filled with water.

14. The robot moves to the cats' corner and pours about 200ml of water in each water bowl.
15. The robot moves back to the kitchen and places the water can in its place.
16. The robot picks up the food bowl left previously in the kitchen and brings it back to the cats' corner, then comes back to the kitchen.
17. The robot opens another drawer, which contains two electronically activatable food dispenser devices, one filled with Beef Brekkies, the other with Chicken Brekkies.
18. The robot picks the dispenser with Chicken Brekkies and moves to the cats' corner, where it locates the dispensers next to one of the food bowls. It activates the dispenser to serve about 60 g of Brekkies, then stops the device and places it next to the other food bowl. Again, the robot activates the dispenser and serves about 60g of Brekkies. Then it stops the device and carries it back to its place in the kitchen.
19. The robot moves back to the living room, about 2-3 m away from the cats' corner and gives Granny Annie a good view of how her hungry darlings devour their food servings.

Discussion of variations: To the best of our knowledge, there has been little research on pets in service robot applications so far. Therefore, the inclusion of an episode that explicitly introduces this aspect *per se* presents an innovation and a significant variation of the commonly assumed service robot scenarios. The relevance of this aspect can be supported with statistical data, some of which are presented in the graphical illustration in Figure 2.4: In 2012, about 7.9 million German households kept about 12.3 million cats. Overall, more than 15 million households had well over 35 million pets.

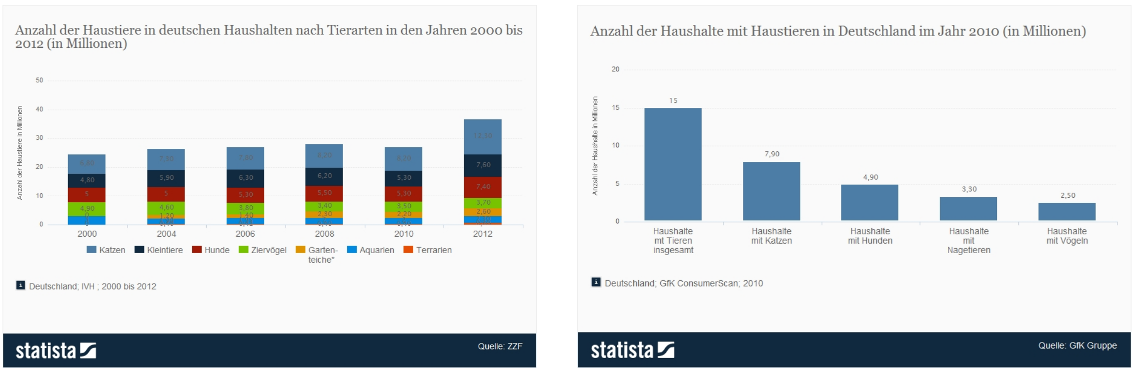


Figure 2.4: Some statistical data on pets in German households.

Like in the previous user task, the home pet handling user task bears significant potential for variation:

- ***Manipulating pet-related tools and objects:*** The episode described above intentionally foresees specially-designed devices, e.g. for serving food. The reason is that little experience exists in service robotics with the kind of manipulation required to handle the usual pet-related tools and objects, all of which have been designed to suite pets and humans. The scenario can be made significantly more complex by introducing more such everyday objects.

- ***Serving food and water:*** The episode includes an activity by the robot to serve dry cat food. Another road to increase the challenge is to have the robot serve various kinds of pet food, including moist food that must be taken out of cans or similar containers and portioned using a tool such as spoon.
- ***Caring for different kinds of pets:*** Cats are the most common pet found in households, but present only about one third of all pets. Variations of the episode would include caring for dogs, birds, turtles, hamsters, or fish.
- ***Interacting with the pets:*** For cats and dogs, an interesting variation of the scenario would be the request of Granny Annie that the robot should "shepherd" her pets to wherever she currently is in her appartment.

Aside of these variations, several others already described for the previous episode can also be applied to this episode, e.g. varying the order of subtasks, the natural language dialog, or ad hoc plan changes.

2.1.1.3 User Task "*Find the reading glasses*"

After seeing her cats well taken care of, Granny Annie wants to read for a while:

1. Granny Annie wants to read now while still in bed, but she realizes she has left her book on the living room table last night before going to bed.
2. Granny Annie: "*Jenny, please get me the book on the table in the living room.*"
3. Jenny: "*Okay, will do.*"
4. The robot stops observing the cats and moves to the living room table.
5. The robot looks at the table and sees three books; two stacked on each other somewhere near the table border, and one opened, upside down more centrally located on the table.
6. The robot assumes the opened book is the one Granny Annie wants, but wants to verify before carrying it to the bedroom. It sends a snapshot of the book to Annie's touchpad and asks:
7. Jenny: "*Is the book shown on the image on your touchpad the one you want?*"
8. Granny Annie: "*Yes, it is.*"
9. The robot picks up the book and carries it to the bedroom, handing over the book to Granny Annie.
10. Jenny: "*Here we are. Please take the book out of my hand. Enjoy reading!*"
11. Granny Annie: "*Thanks, Jenny. Hold on, wait a minute. I also miss my reading glasses. Please find them for me.*"
12. Jenny: "*Will do.*"
13. The robot reasons that Granny Annie probably used the reading glasses last where she had been reading the book and assumes it will find the glasses somewhere on the living room table.
14. The robot moves to the living room table, looks at it, but cannot find any reading glasses.

15. The robot also checks the small table next to the sofa, but fails to find the reading glasses there either.
16. Jenny: "*Sorry, I cannot find the reading glasses anywhere near the sofa. Do you have any idea where you used them last?*"
17. Granny Annie: "*Oh, I see. You might want to check in the kitchen; I think I used them yesterday to read the cup cake recipe.*"
18. Jenny: "*Okay. I keep my camera on and let you watch out for it with me. Let me know if you see them anywhere or remember places where you used them.*"
19. The robot turns on video streaming of its camera images to Granny Annie's touchpad and starts moving towards the kitchen, eventually passing by the dining table. As the dining table comes into view ...
20. Granny Annie: "*Ah, hold on. I may have used them last night to read a magazine article after I had dinner. Please check.*"
21. Jenny: "*Okay.*"
22. The robot interrupts its travel to the kitchen and has a closer look at the dining table. It finds the reading glasses sitting there on a magazine.
23. Jenny: "*Thanks, Annie, for the tip. I indeed found them here at the dining table. You'll have them in another minute.*"
24. The robot picks up the glasses and delivers them to Granny Annie's bedside table.

Discussion of variations: The variations for the object search user task include:

- ***Increasing the autonomy of object identification:*** In the episode the robot needs the help by the human user to verify that it has found the correct item (e.g. the book Granny Annie wants to read, or her glasses). The autonomy of the robot can be increased by enabling it to verify the correct item itself, e.g. by using memory (remembering the book Granny Annie read last night), inference (reasoning that Granny Annie probably wants to continue reading the same book), and information retrieved from the web (retrieving images of the book's cover pages).

- ***Increasing the autonomy of object search:*** In the current episode it is further foreseen that the human user provides significant guidance wrt. where to search during the object search activity. Improved probabilistic and semantic mapping capabilities may enable the robot to depend less on hints by humans.

- ***Increasing the ability to handle print products:*** The episode is still a bit imprecise about which kind of book the robot needs to handle, and how it is supposed to do so. Books themself can vary greatly in their dimensions, weight, and stiffness. In addition, there are other print products like magazines, newspapers, and greeting cards that the human user may ask for. Picking up comparatively thin printed material from a flat surface poses a significant challenge for service robots, as does the manipulation of heavy books.

- ***Varying the objects to be searched:*** By using a book and reading glasses as search objects in the episode we already introduce two objects seldomly used so far in other scenarios (where various kinds of cups, bottles, and boxes are used).

Both pose interesting challenges, both for perception as well as for manipulation. The range of such objects can be easily extended using glasses, keys, credit cards, currency bills, coins, and jewelry.

2.1.1.4 User Task "*Welcome a visitor*"

Ten minutes after Granny Annie started reading, various events occur:

1. The door bell rings.
2. Granny Annie: "*Jenny, please check who is at the door.*"
3. Jenny: "*Will do.*"
4. The robot moves to the front door and activates the intercom. The camera located outside above the door is activated and the image is displayed both on the intercom and automatically sent to Annie's touchpad.
5. Granny Annie: "*Oh, this is doctor Kimble. He comes to do a check-up on me. Please let him in.*"
6. Jenny (to Granny Annie): "*Okay, will do.*"
7. The robot activates the door opener and opens the door.
8. Jenny (to Dr. Kimble): "*Welcome, Dr. Kimble. Please come in. Your patient is awake, but preferred to stay in bed for a little while. Please go to the bedroom, you know the way.*"
9. Dr. Kimble: "*Good morning. Thanks. I go ahead.*"
10. The doctor enters the appartment and moves to the bedroom.
11. The robot closes the door, then follows the doctor to the bedroom, but stays outside.
12. After 10 minutes the doctor's visit is over. Everything is okay, but the doctor leaves a prescription for a resupply of the medicine to control Granny Annie's hypertension.
13. Dr. Kimble: "*I will leave the prescription on the sideboard in the hallway. Please call the pharmacy so that they can get it and deliver it later.*"
14. Granny Annie: "*Fine, Dr. Kimble. And thanks for stopping by. Jenny, please guide Dr. Kimble to the door.*"
15. Dr. Kimble: "*Thanks a lot, but this is not necessary. I know the way. Good bye and stay healthy. I stop by again next week.*"
16. Dr. Kimble leaves the bedroom and the appartment. As Dr. Kimble is always on the run, he forgets to properly close the front door.
17. The robot checks whether the visitor has left and closed the door. It detects that the door is not properly closed and closes it.
18. Five minutes later, the door bell rings again.
19. Granny Annie: "*Geez, we got real traffic this morning. Jenny, check who is at the door.*"
20. Jenny: "*Will do.*"

21. The robot moves to the front door and activates the intercom. The camera located outside above the door is activated and the image is displayed both on the intercom and automatically sent to Annie's touchpad.
22. Granny Annie: "*Ah, my breakfast is coming. Great! Please let him in and have him deliver the breakfast to the kitchen counter.*"
23. Jenny: "*Okay, will do.*"
24. The robot activates the door opener and opens the door.
25. Jenny (to the Deli Man): "*Good morning. You have the breakfast for Mrs. Kennedy?*"
26. The Deli Man: "*Good morning. Yes, I do. Where do you want me to put it?*"
27. Jenny (to the Deli Man): "*Come in and close the door, please. I will guide you to the kitchen. Mrs. Kennedy wants you to place it on the kitchen counter.*"
28. The Deli Man enters and closes the door. The robot checks (visually) whether it is safely closed, then moves to the kitchen while observing the Deli Man.
29. Once there, the robot points to the place where the Deli Man should put the breakfast.
30. Jenny (to the Deli Man): "*Please put it here.*"
31. The Deli Man places the breakfast on the counter. He sees the box he has delivered yesterday standing a corner of in the kitchen.
32. The Deli Man: "*Can I already take yesterday's box with me?*"
33. Jenny (to the Deli Man): "*Wait, please, I need to check with Mrs. Kennedy.*"
34. Jenny (to Granny Annie via the touchpad): "*Mrs. Kennedy, should the Deli Man take yesterday's breakfast box with him?*"
35. Granny Annie: "*Yes, please*"
36. Jenny (to the Deli Man): "*Yes, Mrs. Kennedy wants you to take it with you. Thanks a lot.*"
37. The Deli Man picks up the box and starts moving towards the front door. Jenny opens the front door, lets the Deli Man move out, and closes it again.
38. The robot moves to the bedroom.
39. Jenny: "*Breakfast is now ready.*"
40. Granny Annie: "*Yeah, great. I'll come.*"

Discussion of variations: The controllable variations of the visitor handling task include the following:

- ***Closing doors:*** In order to ensure the inhabitant's safety, the robot should ensure that the front door is properly closed whenever a visitor entered or left the appartment. The episode can be tested with the front door being left open in different states, e.g. widely open, or almost closed.
- ***Opening doors:*** Aside of variations wrt. the door handle, there could be various mechanisms for opening the door: just pushing down a door handle, turning a knob, unlocking by turning a key before operating the handle, simply activating an electronic door opening device, etc.

- ***Understanding instructions:*** The episode can be easily extended by widening the range of instructions the doctor can give to the robot, e.g. about making appointments with physiotherapists, dietary instructions, or when and how to take how much of the prescribed medicine.
- ***Handling simultaneous arrival of visitors:*** An interesting variation would be to handle the simultaneous arrival of several visitors at the appartment, e.g. the doctor and the Deli Man.

2.1.2 Episode 2: Breakfast Business

□ To be revised and included for revision 2.0 □

It is 8am now. Granny Annie has gotten up and wants to have breakfast. The robot has to set the breakfast table (see Figure 2.5). Before doing so, the robot must ask Granny Annie what she would like to have for breakfast, e.g. cereal, yoghurt, fruit, orange juice, tea, coffee, jam, bread, rolls, butter, sausages, fried, scrambled, or cooked eggs, etc. Once the robot knows what Granny Annie wants to have for breakfast, a list of required items can be determined, which the robot needs to fetch and set on the table in a well-defined arrangement. For example, a light breakfast for Granny Annie may require setting only a bowl for cereal, a spoon, and a mug for tea or coffee, while Granny Annie's more savory Sunday breakfast may include a plate, a tea cup with saucer, knife, fork, tea spoon, an egg cup and egg spoon, butter dish, two different glasses of jam, a drinking glass, a jug of orange juice, a basket of bread, rolls, and toast, a bowl with freshly sliced fruit, and a plate with hams and cheeses.

(a) A breakfast table setup. [2]

(b) Two household assistant robots. [3],

Figure 2.5: Images illustrating the breakfast table setup scenario.

As one of the subtask of this scenario, the robot should learn (by demonstration) a semantic map about the environment, such that it knows where to find all required items. This is, of course, not part of a daily procedure, but an activity necessary at the very beginning, and at various occassions later on. It should never be assumed that the robot can learn a *complete* map of the environment in a single session. Rather, it should expect to get to know what Granny Annie comes to mind as being important for the robot to know. As Granny Annie becomes acquqinted with using the robot and starts to exploit its flexibility, situations will inadvertently occur where Granny Annie refers to objects and places not yet known to the robot. The robot should recognize such situations and request clarification, thereby initiating an activity that will result in an update and extension of the semantic map of the environment.

2.1.3 Episode 3: Bathroom Duties

☐ To be revised and included for revision 3.0. The tasks involved for this episode are deemed the most challenging for domotic service robotics. ☐

Scenario Task Idea: Cleaning has become a very difficult task for Granny Annie, as she is suffering from gradually constrained mobility. The bathroom is difficult in particular, as Granny Annie is very hygiene-conscious and wants her bathroom cleaned diligently twice a week. Wouldn't it be nice if the robot can give a hand?

We start with having the robot to assist in cleaning various planar surfaces in the bathroom, e.g. a mirror or a tiled wall. Edges and corners will be added later. A sink and a bath tub will follow, first without, later with cleaning the faucets. For each item to be cleaned, the robot must apply the appropriate cleaning tools and cleaning agents. Eventually, the robot can clean a complete bathroom.

(a) (b)

Figure 2.6: Some example bathrooms.

(a) A modern shower cabin made of glass.

(b) A typical bathroom mirror with lights and tray.

Figure 2.7: Bathrooms present challenging problems for robotics, especially for perception and manipulation. Two examples are illustrated in this figure.

2.1.4 Episode 4: Bridge Round and Tea Party

□ To be revised and included for revision 2.0 □

Despite her age, Granny Annie is still diligently maintaining her social contacts. Twice a week, she hosts a couple of her friends for a round of bridge, which usually ends in a tea party (see Figure 2.8). The robot is supposed to set the table for the bridge round. When the guests arrive, the robot needs to welcome them at the door, ask whether it can receive and store any items (umbrella, hat, hand bag), and guide them to the bridge table. The robot serves drinks for the guests during the bridge round. When a glass or cup is emptied, the robot will ask if it should serve more. Finally, just before tea time, the robot will set the table for the tea party, with freshly brewed tea, and serve pastries and light sandwiches it has ordered before from a delivery service. The robot will prepare the items for the tea party on a cart, which it can push or pull from the kitchen towards the dining table.

(a) Grannie Annie playing bridge. [4]

(b) Table setup for the tea party [5].

Figure 2.8: Images illustrating the tea party scenario.

2.2 Analysis of Challenges in RoCKIn@Home

☐ This section is planned for inclusion in revision 2.0 ☐

2.2.1 Robot System Design Challenges

2.2.2 Interaction Challenges

2.2.3 Perceptual Challenges

2.2.4 Robot Motion Challenges

2.2.5 Cognitive Challenges

2.2.6 Software Engineering Challenges

2.3 Concepts and Objectives Behind RoCKIn@Home

☐ This section is planned for inclusion in revision 2.0 ☐

2.3.1 Supporting Replication and Repeatability

2.3.2 Boosting Benchmarking

2.3.3 Contributing To Standardization

2.3.4 Stimulating Cooperative Team Work

2.4 RoCKIn@Home and RoboCup@Home: Commonalities and Differences

☐ This section is planned for inclusion in revision 2.0 ☐

To round up the description of the RoCKIn@Home competition, we briefly oultine the commonalities and differences of the RoCKIn@Home and RoboCup@Home competitions. The comparison is based on the information documented the 2013 Rule Book for RoboCup@Home.

2.4.1 Commonalities

2.4.2 Modified Commonalities

2.4.3 Differences

Chapter 3

The RoCKIn@Home Scenario

This chapter describes and defines in more detail the RoCKIn@Home environment, the robots and the tasks based on a comprehensive set of features and constraints. A feature or constraint is defined similar to a law in a legal code with a unique identifier and a rather short and but precise description. In the remainder of the document, such a definition of a feature or a constraint is referred to as a *Scenario Specification* or a *Scenario Constraint*, if it is pertaining to the environment, as a *Robot Specification* or a *Robot Constraint* if it is pertaining to the targeted robots, and as a *Performance Rule* if it is pertaining to one of the tasks of the RoCKIn@Home Scenario. The subsequent rules have been derived from the *General Scenario Features* of Deliverable D-1.1 [1] and extended based on the previously described user story episodes in Chapter 2.1.

3.1 The RoCKIn@Home Environment

The goal of the RoCKIn@Home environment is to reflect an ordinary European apartment with all its environmental aspects, like walls, windows, doors or blinds as well as common household items, furniture, decoration and so on. The appartment depicted in Figure 3.1, already used in the previous chapter, may serve as an example. A small collection of alternative layouts can be found in Section B.1 of Appendix B. The next subsection first provides some information about the structure and the overall dimensions of the environment. Subsequent subsections describe specific rooms or spatial areas of the environment in more detail. **Note: Many things are still open for discussion and change!**

3.1.1 Structure and Dimensions of the Environment

The following set of scenario specifications provides a basic framework for the environments used for RoCKIn@Home.

Scenario Specification 3.1 (*Structured Environment*)

The environment consist of an ensemble of several spatial areas.

Scenario Constraint 3.1 (*Flat Environment*)

All spatial areas all located on the same level, except where specified otherwise. There are no stairs in the environment.

Scenario Specification 3.2 (*Spatial Areas and Rooms*)

Spatial areas completely enclosed by walls are referred to as rooms. In appartments following an open plan architecture, several spatial areas may be connected to each

Figure 3.1: Granny Annie's appartment.

other by open space and be only jointly surrounded by walls. In human-robot interaction, such spatial areas may also be referred to as rooms.

Scenario Specification 3.3 (*List of Rooms*)

The environment features the following spatial areas:

1. *a hallway*
2. *a living room*
3. *a dining room*
4. *a kitchen*
5. *a bedroom*
6. *a bathroom*
7. *a patio*

The use of the word "room" in the name of an area is purely for linguistic pragmatics and does not imply that the area is indeed a room according to the previous specification.

The appartment shown in Figure 3.1 meets these specifations.

Scenario Specification 3.4 (*Connectivity of Spatial Areas*)

The environment is accessible from outside through a front door to the hall way. The hallway is openly connected to the living room by a portal. The living room is connected to the bedroom by a door. The living room is connected to the bathroom *by a door. The living room is openly connected to the kitchen. The living room is openly connected to the dining room. The dining room is openly connected to the kitchen. The dining room is connected to the patio by a door.*

The connectivity of the spatial areas is illustrated by the topological graph depicted in Figure 3.2.

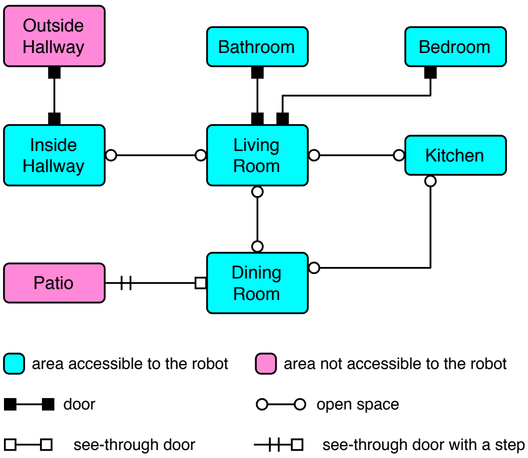


Figure 3.2: Graph showing the topological structure of environment.

Scenario Specification 3.5 (*Bedroom*)

The bedroom has a window, which can be opened and tilted. It has a rolling shutter that is operated electrically. The furniture includes a double bed, two bedside tables, a large wardrobe, a large mirror, a dressing table, and a carpet. The lighting includes ceiling lights and two bedside lamps.

Scenario Specification 3.6 (*Living Room*)

The living room has a large window front side to the patio. These windows cannot be opened. These windows have inside blinds that are operated electrically. The furniture includes a large carpet, a coffee table, a couch, two armchairs, a low-height sideboard, and a bookshelf. A TV set is mounted on the wall above the sideboard. The lighting includes central ceiling lights, a band of dimmable ceiling spots, and a large floor light.

Scenario Specification 3.7 (*Dining Room*)

The dining room has a window, which can be opened and tilted. It has a rolling shutter that is operated electrically. The furniture includes a dining table seating four, and four chairs. The lighting consists of ceiling lights above the dining table.

Scenario Specification 3.8 (*Kitchen*)

The kitchen has no window and no door. The furniture includes several cupboards with drawers and doors. The installation include a fridge/freezer combination, a sink, a dishwasher, a stove, a baking oven, and an exhaust hood. Two rows of ceiling lights make for the lighting. (Details of the kitchen will be specified in more detail as needed.)

Scenario Specification 3.9 (*Bathroom*)

The bathroom has no window. The bathroom installation include a bath tub, a shower, a sink, a toilet bowl, and a mirror above the sink. The furniture includes a bathroom closet and a stool. The lighting includes a ceiling light and two wall lamps around the mirror.

Scenario Specification 3.10 (*Hallway*)

The hallway has no windows. The furniture consists of a coat rack. The lighting consists of three ceiling spotlights.

Scenario Specification 3.11 (*Patio*)

The patio is separated from the living room by a large window front and from the dining room by a wall with a French door. There is a door step of about 10 cm between the dining room floor and the patio floor. Patio edges not bordering the living room or the dining room are surrounded by a balustrade. The furniture consist of a small garden table and two garden chairs.

Scenario Specification 3.12 (*Dimensions*)

The precise dimensions and the arrangement of the spatial areas are not predefined. The bounding rectangular box of the environment has a minimum area of $50m^2$ *and a maximum area of* $200m^2$*. The minimum size of the spatial areas is as follows (in* m*): hallway* 1×2*, bathroom* 2×3*, bedroom* 3×4*, kitchen* 2×3*, dining room* 2×3*, living room* 4×4*, patio* 1×2*.*

Scenario Specification 3.13 (*Infrastructure*)

The environment must have a suitable electrical installation to ensure the operation of lights, electrical appliances, etc. Installations for water supply and sewage water disposal are not required. Air conditioning may be optionally foreseen. The environment will be equipped with a wireless local area network (802.11 b/g/n) to which suitably-equipped electronic devices, such as tablet PCs, robots, remotely controllable actuators, sensors, household appliances, medical devices etc. can connect and interact.

Scenario Constraint 3.2 (*Detail vs Variability*)

All elements of the environment, including the objects present in each room and the objects relevant for manipulation by the robot, have to be specified in more detail. Such specifications should be such to ensure still significant variability, e.g. by allowing for a wide variety of objects to be used in environments, but may impose suitable constraints on their features such as weight, size, shape, stiffness, etc. to ensure that the targeted robots can handle them.

This first set of specifications and constraints concludes the general outline of the scenario environment. Of course, the envionment and its element will have to be further detailed, and the next few sections outline which information about the environments needs to be specified in due time before the competition. There exists, however, a **conflict between level of detail and range of variability**. The organizers of an event, who are in charge of constructing a competition arena and test beds, the developers of suitable simulation tools, and the potential participants have a natural desire to describe and fix everything to the very detail a long time in advance. This allows organizers to calculate costs, developers to build truely good simulation models, and teams to prepare their robots very well. However, it also bears a great risk to see many overengineered, brittle solutions, which break down or become at least partially dysfunctional as soon as even slight deviations from the specifications are observed.

In order to void overengineering and to foster the development of solutions which can deal with significant variation in the environment, we provide **essential** information first; as it turned out, this is already a lot. The above specification **do** provide a lot of information which gives a clear picture of the what kind of environment the robots will face, and which allows teams to start developing solutions. The specifications on one hand make specifications which **require** the presence of certain features; the RoCKIn@Home environment must clearly consist of several rooms or spatial areas, for example. On the other hand, certain constraints are made, which clearly **exclude** the presence of certain features; in our environment, steps and stairs are exlcuded, for example, and the whole environment is surrounded by a wall which prevents the robot from accidentally leaving the environment (except for the front door and the patio door). Leaving certain issues open provides also some flexibility for the event organizers to adapt the design of the environment in order to accommodate local constraints and requirements of the event site. Both simulation developers and teams should get a sufficiently well-defined idea about the environment and be able to build their artefact to deal with the variability still intrinsic to the specification.

The information provided in successive subsections and Appendix A is, both in principle and in the terminology defined in Deliverable 1.1 (see [1]), *information about objects*. However, for certain categories of objects many of the aspects defined in that document are not relevant. For example, a wall does of course have a weight, but it is irrelevant in our context. Such aspects are simply left out in our specifications. In the medium term, it would be useful to supplement the project efforts with a suitable formal ontology, which would define which aspects are relevant for a particular category of objects, and which could as well be beneficially used by the teams and their robots participating in the competition.

3.1.2 Details on Particular Rooms or Spatial Areas

The details on rooms and spatial areas include information about the existence/presence and (if positive) the features of the following elements:

- Floors, walls, and ceilings
- Windows and doors, both interior and exterior
- Shutters (outside blinds), both for windows and exterior doors
- Blinds (inside blinds), both for windows and exterior doors
- Curtains, both for windows and exterior doors
- Installations for water, wastewater, heating, and air conditioning, including bath tubs, shower, washing basins, toilet basins, heating vents, etc.
- Electrical installations and lighting, including the position of power outlets, any kind of switches (key switches, spring-loaded switches, dimmer switches, toggle and intermediate switches), positions of lamps on walls and ceilings, and information on wiring and fusing

- Media installations, which are fixed to the environment, not movable, and non-mobile, such as flatscreens attached to walls, speakers or microphones fixed to walls or ceilings, and the like, and information on wiring
- Communication infrastructure, including any kind of networks such LAN, WLAN, Bluetooth, X10, KNX, OpenHAB (positions of outlets, connectors, routers, switches, and access points, as well as networking topology and wiring)
- Ambient intelligence infrastructure, including sensors such as cameras, PIRs, infrareds etc. and actuators embedded in the environment (e.g. for actuating doors, drawers, etc.), and their accessibility and connectivity

Specifications for these items are given on a per-room basis and are already partially included in Appendix A. Future revisions of this document may extend these specifications.

3.1.3 Navigation-Relevant Objects

Navigation-relevant objects in rooms and spatial areas include mainly objects that influence or constrain a robot's navigation behavior, such as furniture, but will usually not be the target of manipulation. Some examples include:

- Furniture, including items hanging on walls
- Rugs placed on top of floors
- Artwork placed on floors, which constrains free space, such as sculptures
- Plants and flowers
- Trash cans
- Floor lamps, which could be repositioned by humans, albeit not frequently
- Media installation which is movable, such as clock radios
- Pet equipmemt which is stationary, such as litter boxes, dog/cat baskets, scratching posts, or similar

Specifications for these items are given on a per-room basis and are already partially included in Appendix A. Future revisions of this document may extend these specifications.

3.1.4 Manipulation-Relevant Objects

Task-relevant objects in rooms and spatial areas which may become the target of manipulation, e.g. for grasping and carrying, performing any kind of operation on it (such as opening a bottle, turning a knob of the cooker), include:

- Books of various sizes and weights
- Magazines and newspapers
- Cutlery and silverware
- Tableware for breakfast, lunch, coffee, and dinner
- Tablecloth, napkins, candles and candle holders
- Kitchen equipment
- Media gadgets, such as touchpads, mobile phones, MP3 players
- Media items, such as CDs or DVDs

- Pet equipment which is non-stationary, such as water and food bowls, food dispensers, pet toys
- Personal items, such as glasses, wallets, handbags, keys, plastic cards and chip cards (credit and debit cards, membership cards, driver's license, ID card, health insurance card)

Because many of these items can be anywhere in the appartment or at least in several differnet places, they will not be specified on a per-room basis. An ontology for RoCKIn-@Home should, hoever, provide information on where these items are usually expected to be found. Specifications for these items will be included in Appendix A in future revisions of this document.

3.1.5 Perception-Relevant Objects

Last but not least we specify a list of objects that will not be directly task-relevant, but which may influence — positively or negatively — the perception performance of the robots. For example, picture place on walls can be used for disambiguiation in localization, while the reading glasses lying on top of a book cover or a magazine cover may be much harder to perceive than them lying on a plain white table surface. Some examples include:

- Artwork fixed to walls, such as paitings of photography, or placed on top of furniture, such as miniatures
- Wall clocks
- Pillows on sofas
- Tea-cloth
- Coverlets and bedcovers
- Cut flowers
- Stuffed animals and plush toys
- And other kind of decoration item

Specifications for these items will be included in Appendix A in future revisions of this document.

3.1.6 Common Environment Features

The following list describes a set of environment features that are not specific to particular spatial areas and apply to the whole environment. Each of them should be measured and recorded for all experiments performed in the scenario environment.

Scenario Constraint 3.3 (*Air Temperature*)

The air temperature of the environment is measured in degrees Celsius (°C)*. The air temperature should not be less than* 16 °C *and no more than* 26 °C*; it should typically be between* 20 °C *and* 22 °C.

The air temperature is usually quite evenly distributed through environment space, but temperature deviations may occur near heat sources (heating radiators, cookers, baking ovens, electric kettles, coffee makers, lamps, etc) or heat sinks (open fridges and freezers, etc.). If such elements are used in an environment, the air temperature in their vicinity should be measured and recorded for each experiment.

Scenario Constraint 3.4 (*Atmospheric Pressure*)

The atmospheric pressure in the environment is measured in hectopascals (hPa). The atmospheric pressure should be no less than 950 hPa *and no more than* 1050 hPa*; it should typically be between* 980 hPa *and* 1020 hPa.

The atmosperic pressure is evenly distributed through the environment space.

The previous two features are known to influence e.g. the performance of acoustic time-of-flight sensors such as sonars. In addition, they also influence the next feature, relative humidity, which may prevent safe operation of the robot (due to constraints imposed by its electronic components) or influence the robot's ability to perform manipulation tasks.

Scenario Constraint 3.5 (*Relative Humidity*)

The relative humidity in the environment is measured in percent (%). The relative humidity should be no less than 10 % *and no more than* 90 %*; it should typically be between* 30 % *and* 60 %.

The relative humidity is usually quite evenly distributed through environment space, but deviations may occur if water supplies are in the vicinity of heat sources (e.g. water boiling in a pot on the cooker or in an electric kettle) or near heat sinks.

The next two feature obviously influence the performance of optical sensor system, such as cameras, 3D cameras, or infrared sensors. Illuminance is "the total luminous flux incident on a surface" [6] and a measure of the intensity (aka brightness) of lighting in the environment. Color temperature is a measure to quantify the color of a light source, sometimes also referred to as the "warmth". Both features influence the behavior of optical sensors and how colored surfaces will be perceived.

Scenario Constraint 3.6 (*Illuminance*)

Illuminance is measured in lux (lx). Illuminance in the environment can be as low as 0 lx *and should not exceed* 10000 lx*; the typical range should be between* 500 lx *and*1500 lx.

Illuminance cannot be expected to be evenly distributed throughout the environment. The specific interior design, the placement of furniture, the configuration and placement of lamps and other light sources may create significant variance of illuminance in the environment (dark corners, bright spots). Daylight in the environment would be desirable, even if it is rapidly changing due to weather conditions, but it is not required. If daylight influence is present, the scanrio environment should foresee a device to record illuminance levels during experiments.

Scenario Constraint 3.7 (*Color Temperature*)

Color temperature is measured in Kelvin (K), the unit of absolute temperature. The color temperature in the environment will not be less than 1000 K *and not exceed* 8000 K*; the typical range will be between* 1500 K *and* 5000 K*, with up to* 8000 K *with daylight influence.*

In speech-based human-robot intercation, the robot's performance may critically depend on the level of acoustic noise present in the environment.

Scenario Constraint 3.8 (*Acoustic Noise*)

Acoustic noise will be measured in decibels (dB). The noise level in the environment can be as low as 0 db *and should under no circumstance exceed* 100 db*, the typical* *range should be between* 0 *db and* 60 *db, with occassional exceptions (vacuum cleaner operating; open window to a busy street) of up to* 80 *db.*

The experiments should foresee tests of the speech understanding capabilities in different situations, e.g.

- **Home Silence:** Nothing much is happening in the environment. The robot is not moving and waiting to be called by its user. None of the sound-generating devices in the environment is active, except maybe for a ticking clock.
- **Human Dialogue:** Two humans in the environment are talking to each other, for example the doctor leading a conversation with Granny Annie about her well-being. In midst of such a dialog, the users may address the robot and give it a command.
- **Home Noise:** This noise level is present when typical household appliances are active and operating, for example a dishwasher, a laundry machine, a phone ringing, the door bell sounding, water is boiling in an electric kettle, the fume hood is switched on, the shower is running, etc.
- **Entertainment Noise:** At this noise level, a radio playing in the appartment, or a TV set is running.
- **Cocktail Party:** Yet a different kindof noise is the one caused by a (potentially large) group of people, for example Granny Annie's bridge round or the guests for Granny Annie's birthday party.

Aside of communicating by speech, the robot and other devices may (have to) use the local network infrastructure, and both performance and robustness of the robot's services may critically depend on the situation on the network. In particular, utilization of the network for other purposes than the operation of the robot and servicing its functioning, may reduce the effectively available bandwidth usable by the robot, and it may not any more be able to deliver certain services in a robust manner.

Scenario Constraint 3.9 (*Wireless Communication Noise*)

The wireless communication noise will be measured in kilobytes per second (Kb/s) *and will be recorded both as absolute value and as relative value (percentage) of the maximum available bandwith. The wireless communication noise level may range from* 0 % *to* 100 % *of the available bandwidth. The typical range will be between* 10 % *and* 50 %.

When wireless communication is relevant for particular experiments, these experiments should foresee test runs using different situations, e.g.

- **Negligible Traffic** Almost no traffic is detected on the network.
- **Noise Traffic** Erratic random noise is detected at different levels.
- **Browsing Traffic** The use is doing normal Internet browsing, emailing, and uses social media.
- **Communication Traffic** At this level of communication noise, streaming of some kind is occurring, e.g. by Internet telephony or (non-HD) video calling (skyping).
- **Entertainment Traffic** At this level, the user would do full-HD video streaming, e.g. viewing Internet TV or downloading full HD videos via the Internet.

3.2 The RoCKIn@Home Robots

The purpose of this section is twofold:

1. It specifies information about various robot features that can be derived from the environment and the targeted tasks. These features are to be considered at least as desirable, if not required for a proper solution of the task. Nevertheless, we will try to leave the design space for solutions as large as possible and to avoid premature and unjustified constraints.

2. The robot features specified here should be supplied in detail for any robot participating in the competition. This is necessary in order to allow better assessment of competition and benchmark results later on.

Robot Specification 3.1 (*Type/Class*)

A competition entry may use a single robot or multiple robots acting as a team.

☐ *The classification should be extended to refer to a standard ontology.* ☐

Robot Specification 3.2 (*Mobility Subsystems*)

At least one of the robots entered by a team must be mobile and able to visit different task-relevant locations by autonomous navigation. Teleoperation of robots for navigation is not permitted. The robot mobility must work in the kind of environments specified for RoCKIn@Home and on the kind of floors defined in the RoCKIn@Home environment specifications.

Robot Specification 3.3 (*Manipulation Subsystems*)

At least one of the robots entered by a team must be able to autonomously manipulate at least several different task-relevant objects. The specific kind of manipulation activity required is to be derived from the task specifications. Teleoperation of robots for manipulation is not permitted. The robot's manipulation capability must work in the kind of environments specified for RoCKIn@Home and at least for several objects of the kind defined in the RoCKIn@Home environment specifications. If the required manipulation of objects requires that the object must be grasped, then this robot must also have a grasping subsystem.

Robot Specification 3.4 (*Grasping Subsystems*)

At least one of the robots entered by a team must be able to autonomously grasp different task-relevant objects. The specific kind of grasping activity required is to be derived from the task specifications. Teleoperation of robots for grasping is not permitted. The robot's grasping capability must work in the kind of environments specified for RoCKIn@Home and at least for several objects of the kind defined in the RoCKIn@Home environment specifications.

Robot Specification 3.5 (*Sensor Subsystems*)

Any robot used by a team may use any kind of ***onboard*** *sensor subsystem, provided that the sensor system is admitted for use in the general public, its operation is safe at all times, and it does not interfere with other teams or the environment infrastructure.*

A team may use any kind of sensor system ***provided as part of the environment*** *by correctly using a wireless communication protocol specified for such purpose and* *provided as part of the scenario.*

☐ *This should be determined until end of Q1/2014.* ☐

A team may install ***its own sensor systems in the environment*** *under the following conditions: ...*

☐ *Decision to be taken by the consortium.* ☐

Robot Specification 3.6 (*Communication Subsystems*)

Any robot used by team may ***internally*** *use any kind of communication subsystem, provided that the communication system is admitted for use in the general public, its operation is safe at all times, and it does not interfere with other teams or the environment infrastructure.*

A robot team must be able to use the communication system provided ***as part of the environment*** *by correctly using a protocol specified for such purpose and provided as part of the scenario.*

☐ *This should be determined until end of Q1/2014.* ☐

A team may install ***its own communication systems in the environment*** *under the following conditions: ...*

☐ *Decision to be taken by the consortium.* ☐

Robot Specification 3.7 (*Power Supply*)

Any mobile device (esp. robots) must be designed to be usable with an onboard power supply (e.g. a battery). The power supply should be sufficient to guarantee at least 30 minutes of electrical autonomy before recharging of batteries is necessary. Some scenarios may specify tasks requiring longer periods of autonomy.

Preferably, all non-mobile or stationary devices used in the environment should work on battery as well.

In exceptional cases, teams may be able to use a power outlet provided by the environment. If a team plans to use power outlets for supplying power to the robots, they need to request permission from the event organizers in advance and at least 3 months before the competition. Detailed electrical specifications need to be supplied with the request for permission.

Charging of robot batteries must be done outside of the competition environment. The team members are responsible for safe recharging of batteries. If a team plans to use inductive power transmission devices for charging the robots, they need to request permission from the event organizers in advance and at least 3 months before the competition. Detailed specifications about the inductive device need to be supplied with the request for permission.

Robot Constraint 3.1 (*Computational Subsystems*)

Any robot or device used by a team as part of their solution approach must have suitably equipped with computational devices (such as onboard PCs, microcontrollers, or similar) with sufficient computational power to ensure safe autonomous operation. Robots and other devices may use external computational facilities, including Internet services and cloud computing to provide richer functionalities, but the safe operation of robots and devices may not depend on the availability of communication bandwidth and the status of external services.

☐ *Decision by the consortium needed about what to exclude and what to allow.* ☐

Robot Constraint 3.2 (*Safety and Security Aspects*)

For any device a team brings into the environment and/or the team area, and which features at least one actuator of any kind (mobility subsystems, robot manipulators, grasping devices, actuated sensors, signal-emitting devices, etc.), a mechanisms must be provided to immediately stop its operation in case of an emergency (emergency stop). For any device a team brings into the environment and/or the team area, it must guarantee safe and secure operation at all times. Event officials must be instructed about the means to stop such devices operating and how to switch them off in case of emrgency situations.

Robot Constraint 3.3 (*Environmental Aspects*)

Robots, devices, and apparatus causing pollution of air, such as combustion engines, or other mechanisms using chemical processes impacting the air, are not allowed.

Robots, devices, and any apparatus used should minimize noise pollution. In particular, very loud noise as well as well-audible constant noises (humming, etc.) should be avoided. The regulations of the country in which a competition or benchmark is taking place must be obeyed at all times. The event organizers will provide specific information in advance, if applicable.

Robots, devices, and any apparatus used should not be the cause of effects that are perceived as a nuisance to the humans in the environment. Examples of such effects include causing wind and drafts, strong heat sources or sinks, stenches, or sources for allergic reactions.

Robot Specification 3.8 (*Robot Functionality*)

The robots used for RoCKIn@Home should feature at least the following functionalities:

- *understanding speech*
- *producing speech*
- *interacting with humans by naturallanguage dialogue*
- *managing an agenda of activities (goals, intentions)*
- *acquire, maintain, and extend suitable representations of task-relevant knowledge*
- *planning complex tasks and activities*
- *scheduling, executing, and monitoring activities*
- *handling contingencies (possibly with the help of the user)*
- *navigating in the scenario environment*
- *manipulating task-relevant objects*
- *grasping task-relevant objects*
- *perceiving the environment*
- *perceiving task-relevant objects, including estimating their pose*
- *perceiving and tracking humans (including possibly gestures and emotional state) and other animated agents (pets) in the environment.*

3.3 The RoCKIn@Home Tasks

This section analyzes the RoCKIn@Home tasks and their sub-tasks. For each (sub-)task the initial and final situation, the activities to be performed, the quality criteria, constraints and features are investigated below.

3.3.1 Task "Continuous user interaction"

In several further tasks the robot is required to continuously receive commands from the user. These commands also need to be integrated into the currently executed actions.

Initial situation

- The task to perform is unknown.

Activities

- Get a command or more details about the current action by
  - either actively asking the user
  - or receiving a command from the user
- Receive, understand and interpret the user's reply.

Final situation

- The task to perform is either partially or completely specified.

Performance or quality criteria

- The time it takes the robot to understand the user.
- The number of incorrectly understood commands.
- The number of missed commands, specifications or constraints on the currently performed task.
- The number of times that the robot has to repeat its questions.
- The evaluation of the previous points with respect to a specific input device (touch-based or microphone on the touchpad and microphone on the robot).

Constraints during execution

- Only the user is located in the environment.
- Only the user is involved in the human-robot interaction.

Features

1. The robot and the user communicate via a tablet computer or natural language.

3.3.2 Task "Cater for bedroom comforts"

This task requires the performance of several subtasks.

3.3.2.1 Subtask “Operate devices”

The robots needs to operate different *devices*, such as automatic shutters and windows by the associated *control elements* (e.g. switches, knobs or handles).

Initial situation

- The locations of the control elements are approximately known.
- The locations of the devices are known.
- The association between control elements and devices is not known.
- The actual states of the devices are not known.
- The desired states of the devices are known.

Activities

- Find and localize the control elements.
- Associate the control elements with the correct devices.
- Identify the type of control element (switch, knob, handle, ...)
- Operate the device via the ontrol element (e.g. by pressing, turning or pulling) or, if available, via a remote connection.
- Continuously monitor the actual state of the devices.

Final situation

- The locations of the control elements are known.
- The association of the control elements and the devices is known.
- The device is in the desired state.

Performance or quality criteria

- Difference between actual and desired state of the device.
- The number of incorrectly associated devices and control elements.
- The number of correctly classified types of control elements.

Constraints during execution

- The devices are fully functional.

Features

1. The type of control element varies.
2. Switches or knobs can be hidden behind curtains.

3.3.2.2 Subtask "Integrate feedback into action execution"

Initial situation

- The robot is operating a control element.

Activities

- During the action execution, the robot receives a command (e.g. to stop the current action or a new desired state of the operated device)

Final situation

- The device is in the new desired state.

Performance or quality criteria

- The delay between the time when the new command has been issued and the time when the feedback is accounted for in the action execution.
- Difference between actual and desired state of the device.

Constraints during execution

- None

Features

1. The type of control element varies.

3.3.3 Task "Handle the home pets"

3.3.3.1 Subtask "Search pets"

Initial situation

- It is unknown, if there are pets in the appartment.
- The locations of the pets are unknown.

Activities

- Move around in the appartment.
- Detect, recognize and localize pets.

Final situation

- It is known, if there are any pets in the appartment or not.
- If there are pets in the appartment:
  - The locations of the pets are known.
  - Names are associated with the right pets.

Performance or quality criteria

- Time to find the pets.

- Exploration/search strategy.
- Handling of the case that no pets are in the appartment.
- Distinguishing between different pets.
- Distinguishing between different pet types.

Constraints during execution

- When there are pets in the appartment at all, they always stay within the appartment.

Features

1. Zero to two $(0-2)$ pets are located in the appartment.
2. The types of pets are cat, dog or rabbit.
3. Pets lie, stand or move in the environment.
4. Pets are located on the floor, on furniture or underneath objects.
5. During the search the user may provide additional hints.
6. The hints restrict or broaden the locations in which to search.

3.3.3.2 Subtask “Open cat flap and monitor pets”

Initial situation

- The cat flap is locked.
- The pets are outside of the appartment.

Activities

- Unlock the cat flap directly or by a remote controller.
- Monitor the pets as soon as they are inside of the appartment.

Final situation

- The cat flap is unlocked.
- The pets are inside of the appartment.
- The pets are visible in the tablet computer.

Performance or quality criteria

- Time it takes to unlock the cat flap.
- Comparison of the applied force and the required force on the cat flap’s lock.
- Evaluation of the tracking behavior.

Constraints during execution

- Only the actions of the robot change the appartment.

Features

1. A door as specified in the environment description 3.1 is used.
2. The lock on the cat flap can either be operated directly or by a remote control.

3.3.3.3 Subtask "Check level of liquid or food"

Initial situation

- The robot does not know how much substance is in the water or food bowls.

Activities

- Detect and localize the bowls.
- Either
  - Perceive the filling level of the bowls.
  - Stream a video of the observed bowls to the user (on the tablet computer) and let the user identify the filling level of the bowls.

Final situation

- The robot knows how much substance is in the water or food bowls.

Performance or quality criteria

- The filling level is measured as height from lowest point of bowl.
- For water bowls compare the real filling level to the filling level observed by the robot.
- For food bowls compare either the weight, filling level or absolute/relative volume perceived by the robot to the actual value.
- Measure the time it takes the robot to detect and localize the bowls.
- Measure the time it takes the robot to identify the filling level of the bowls.

Constraints during execution

- The environment only changes by actions of the robot.

Features

1. The filling level of the bowls varies between empty and full ($0\% - 100\%$)
2. There are one to five ($1 - 5$) water and food bowls, each.
3. The shape of the water and food bowls is either a hollow half-sphere, a cuboid, a cylinder, a frustum, or a flat cylinder (i.e. cylinder with an elliptical base).
4. The type of liquids is water or milk.
5. The type of food is dry food or moist food.
6. Bowls are tilted between $0°$ and $180°$.
7. Bowls are elevated above the ground between $0m$ and $1.5m$.

3.3.3.4 Subtask "Refill bowls"

Initial situation

- The bowls are filled to different levels.
- The supply containers from which the bowls are refilled, contain a sufficient amount of substance to refill the bowls.
- The initial filling level is below or equal to the desired filling level.

Activities

- By either active manipulation or remote manipulation:
  - Identify water bowls and food bowls.
  - Pour liquid into the water bowls.
  - Pour or otherwise fill food into the food bowls.
- Observe the filling level during the task execution.
- Stop filling when the desired level has been reached.

Final situation

- The bowls are filled to the desired levels.

Performance or quality criteria

- Compare type of bowls (water or food) perceived by robot with the real type of bowls.
- Compare the desired to the actual filling levels.
- Compare the amount of spilled substance to the amount of substance in the bowls.
- Measure the time it takes the robot fill the bowls.
- Evaluate the order (task plan) in which the bowls are refilled.

Constraints during execution

- The environment only changes by actions of the robot.

Features

- The initial filling level of the bowls varies between empty and full ($0\% - 100\%$)
- The desired filling level of the bowls varies between empty and full ($0\% - 100\%$)
- There are one to five ($1 - 5$) water and food bowls, each.
- The shape of the water and food bowls is either a hollow half-sphere, a cuboid, a cylinder, a frustum, or a flat cylinder (i.e. cylinder with an elliptical base).
- The type of liquids is water or milk.
- The type of food is dry food or moist food.
- Bowls are tilted between $0°$ and $180°$.
- Bowls are elevated above the ground between $0m$ and $1.5m$.

3.3.4 Task "Find the reading glasses"

3.3.4.1 Subtask "Semantic-guided object search"

Initial situation

- The robot does not know where the requested object (e.g. a book or a pair of glasses) is.

Activities

- Move around in the appartment.
- Recognize and localize the desired object.

Final situation

- The robot knows where the object is.

Performance or quality criteria

- Time to find the object.
- Search strategy.
- Handling of the case that the object is not in the appartment.
- Distinguishing between different object instances.
- Distinguishing between different object classes.
- Semantic map

  □ Not clear how to test this appropriately. Maybe a specific technical challenge may address this issue. □

Constraints during execution

- The environment only changes by actions of the robot.

Features

- Zero to ten $(0 - 10)$ objects are located in the appartment.
- The objects are in the class of common household objects.
- Objects lie or stand in the appartment.
- Objects are located on the floor, on furniture or underneath objects.
- During the search the user may provide additional hints.
- The hints restrict or broaden the locations in which to search.

3.3.4.2 Subtask "Pickup object"

Initial situation

- The requested object is located in the environment near the robot.
- At least one hand of the robot is free.

Activities

- Recognize and localize the requested object
- Grasp the requested object
- Lift the object
- Verify that the grasped object is the requested object (e.g. by reading the imprint)

Final situation

- The requested object is in the hand of the robot.

Performance or quality criteria

- Time to plan the grasp
- Time to plan the arm motions
- Time to execute the grasp
- Time to execute the arm motions
- Grasping the correct object
- Grasp quality
- Time to verify the type of grasped object
- Quality of the verification

Constraints during execution

- The environment remains static during the manipulation task, except for changes due to actions performed by the robot.

Features

- Requested object is any object specified in the environment description (see section 3.1)
- Zero to ten $(0 - 10)$ obstacles are placed around the requested object
- Obstacles are any object specified in the environment description (see section 3.1)
- Distance between closest points of obstacles and requested object $(0m - 1m)$
- Obstacles may or may not be touched
- Obstacles may or may not be moved away
- Task to perform after grasping: Transporting, placing, hand-over

3.3.4.3 Subtask "Return object"

Initial situation

- The robot is transporting an object.
- The user does not have the object.

Activities

- Move to the user.
- Hand-over the object.

Final situation

- The robot is not transporting the object.
- The user has the object.

Performance or quality criteria

- Time to return to user
- Time to execute hand-over
- Usability

Constraints during execution

- The user does not change its location.

Features

- The robot knows or does not know where the user is
- Type of hand-over: Directly to person, request to take, or place somewhere nearby

3.3.5 Task "Welcome a visitor"

3.3.5.1 Subtask "Handle the intercom"

Initial situation

- The intercom is disabled.
- A visitor is waiting outside.
- The robot does not know the visitor.
- The door is closed.

Activities

- The robot activates the intercom by pressing the according button.
- When requested to do so, the robot opens the door (e.g. manually or via an according button on the intercom).
- Identify the visitor (either by the robot itself or by the comments of the user).

Final situation

- The intercom is enabled.
- The robot knows the visitor.
- If desired, the door is open and the visitor is in the appartment.

Performance or quality criteria

- Time taken to identify the visitor.
- Matching between apperance of visitor and communicated identity of the visitor.
- Number of false positives (i.e. a wrong visitor has been granted access) and false negatives (i.e. a wrong visitor has been denied access).

Constraints during execution

- None

Features

- The visitor can be a doctor, a breakfast service man, or a mailman.
- Apperance of doctor, mailman (e.g. Deutsche Post, UPS, FedEx) and breakfast service man
- Nationality and locality of visitor
- Goal of visitor: Look after user, bring an item
- Number of simultaneous visitors

3.3.5.2 Subtask "Instruct and monitor the visitor"

Initial situation

- The visitor does not know what to do.
- The robot might have a rough idea what the visitor should do based on the user's preferences.

Activities

- If it is unknown/imprecisely known what the vistor should do, clarify with the user.
- Instruct the visitor what to do.
- The robot monitors the user while he/she is following the instructions. When the visitor deviates from the expected behavior, the user is informed.

Final situation

- The visitor knows what to do.
- The visitor has followed the instructions.

Performance or quality criteria

- Time taken to instruct the visitor.
- Number of incorrectly understood phrases.
- Number of questions posed by the robot.
- Identified deviations of the visitor from the instructions.
- Usability.

Constraints during execution

- None

Features

- Background information about the user: All preferences are known to no preferences are known.
- The visitor either follows the instructions to the point or deviates from the instructions.

3.3.5.3 Subtask "Handle the door"

Initial situation

- The robot knows the desired state (open or closed) of the door.
- The robot does not know the current state of the door.

Activities

- Operate the door directly or by a remote control (e.g. a button on the intercom).

Final situation

- The door is in the desired state.

Performance or quality criteria

- Time it takes to open the door.
- Force applied to the door vs. torque required to open the door.
- Robustness of door detection and door state detection (e.g. based on different opening states of the door)

Constraints during execution

- None

Features

- How far the door is open in the beginning, from closed to completely open.
- How far to open the door, from closed to completely open.
- The door is known or unknown (i.e. the robot has not seen it before).
- The door is either locked or unlocked.
- There is no to lots of clutter on the ground around the door.

3.4 Functionalities Required for RoCKIn@Home

Below we provide an initial list of functionalities that the user story episodes and the scenario seem to require:

- Human-robot communication (see Section 3.3.1)
  - Speech recognition
  - Natural language understanding and interpretation
  - Speech synthesis
- Human-robot physical interaction
  - Object hand-over (Section 3.3.4.3)
- Perception
  - Detection (visual, tactile, auditory)
    - Pet detection (Section 3.3.3.1)
    - People detection
  - Recognition/identification (visual, tactile, auditory)
    - Pet recognition (Section 3.3.3.1)
    - Object (part) identification (Sections 3.3.3.2 and 3.3.4.2)
  - Localization/pose estimation (visual, tactile, auditory)
    - Pet localization (Section 3.3.3.1)
    - Object (part) pose estimation (Sections 3.3.3.2, 3.3.3.3, and 3.3.4.2)
  - Classification (visual, tactile, auditory)
    - Pet classification (Section 3.3.3.1)
    - People classification
  - Filling level detection (Sections 3.3.3.3 and 3.3.3.4)
- Manipulation
  - Task-oriented grasp planning (Sections 3.3.3.2 and 3.3.4.2)
  - (Reactive and compliant) grasp execution (Sections3.3.3.2 and 3.3.3.4)3.3.4.2
  - Tool use (e.g. pouring from bowls) (Section 3.3.3.4)
  - Motion planning for a manipulator (Section 3.3.3.4)
  - (Reactive and compliant) arm motion execution (Sections 3.3.3.2 and 3.3.4.2)
- Locomotion
  - Base motion execution (Sections 3.3.3.1, 3.3.4.1 and 3.3.4.3)
  - (Reactive) obstacle avoidance (Sections 3.3.3.1, 3.3.4.1 and 3.3.4.3)
- Mobile manipulation
  - Motion planning for the joined arm and base (Section 3.3.3.2)
  - Coordination of arm, hand and base motions (Section 3.3.3.2)
- Task planning (e.g. to determine the order in which to refill containers) (Section 3.3.3.4)

Chapter 4

RoCKIn@Home Competition Design

4.1 Competition Elements

□ To be included in a future revision: a general explanation of the competition elements, like competition stages, tests, technical challenges, reliability exercises, and open demonstrations. □

4.2 Stages

The stage system is unavoidable when there is a large number of participant. In accordance to the RoCKIn principle, the use of stage system in the RoCKIn@Work competition will be minimize (only in final stage). In the occasion that the stage system is being used, the OC and the TC will jointly determine which teams will be qualified to proceed further in the competition. The team qualification will be based on the following criteria:

- The score difference in team ranking.
- Innovation aspect of the solution shown in the earlier test.

In the case of final stage, the following additional criteria will be evaluated:

- The number of test solved with satisfactory result.
- The repeatability in performing the tests.
- The reliability in executing the task.

4.3 Tests

The subsequent sections describe tests to be included in RoCKIn@Work:

4.3.1 Search test

The robot searches one or several objects, persons, or pets.

4.3.1.1 Functionality Benchmarked by the Test

- (User-guided) exploration/search strategy
- Reactive motion execution of the mobile base
- Visual pet detection
- Visual pet recognition
- Visual pet localization

4.3.1.2 Benchmark Metrics

4.3.1.3 Benchmark Scenario

- Search pet scenario task (see Section 3.3.3.1)
- Environment (see Chapter 3)
- Robot (see Section 3.2)

4.3.1.4 Feature Variation

The robot features are not restricted (but must be within their feature domain). This test requires the robot to have at least a locomotion system and a vision system.

Complexity I

- Task features:
  - No hints are provided by the user.
  - There are exactly two cats in the environment.
  - The pets lie or stand on the floor.
- Environment features:
  - The default environment is used. Default environment refers to the environment as instantiated in the competition place.

Complexity II

- Task features:
  - No hints are provided by the user.
  - There are exactly two cats and exactly two dogs in the environment.
  - The pets lie, stand or move on the floor or on furniture.
- Environment features:
  - The default environment is used.
  - There are additional static obstacles on the floor.

Complexity III

- Task features:
  - The user provides hints about where to search.
  - There are up to two cats and up to two dogs in the environment.
  - The pets lie, stand or move on the floor, on furniture or underneath objects.
- Environment features:
  - The default environment is used.
  - There are additional static and dynamic obstacles on the floor.

4.3.1.5 Test Procedures

1. Camera above the arena tracks the robot and sends the results to the referee box
2. Referee box sends out the initial test specification and a start signal
3. Robot starts moving and searches
4. If the robot thinks that it has found a pet, it sends a message to the referee box, that it has found a pet (detection). Then in arbitrary order:
   - A message, where it has found the pet (localization)
   - A message, which pet it has found (recognition)
   - A message, which pet type it has found (classification)
5. The referee box sends a message to the robot when it should continue searching
6. When the robot has finished the search it informs the referee box, saying that it either has found all pets, that there are no pets or that it gives up searching.

At any time between steps 2 and 5 the referee box can send an updated test specification to the robot.

4.3.1.6 Rules

- Timing restrictions
- Safety rules: Robot may not hit objects, obstacles or persons while navigating
- Robot may remove obstacles (but must announce this to the referee box)
- Initial pet placement
- The localization is considered correct, when the position specified by the robot is within a radius of 0.2m around the ground truth position
- A mapping between a cat and a name is specified before the test

4.3.1.7 Acquisition and Logging of Measurements

- Measurements required from the arena's sensor net:
  - Track robot's pose
  - Track pets' positions
- Measurements required from the robot:
  - Association of pets' names, types and positions at specified time

4.3.1.8 Scoring

- A correctly localized pet gives 100 points
- An incorrectly localized pet gives −50 points
- A correctly recognized pet gives 100 points
- An incorrectly recognized pet gives −50 points
- A correctly categorized pet gives 100 points
- An incorrectly categorized pet gives −50 points
- Time:

$$\frac{time_{max} - time}{time_{max}} \times 100 \text{ points} \tag{4.1}$$

- Search strategy:

$$coverage[\%] \times \frac{time_{max} - time}{time_{max}} \times 100 \text{ points} \tag{4.2}$$

4.3.2 Refill Test

This test combines the evaluation of a robot's fill level detection and the container refilling capability.

4.3.2.1 Functionality Benchmarked by the Test

- Filling level detection
- Tool use
- Motion planning for a manipulator
- Object pose estimation
- Task planning

4.3.2.2 Benchmark Metrics

- ...

4.3.2.3 Benchmark Scenario

- Check filling level task (see Section 3.3.3.3) and refill bowls task (see Section 3.3.3.4)
- Environment (see Chapter 3)
- Robot (see Section 3.2)

4.3.2.4 Feature Variation

The robot features are not restricted (but must be within their feature domain). This test requires the robot to have at least a manipulation system, a grasping system and a vision system.

Complexity I

- Task features:
  - Neither the initial nor the desired filling level is specified a-priori.
  - There is exactly one food bowl.
  - The shape of the bowl is a hollow half-sphere.
  - The type of food is dry food.
  - The bowl is not tilted ($0°$).
  - The bowl is not elevated above the ground ($0m$).
- Environment features:
  - The default environment is used. Default environment refers to the environment as instantiated in the competition place.

Complexity II

- Task features:
  - Neither the initial nor the desired filling level is specified a-priori.
  - There are one to five water and food bowls, each.
  - The shape of the water and food bowls is either a cuboid, a cylinder, a frustum, or a flat cylinder (i.e. cylinder with an elliptical base).
  - The type of liquid is water or milk.
  - The type of food is dry food or wet food.
  - Bowls are not tilted ($0°$).
  - Bowls are not elevated above the ground ($0m$).
- Environment features:
  - The default environment is used.

Complexity III

- Task features:
  - Neither the initial nor the desired filling level is specified a-priori.
  - There are one to five water and food bowls, each.
  - The shape of the water and food bowls is either a cuboid, a cylinder, a frustum, or a flat cylinder (i.e. cylinder with an elliptical base).
  - The type of liquid is water or milk.
  - The type of food is dry food or wet food.
  - Neither the tilting level nor the elevation above the groundare specified a-priori.
- Environment features:
  - The default environment is used.

4.3.2.5 Test Procedures

4.3.2.6 Rules

- Timing restrictions
- Safety rules: Robot may not hit objects, obstacles or persons while navigating
- Robot may remove obstacles (but must announce this to the referee box)
- Initial pet placement
- The localization is considered correct, when the position specified by the robot is within a radius of 0.2m around the ground truth position
- A mapping between a cat and a name is specified before the test

4.3.2.7 Acquisition and Logging of Measurements

- Measurements required from the arena's sensor net:
- Measurements required from the robot:

4.3.2.8 Scoring

- A correctly identified bowl (water or food) gives 100 points
- An incorrectly identified bowl (water or food) gives −50 points
- The detection of the correct filling level gives 100 points
- The detection of an incorrect filling level gives −50 points
- Refilling a correct bowl gives 100 points
- Refilling an incorrect bowl gives −50 points

- Difference between actual and desired filling level (e.g. based on relative difference)
- Time:

$$\frac{time_{max} - time}{time_{max}} \times 100 \text{ points} \tag{4.3}$$

Chapter 5

RoCKIn@Home Organization

5.1 RoCKIn@Home Management

The management structure of RoCKIn@Home has been divided into three committees, namely *Executive Committee*, *Technical Committee* and the *Organization Committee*. The rolls and responsibilities of those committees are described in the following paragraphs.

5.1.1 RoCKIn@Home Executive Committee

The Executive Committee (EC) is represented by the coordinators of each RoCKIn partner related to the respective activity area. The committee is mainly responsible for the overall coordination of RoCKIn@Home activities and especially for dissemination in the scientific community.

☐ add further responsibilities as needed ☐ GKK:

- Daniele Nardi (Sapienza Università di Roma, Italy)
- Pedro Lima (Instituto Superior Técnico, Portugal)
- Gerhard Kraetzschmar (Bonn-Rhein-Sieg University, Germany)
- Matteo Matteucci (Politecnico di Milano, Italy)

5.1.2 RoCKIn@Home Technical Committee

The Technical Committee (TC) is responsible for the rules of the league. Each member of the committee is involved in maintaining and improving the current rule set and also in the adherence of these rules. Other responsibilities include the qualification of teams, general technical issue within the league as well as resolving any conflicts inside the league during a ongoing competition. The members of the committee are further responsible for maintaining the RoCKIn@Home Infrastructure.

The Technical Committee currently consists of the following members:

- Daniele Nardi (Sapienza Università di Roma, Italy)
- Sven Schneider (Bonn-Rhein-Sieg University, Germany)
- Aamir Ahmad (Instituto Superior Técnico, Portugal)
- Matteo Matteucci (Politecnico di Milano, Italy) ☐ To be confirmed. ☐

This committee can also include members of the Executive Committee.

5.1.3 RoCKIn@Home Organizing Committee

The Organizing Committee (OC) is responsible for the actual implementation of the competition, i.e. providing everything what is required to perform the various tests. Specifically, this means providing setting up the test arena(s), providing any kind of objects (e.g. manipulation objects), scheduling the tests, assigning and instructing referees, recording and publishing (intermediate) competition results and any other kind of management and advertisement duties before, during and after the competition.

The Organizing Committee currently consists of the following members:

- **Chair:** Pedro Lima (Instituto Superior Técnico, Portugal)
- Frederik Hegger (Bonn-Rhein-Sieg University, Germany)
- Luca Iocchi (Sapienza Università di Roma, Italy)
- Matteo Matteucci (Politecnico di Milano, Italy) ☐ To be confirmed. ☐
- Greg Eredics (InnoCentive, UK) ☐ To be confirmed. ☐

This committee can also include members of the Executive and Technical Committee.

5.2 RoCKIn@Home Infrastructure

5.2.1 RoCKIn@Home Web Page

The official RoCKIn@Home website can be reached at

`http://rockinrobotchallenge.eu/home.php` ☐ To be confirmed. ☐

On those web pages, teams can find introductory information about the league itself as well as relevant information about upcoming events, the most recent version of the rulebook, videos and pictures of past competitions and links to further resources like the official mailing list or wiki.

5.2.2 RoCKIn@Home Mailing List

The official RoCKIn@Home mailing list maintained by the league is as follows

`rocking-at-home@rockinrobotchallenge.eu` ☐ To be confirmed. ☐

Anyone can subscribe by using the following subscription page.

`http://rockinrobotchallenge.eu/mailman/listinfo/rocking-at-home`
☐ To be confirmed. ☐

Every subscriber is requested to register either with an email address which already encodes the real name or alternatively specify it in the provided field at the subscription page. In order to prevent the mailing list from spammers, this mailing list is moderated.

The mailing list will be used for any kind of official announcement, e.g. upcoming RoCKIn@Home competitions, rule changes, registration deadlines or infrastructure changes. Teams are also welcome to raise any kind of question regarding the league on this list.

5.3 RoCKIn@Home Competition Organization

5.3.1 Qualification and Registration

Participation in RoCKIn@Home requires successfully passing a qualification procedure. This procedure is to ensure a well-organized competition event and the safety of participants. Depending on constraints imposed by a particular site or the number of teams interested to participate, it may not be possible to admit all interested teams to the competition.

All teams that intend to participate at the competition have to perform the following steps: ☐ To be confirmed. ☐

1. Preregistration (may be optional; currently by sending an email to the TC)
2. Submission of qualification material (e.g. team description paper)
3. Final registration (qualified teams only)

5.3.1.1 Preregistration

All teams that intend to participate at the competition have to perform the preregistration process using the following registration website:

`http://rockinrobotchallenge.eu/athome-preregistration.php`

☐ To be confirmed. ☐

A team must provide the following information during the preregistration process:

- Team name
- Affiliation
- Country
- Team website
- Team leader name
- Team leader email address

This step can be considered as an *Intention of Participation* declaration and serves as planning basis for the Organizing Committee.

5.3.1.2 Qualification

The qualification process serves a dual purpose: It should allow the Technical Committee to assess the safety of the robots a team intents to bring to a competition, and it should allow to rank teams according to a set of evaluation criteria in order to select the most promising teams for a competition, if not all interested teams can be permitted. The TC will select the qualified teams according to the qualification material provided by the teams.

The evaluation criteria will include: ☐ To be confirmed. ☐

- Team description paper
- Team web site
- Relevant scientific contribution/publications
- Professional quality of robot and software

- Novelty of approach
- Relevance to domestic service robotics
- Performance in other competitions
- Contribution to RoCKIn@Home league (e.g. by organization of events or provision and sharing of knowledge)

The Team Description Paper (TDP) is a central element of the qualification process and has to be provided by each team as part of the qualification process. The TDP should at least contain the following information in the author/title section of the paper:

- Name of the team (title)
- Team members (authors), including the team leader
- Link to the team web site
- Contact information

The body of the TDP should contain information on the following: focus of research/research interests:

- Description of the hardware, including an image of the robot(s)
- Description of the software, esp. the functional and software architectures
- Innovative technology (if any)
- Reusability of the system or parts thereof
- Applicability and relevance to domestic service robotics

The team description paper should cover in detail the technical and scientific approach, while the team web site should be designed for a broader audience. Both the web site and the TDP have to be written in English.

The length of the team description paper is limited to 6 pages and has to be to submitted in the IEEE Conference Proceedings format[1].

5.3.1.3 Registration

Only if team has passed the qualification procedure successfully it is allowed to register officially for the competition and has to provide additional information e.g. the exact number of team members. Further information about the registration procedure will be communicated through the mailing list mentioned in Section 5.2.2.

The number of people to register per team is not limited, but during the competition the organizers will provide space only for 6 persons to work at tables in the team area.

GKK: ☐ Confirm number. ☐

During the final registration, each team has to designate one member as team leader. A change of the team leader must be communicated to the Organizing Committee.

[1] http://www.ieee.org/conferences_events/conferences/publishing/templates.html

5.3.2 Setup and Schedule

☐ The schedule is still under discussion. ☐

Setup: For the arrival, setup, and preparation of teams participating in the competition, the following procedures apply:

- A first draft of the rulebook will be made public X weeks before the actual event by the the TC.
- The final version of the rulebook will be made public X weeks before the actual event by the the TC.
- The competition side will be divided into a competition and a team area.
- The competition area consists of one or more testbeds (the arena) and is open for public.
- The arena must be kept clean and in a representable condition all the time.
- The team area is a dedicated area only for team members, no public access here.
- Each team will be assigned to a designated area with tables and chairs (based on the number of team members), with power sockets, a shelf internet connection and a reasonable area to park their robot and other equipment.

☐ Revise the list below. Most of it does not belong here. This info given here should concern only on-site setup procedures for teams, e.g. mention how much time there is for unpacking robots, setting them up, and testing in the arena. ☐

Schedule: For the scheduling of particular stages, tests, and technical challenges of the competition the following applies:

- The exact schedule of task-/functionality tests will be announced one week before the actual competition by the OC on both, the website and the mailing list.
- In order to avoid to much "traffic" inside the testbed, an additional schedule only for test slots will be established on site by the OC.
- A set of test slots will be assigned to each team between the official test slots, where a team has exclusive access to the testbed without any other team/robot inside the arena.

5.3.3 Competition Execution

- Referees will be determined by the OC out of the group of team leaders and TCs.
- The referees ensure the correct execution of a test, are in charge of keeping the time and counting the scores.
- In case of any dangerous situation the referees are allowed to immediately stop a run and trigger the emergency stop functionality of the respective robot.

- The official language for all kind of communication within the league is English (e.g. team leader meetings, announcements, schedule, etc.)
- The order in which the teams have to perform a particular test will be determined by a draw through the OC.
- The order will be announced one the day before the actual test.
- No team members or other persons are allowed to be in the arena during an official test (only if the rulebook explicitly allows this).
- Regular team leader meetings (every day) will be organized and announced by the TC/OC during the competition in order to discuss open issues for upcoming tests.

5.3.4 Competition Evaluation and Assessment

5.3.4.1 Measurements Recording

5.3.4.2 Scoring

For each test the calculation of scores is defined individually, comprising points for achieving certain subtasks, points for winning a run, negative points for reducing the difficulty, and penalty points. ☐ To be confirmed. ☐

5.3.5 Awards

- A ranking is established based on the scoring achieved in the particular task/functionality tests described in Section 4.3. According to the ranking there will be a 1st, 2nd and 3rd place.
- Beside the ranking awards there are additional awards for the Technical Challenges (only one per challenge) and for the Open Demonstrations (only one per demonstration). ☐ To be confirmed. ☐

5.3.6 Post-Competition Procedures and Workshop

☐ To be decided. ☐

Appendix A

RoCKIn@Home Environment Details

In this appendix, we provide further details on the environment used in the RoCKIn-@Home scenario.

☐ This version is partially complete. The focus is on specifying first items that need to be known for preparing the construction of scenario environment and for building suitable simulators. Thus, we initially focus on items like walls, floors, ceilings, doors, windows, and infrastructure. For other items, such as furniture, decoration items, or the objects to be manipulated, there exists — and will intentionally remain — a wide variability of which objects may be ultimately used in a particular environment. We will detail such objects in future versions of this document. ☐

A.1 Details on Particular Rooms or Spatial Areas

A.1.1 The Bedroom

A.1.1.1 Floor, Walls, and Ceiling

Scenario Specification A.1 (*Bedroom Floor*)

Material features: *The bedroom floor is either carpet or parquet floor. No constraints exist with respect to the colors or patterns used. Carpet floors must be such that safe robot operation is possible.*

Shape/form: *The shape is the same as the bedroom layout.*

Size: *The minimum bedroom size is specified in Scenario Sepcification 3.12. The floor covers the complete spatial area of the bedroom.*

Slope: *The bedroom floor should be well-leveled, but slopes of up to 2° are acceptable.*

Uniqueness: *The bedroom floor may be unique or not, i.e. the floor may be the same as in other spatial areas of the appartment, or it may be different.*

The typical size of the bedroom will be $4m \times 4m$.

Scenario Specification A.2 (*Bedroom Walls*)

Material features: *The bedroom walls have to be made of some stiff material, such as wood, wood-based materials (chipboards), stone, concrete, or metal. For* *competition arenas, walls will usually be made of chipboards in combination with wood or metallic frames.*

The color of the walls will be some light color (such as white, ivory, yellow, light green, to name a few examples).

Patterned wallpaper may be used for finishing the walls.

The walls are not translucent. If some kind of translucent material, such as glass, Plexiglass®, Perspec®, or Lucite®is used, then these wall areas have to be defined as windows.

Shape/form: *The walls are upright. Offsets up to 5cm are allowed to ease construction of testbeds.*

Size: *The minimum height of the walls is 80cm. The walls will usually have a height of 2m or more. Exceptions may be made for up to two connecting walls of the bedroom in order to allow better visibility for the audience at competitions.*

There are no constraints concerning the length of walls.

The width (thickness) of the walls must be large enough to ensure sufficient stability.

Uniqueness: *The bedroom walls may be unique or not, i.e. the wall colors and patterns may be the same as in other spatial areas of the appartment or they may be different.*

The bedroom walls may be decorated with various items

Scenario Specification A.3 (*Bedroom Ceiling*)

The bedroom may or may not be covered by a ceiling. If it is not covered by a ceiling, then special constructions may be foreseen for fixing lamps, sensors, or other objects. If it is covered by a ceiling, the following specifications apply:

Material features: *The ceiling can be of any material.*

Shape/form: *The shape of the ceiling projected to the floor matches the floor layout.*

Size: *The size of the ceiling projected to the floor matches the floor layout.*

Slope: *The ceiling may be (partially or completely) sloped.*

Uniqueness: *The ceiling is not unique.*

A.1.1.2 Doors and Windows

Scenario Specification A.4 (*Bedroom Doors*)

The bedroom has only one door connecting it to the rest of the appartment.

Material features: *The door is made of wood or some laminated material. It can have any color. It does not contain any glass segments or translucent areas.*

Shape/form: *The door has rectangular shape.*

Size: *The height of the door is between 180 cm and 200 cm. The width of the door is between 80 cm and 100 cm.*

Door mechanism: *The door is connected to the door frame using hinge joints. The door opens into the bedroom. The door opens to the right.*

Door locking: *The door may or may not have a lock.*

Door handle: *The door has a handle. The type:* ☐ *To be determined.* ☐

Uniqueness: *The door is not unique.*

Scenario Specification A.5 (*Bedroom Windows*)

Material features: *The bedroom window is made of glass or plexi, with a frame made of wood, aluminium, or plastics. The color of the frame may be any color.*

Shape/form: *The shape of the window is rectangular.*

Size: *The width of the window is between 60 cm and 120 cm, the height of the window is between 60 cm and 120 cm.*

Opening mechanism: *The window can be tilted or opened.*

Window handle: *The window opening mechanism is operated by an L-shaped handle.*

Uniqueness: *The window is not unique.*

A.1.1.3 Shutters, Blinds, and Curtains

Scenario Specification A.6 (*Bedroom Door Shutters*)

The bedroom door has no shutters.

☐ This could apply if the bedroom would have a door to the patio. ☐ GKK: ToDo

Scenario Specification A.7 (*Bedroom Window Shutters*)

Material features: *The bedroom window shutters are made of either wood or plastic. The color of the shutters may be any color.*

Shape/form: ☐ *Not relevant.* ☐

Size: *The shutter covers the whole window on the outside.*

Actuation: *The window shutters are operated by a built-in motor, which can be activated by two push button switches, one for up movement, one for down movement.*

Uniqueness: *The window shutters are not unique.*

Scenario Specification A.8 (*Bedroom Door Blinds*)

The bedroom door has no blinds.

☐ This could apply if the bedroom would have a door to the patio. ☐ GKK: ToDo

Scenario Specification A.9 (*Bedroom Window Blinds*)

The bedroom does not have inside window blinds.

Scenario Specification A.10 (*Bedroom Door Curtains*)

The bedroom door has no curtains.

GKK: ToDo ☐ This could apply if the bedroom would have a door to the patio. ☐

Scenario Specification A.11 (*Bedroom Window Curtains*)

The bedroom window may have a curtain.

A.1.2 The Living Room

A.1.2.1 Floor, Walls, and Ceiling

Scenario Specification A.12 (*Living Room Floor*)

Material features: *The living room floor is either carpet or parquet floor.*

Shape/form: *The shape is the same as the living room layout.*

Size: *The minimum living room size is specified in Scenario Sepcification 3.12. The floor covers the complete spatial area of the living room.*

Slope: *The living room floor should be well-leveled, but slopes of up to* $2°$ *are acceptable.*

Uniqueness: *The living room floor is not unique. In particular, the dining room and the hallway use the same floor. Perceptual ambiguity may be resolved by placing one or more carpets on top of the living room floor.*

The typical size of the living room will be $4m \times 6m$☐ To be determined. ☐ .

Scenario Specification A.13 (*Living Room Walls*)

Material features: *The living room walls have to be made of some stiff material, such as wood, wood-based materials (chipboards), stone, concrete, or metal. For competition arenas, walls will usually be made of chipboards in combination with wood or metallic frames.*

The color of the walls can be any color.

Patterned wallpaper may be used for finishing the walls.

The walls are not translucent. If some kind of translucent material, such as glass, Plexiglass®, Perspec®, or Lucite®is used, then these wall areas have to be defined as windows.

Shape/form: *The walls are upright. Offsets up to* $5cm$ *are allowed to ease construction of testbeds.*

Size: *The minimum height of the walls is* $80cm$*. The walls will usually have a height of* $2m$ *or more. Exceptions may be made for up to two connecting walls of the living room in order to allow better visibility for the audience at competitions.*

There are no constraints concerning the length of walls.

The width (thickness) of the walls must be large enough to ensure sufficient stability.

Uniqueness: *The living room walls may be unique or not, i.e. the wall colors and patterns may be the same as in other spatial areas of the appartment or they may be different.*

The walls may be decorated with various items

Scenario Specification A.14 (*Living Room Ceiling*)

The living room may or may not be covered by a ceiling. If it is not covered by a ceiling, then special constructions may be foreseen for fixing lamps, sensors, or other objects. If it is covered by a ceiling, the following specifications apply:

Material features: *The ceiling can be of any material.*

Shape/form: *The shape of the ceiling projected to the floor matches the floor layout.*

Size: *The size of the ceiling projected to the floor matches the floor layout.*

Slope: *The ceiling may be (partially or completely) sloped.*

Uniqueness: *The ceiling is not unique.*

A.1.2.2 Doors and Windows

Scenario Specification A.15 (*Living Room Doors*)

The living room has two doors connecting to the bathroom and the bedroom. The bedroom door is specified in Scenario Specification A.4. The bathroom door is specified in Scenario Specification A.42.

Scenario Specification A.16 (*Living Room Windows*)

The living room has a window front towards the patio.☐ *To be confirmed.* ☐

Material features: *The living room windows are made of glass or plexi, with a frame made of wood, aluminium, or plastics. The color of the frame may be any color.*

Shape/form: *The shape of the windows is rectangular. The windows can contain muntins (i.e. they are lattice windows).*

Size: *The width of the windows is between 60 cm and 200 cm, the height of the windows is between 60 cm and 200 cm.*

Opening mechanism: *The windows can be tilted or opened.*

Window handle: *The window opening mechanisms are operated by L-shaped handles.*

Uniqueness: *The windows are not unique.*

A.1.2.3 Shutters, Blinds, and Curtains

Scenario Specification A.17 (*Living Room Door Shutters*)

The living room doors have no shutters.

☐ This could apply if the living room would have a door to the patio. ☐ GKK: ToDo

Scenario Specification A.18 (*Living Room Window Shutters*)

Material features: *The living room window shutters are made of either wood or plastic. The color of the shutters may be any color.*

Shape/form: ☐ *Not relevant.* ☐

Size: *The shutter covers the whole window on the outside.*

Actuation: *The window shutters are operated by a built-in motor, which can be activated by two push button switches, one for up movement, one for down movement.*

Uniqueness: *The window shutters are not unique.*

Scenario Specification A.19 (*Living Room Door Blinds*)

The living room doors have no blinds.

GKK: ToDo ☐ This could apply if the living room would have a door to the patio. ☐

Scenario Specification A.20 (*Living Room Window Blinds*)

The living room does have inside window blinds.

Scenario Specification A.21 (*Living Room Door Curtains*)

The living room door has no curtains.

Scenario Specification A.22 (*Living Room Window Curtains*)

The living room window may have a curtain.

A.1.3 The Dining Room

A.1.3.1 Floor, Walls, and Ceiling

Scenario Specification A.23 (*Dining Room Floor*)

Material features: *The dining room floor is either carpet or parquet floor.*

Shape/form: *The shape is the same as the dining room layout.*

Size: *The minimum living room size is specified in Scenario Sepcification 3.12. The floor covers the complete spatial area of the dining room.*

Slope: *The dining room floor should be well-leveled, but slopes of up to* 2° *are acceptable.*

Uniqueness: *The dining room floor is not unique. In particular, the living room and the hallway use the same floor. Perceptual ambiguity may be resolved by placing one or more carpets on top of the dining room floor.*

Scenario Specification A.24 (*Dining Room Walls*)

Material features: *The dining room walls have to be made of some stiff material, such as wood, wood-based materials (chipboards), stone, concrete, or metal. For competition arenas, walls will usually be made of chipboards in combination with wood or metallic frames.*

The color of the walls can be any color.

Patterned wallpaper may be used for finishing the walls.

The walls are not translucent. If some kind of translucent material, such as glass, Plexiglass®, Perspec®, or Lucite® is used, then these wall areas have to be defined as windows.

Shape/form: *The walls are upright. Offsets up to 5cm are allowed to ease construction of testbeds.*

Size: *The minimum height of the walls is 80cm. The walls will usually have a height of 2m or more. Exceptions may be made for up to two connecting walls of the dining room in order to allow better visibility for the audience at competitions.*

There are no constraints concerning the length of walls.

The width (thickness) of the walls must be large enough to ensure sufficient stability.

Uniqueness: *The dining room walls may be unique or not, i.e. the wall colors and patterns may be the same as in other spatial areas of the appartment or they may be different.*

The walls may be decorated with various items

Scenario Specification A.25 (*Dining Room Ceiling*)

The dining room may or may not be covered by a ceiling. If it is not covered by a ceiling, then special constructions may be foreseen for fixing lamps, sensors, or other objects. If it is covered by a ceiling, the following specifications apply:

Material features: *The ceiling can be of any material.*

Shape/form: *The shape of the ceiling projected to the floor matches the floor layout.*

Size: *The size of the ceiling projected to the floor matches the floor layout.*

Slope: *The ceiling may be (partially or completely) sloped.*

Uniqueness: *The ceiling is not unique.*

A.1.3.2 Doors and Windows

Scenario Specification A.26 (*Dining Room Doors*)

The dining room is openly connected to the rest of the appartment and does not have any doors.

Scenario Specification A.27 (*Dining Room Windows*)

Material features: ☐ *To be determined.* ☐

Shape/form: ☐ *To be determined.* ☐
Size: ☐ *To be determined.* ☐
Opening mechanism: ☐ *To be determined.* ☐
Window handle: ☐ *To be determined.* ☐
Uniqueness: ☐ *To be determined.* ☐

A.1.3.3 Shutters, Blinds, and Curtains

Scenario Specification A.28 (*Dining Room Door Shutters*)

The dining room door has no shutters.

Scenario Specification A.29 (*Dining Room Window Shutters*)

Material features: *The dining room window shutters are made of either wood or plastic. The color of the shutters may be any color.*

Shape/form: ☐ *Not relevant.* ☐

Size: *The shutter covers the whole window on the outside.*

Actuation: *The window shutters are operated by a built-in motor, which can be activated by two push button switches, one for up movement, one for down movement.*

Uniqueness: *The window shutters are not unique.*

Scenario Specification A.30 (*Dining Room Door Blinds*)

The dining room door has no blinds.

Scenario Specification A.31 (*Dining Room Window Blinds*)

The dining room windows do not have window blinds.

Scenario Specification A.32 (*Dining Room Door Curtains*)

The dining room door has no curtains.

Scenario Specification A.33 (*Dining Room Window Curtains*)

The dining room window may have a curtain.

A.1.4 The Kitchen

A.1.4.1 Floor, Walls, and Ceiling

Scenario Specification A.34 (*Kitchen Floor*)

Material features: *The kitchen floor is made of tiles, parquet, or linoleum. No* *constraints are made concerning the sizes, shapes, colors, patterns, or layout of the floor.*

Shape/form: *The shape of the kitchen floor results from the kitchen layout, less the space occupied by the kitchen cabinets and equipment.*

Size: *The minimum kitchen size is specified in Scenario Sepcification 3.12. The floor covers the complete spatial area of the kitchen, less the space occupied by the kitchen cabinets and equipment.*

Slope: *The dining room floor should be well-leveled, but slopes of up to 2° are acceptable.*

Uniqueness: *If the kitchen is openly connected to either the dining room and/or the living room in an open floor design, and if a parquet floor is used, then the kitchen floor may be not unique. In all other cases, the kitchen floor will be unique.*

Scenario Specification A.35 (*Kitchen Walls*)

Material features: *The kitchen walls have to be made of some stiff material, such as wood, wood-based materials (chipboards), stone, concrete, or metal. For competition arenas, walls will usually be made of chipboards in combination with wood or metallic frames. The kitchen walls must be stable enough such that kitchen equipment like hanging cupboards can be installed.*

Kitchen walls may be, totally or partially, covered and finished by tiling, fiberglass cloth with paint finish, wooden panels, or colored glass (e.g. in the back of the cooker).

Any colors and/or patterns may be used for the walls.

The walls are not translucent. If some kind of translucent material, such as glass, Plexiglass®, Perspec®, or Lucite®is used, then these wall areas have to be defined as windows.

Shape/form: *The walls are upright. Offsets up to 5cm are allowed to ease construction of testbeds.*

Size: *The minimum height of the walls is 80cm. The walls will usually have a height of 2m or more. Exceptions may be made for up to two connecting walls of the kitchen in order to allow better visibility for the audience at competitions.*

There are no constraints concerning the length of walls.

The width (thickness) of the walls must be large enough to ensure sufficient stability.

Uniqueness: *The kitchen walls are unique.*

The walls may be decorated with various items

Scenario Specification A.36 (*Kitchen Ceiling*)

The kitchen may or may not be covered by a ceiling. If it is not covered by a ceiling, then special constructions may be foreseen for fixing lamps, sensors, or other objects. If it is covered by a ceiling, the following specifications apply:

Material features: *The ceiling can be of any material.*

Shape/form: *The shape of the ceiling projected to the floor matches the floor layout.*

Size: *The size of the ceiling projected to the floor matches the floor layout.*

Slope: *The ceiling may be (partially or completely) sloped.*

Uniqueness: *The ceiling is not unique.*

A.1.4.2 Doors and Windows

Scenario Specification A.37 (*Kitchen Doors*)

The kitchen is openly connected to the rest of the appartment and does not have any doors.

Scenario Specification A.38 (*Kitchen Windows*)

Material features: ☐ *To be determined.* ☐

Shape/form: ☐ *To be determined.* ☐

Size: ☐ *To be determined.* ☐

Opening mechanism: ☐ *To be determined.* ☐

Window handle: ☐ *To be determined.* ☐

Uniqueness: ☐ *To be determined.* ☐

A.1.5 The Bathroom

A.1.5.1 Floor, Walls, and Ceiling

Scenario Specification A.39 (*Bathroom Floor*)

Material features: *The bathroom floor is made of tiles. No constraints are made concerning the sizes, shapes, colors, patterns, or layout of the bathroom floor tiles.*

Shape/form: *The shape is the same as the bathroom layout, less the space occupied by the bathroom installation such as bath tub, shower, etc.*

Size: *The minimum bathroom size is specified in Scenario Sepcification 3.12. The floor covers the complete spatial area of the bathroom, less the space occupied by the bathroom installation such as bath tub, shower, etc.*

Slope: *The dining room floor should be well-leveled, but slopes of up to $2°$ are acceptable.*

Uniqueness: *The bathroom floor is unique.*

The typical size of the bathroom will be $3m \times 3m$.

Scenario Specification A.40 (*Bathroom Walls*)

Material features: *The bathroom walls have to be made of some stiff material, such as wood, wood-based materials (chipboards), stone, concrete, or metal. For competition arenas, walls will usually be made of chipboards in combination with wood or metallic frames. The bathroom walls must be stable enough such that bathroom installations like hanging bathroom closets or toilet basins can be installed.*

Bathroom walls may be, totally or partially, covered and finished by tiling or fiberglass cloth with paint finish.

Any colors and/or patterns may be used for the walls.

The walls are not translucent. If some kind of translucent material, such as glass, Plexiglass®, Perspec®, or Lucite® is used, then these wall areas have to be defined as windows.

Shape/form: *The walls are upright. Offsets up to 5cm are allowed to ease construction of testbeds.*

Size: *The minimum height of the walls is 80cm. The walls will usually have a height of 2m or more. Exceptions may be made for up to two connecting walls of the bathroom in order to allow better visibility for the audience at competitions.*

There are no constraints concerning the length of walls.

The width (thickness) of the walls must be large enough to ensure sufficient stability.

Uniqueness: *The bathroom walls may be unique or not, i.e. the wall colors and patterns may be the same as in other spatial areas of the appartment or they may be different.*

Scenario Specification A.41 (*Bathroom Ceiling*)

The bathroom may or may not be covered by a ceiling. If it is not covered by a ceiling, then special constructions may be foreseen for fixing lamps, sensors, or other objects. If it is covered by a ceiling, the following specifications apply:

Material features: *The ceiling can be of any material.*

Shape/form: *The shape of the ceiling projected to the floor matches the floor layout.*

Size: *The size of the ceiling projected to the floor matches the floor layout.*

Slope: *The ceiling may be (partially or completely) sloped.*

Uniqueness: *The ceiling is not unique.*

A.1.5.2 Doors and Windows

Scenario Specification A.42 (*Bathroom Doors*)

The bathroom has only one door connecting it to the rest of the appartment.

Material features: *The door is made of wood or some laminated material. It can have any color. It does not contain any glass segments or translucent areas.*

Shape/form: *The door has rectangular shape.*

Size: *The height of the door is between 180 cm and 200 cm. The width of the door* *is between 80 cm and 100 cm.*

Door mechanism: *The door is connected to the door frame using hinge joints. The door opens into the bathroom. The door opens to the right.*

Door locking: *The door may or may not have a lock.*

Door handle: *The door has a handle. The type:* ☐ *To be determined.* ☐

Uniqueness: *The door is not unique.*

Scenario Specification A.43 (*Bathroom Windows*)

Material features: ☐ *To be determined.* ☐

Shape/form: ☐ *To be determined.* ☐

Size: ☐ *To be determined.* ☐

Opening mechanism: ☐ *To be determined.* ☐

Window handle: ☐ *To be determined.* ☐

Uniqueness: ☐ *To be determined.* ☐

A.1.6 The Hallway

A.1.6.1 Floor, Walls, and Ceiling

Scenario Specification A.44 (*Hallway Floor*)

Material features: *The hallway room floor is either carpet or parquet floor.*

Shape/form: *The shape is the same as the hallway layout.*

Size: *The minimum hallway size is specified in Scenario Sepcification 3.12. The floor covers the complete spatial area of the hallway.*

Uniqueness: *The hallway floor is not unique. The same floor as in the living room and the dining room will be used.*

The typical size of the hallway will be $1.5m \times 3m$.

Scenario Specification A.45 (*Hallway Walls*)

Material features: *The walls have to be made of some stiff material, such as wood, wood-based materials (chipboards), stone, concrete, or metal. For competition arenas, walls will usually be made of chipboards in combination with wood or metallic frames.*

The color of the walls will be some light color (such as white, ivory, yellow, light green, to name a few examples).

Patterned wallpaper may be used for finishing the walls.

The walls are not translucent. If some kind of translucent material, such as glass, Plexiglass®, Perspec®, or Lucite®is used, then these wall areas have to be defined as windows.

Shape/form: *The walls are upright. Offsets up to 5cm are allowed to ease construction of testbeds.*

Size: *The minimum height of the walls is 80cm. The walls will usually have a height of 2m or more. Exceptions may be made for up to two connecting walls of the hallway in order to allow better visibility for the audience at competitions.*

There are no constraints concerning the length of walls.

The width (thickness) of the walls must be large enough to ensure sufficient stability.

Uniqueness: *The hallway walls may be unique or not, i.e. the wall colors and patterns may be the same as in other spatial areas of the appartment or they may be different.*

Scenario Specification A.46 (*Hallway Ceiling*)

The hallway may or may not be covered by a ceiling. If it is not covered by a ceiling, then special constructions may be foreseen for fixing lamps, sensors, or other objects. If it is covered by a ceiling, the following specifications apply:

Material features: *The ceiling can be of any material.*

Shape/form: *The shape of the ceiling projected to the floor matches the floor layout.*

Size: *The size of the ceiling projected to the floor matches the floor layout.*

Slope: *The ceiling may be (partially or completely) sloped.*

Uniqueness: *The ceiling is not unique.*

A.1.6.2 Doors and Windows

Scenario Specification A.47 (*Hallway Doors*☐ *To be determined.* ☐)

The hallway has only one door connecting it to the outside hallway. It is openly connected to the rest of the appartment.

Material features: *The door is made of wood or some laminated material. It can have any color. It does not contain any glass segments or translucent areas.*

Shape/form: *The door has rectangular shape.*

Size: *The height of the door is between 180 cm and 200 cm. The width of the door is between 80 cm and 100 cm.*

Door mechanism: *The door is connected to the door frame using hinge joints. The door opens into the hallway. The door opens to the right.*

Door locking: *The door may or may not have a lock.*

Door handle: *The door has a handle. The type:* ☐ *To be determined.* ☐

Uniqueness: *The door is not unique.*

Scenario Specification A.48 (*Hallway Windows*)

Material features: ☐ *To be determined.* ☐

Shape/form: ☐ *To be determined.* ☐
Size: ☐ *To be determined.* ☐
Opening mechanism: ☐ *To be determined.* ☐
Window handle: ☐ *To be determined.* ☐
Uniqueness: ☐ *To be determined.* ☐

A.1.7 The Patio

A.1.7.1 Floor, Walls, and Ceiling

Scenario Specification A.49 (*Patio Floor*)

Material features: *The patio floor is one of artificial lawn, tiles, or wood.*
Shape/form: *The shape is the same as the patio layout.*
Size: *The minimum patio size is specified in Scenario Sepcification 3.12. The floor covers the complete spatial area of the patio.*
Slope: *The patio floor should be well-leveled, but slopes of up to* $5°$ *are acceptable.*
Uniqueness: *The patio floor is unique.*

The typical size of the patio will be $1.5m \times 3m$.

Scenario Specification A.50 (*Patio Walls*)

☐ *To be defined.* ☐

Scenario Specification A.51 (*Patio Ceiling*)

The patio has no ceiling.

A.1.7.2 Doors and Windows

Scenario Specification A.52 (*Patio Doors*☐ *To be determined.* ☐)

The patio is currently not connected to the rest of the appartment and does not have any doors.

Scenario Specification A.53 (*Patio Windows*)

Material features: ☐ *To be determined.* ☐
Shape/form: ☐ *To be determined.* ☐
Size: ☐ *To be determined.* ☐
Opening mechanism: ☐ *To be determined.* ☐
Window handle: ☐ *To be determined.* ☐
Uniqueness: ☐ *To be determined.* ☐

A.2 Navigation-Relevant Objects

A.2.1 Bedroom Objects

Scenario Specification A.54 (*Furniture*)

The furniture in the bedroom includes the following items:

- *a double bed*
- *two bedside tables*
- *a large wardrobe*
- *a dressing table*
- *a large mirror above the dressing table*

Scenario Specification A.55 (*Bed*)

Type/class: □ *To be filled from a suitable ontology* □
Uniqueness:
Size:
Weight: *Not applicable*
Shape/form:
Material features:
Moveability: *The is not movable.*
Mobility: *The is not mobile.*

Scenario Specification A.56 (*Bedside Tables*)

Type/class: □ *To be filled from a suitable ontology* □
Uniqueness:
Size:
Weight: *Not applicable*
Shape/form:
Material features:
Moveability: *The is not movable.*
Mobility: *The is not mobile.*

Scenario Specification A.57 (*Wardrobe*)

Type/class: □ *To be filled from a suitable ontology* □
Uniqueness: *The wardrobe is unique in the environment.*
Size: *The minimum height of the wardrobe is 180cm, the maximum height is 250cm. The width of the wardrobe is between 50cm and 70cm. The length of the wardrobe is between 100cm and 320cm.*

Weight: *Not relevant.*

Shape/form: *The wardrobe has a rectangualr shape.*

Material features: *The wardrobe is made wood. The surface may have visible "maserung". It may be painted or be "foliert" in some color and/or pattern. One or more of the front doors may be covered partially or fully by a mirror.*

Moveability: *The wardrobe is not movable.*

Mobility: *The wardrobe is not mobile.*

Scenario Specification A.58 (*Dressing Table*)

Type/class: □ *To be filled from a suitable ontology* □

Uniqueness: *the dressing table is unique.*

Size: *TBD*

Weight: *Not relevant.*

Shape/form: *Rectangular/cuboid.*

Material features: *Same as wardrobe.*

Moveability: *The dressing table is not movable.*

Mobility: *The dressing table is not mobile.*

□ To be extended for all rooms foreseen in the scenario environment. □

A.3 Manipulation-Relevant Objects

□ To be included in future revisions. □

□ For the variety of objects to be considered, it is not obvious which features need to be described for each of them. An ontology would be useful. □

A.4 Perception-Relevant Objects

Scenario Specification A.59 (*Wall Mirror*)

The bedroom has a wall mirror.

Type/class: □ *To be filled from a suitable ontology* □

Uniqueness: *If existent, the wall mirror is unique.*

Size: *The minimum size of the wall mirror is $20cm times 30cm$, the maximum size will be less than $90cm \times 200cm$.*

Weight: *Not relevant.*

Shape/form: *The wall mirror may have any shape. Typical shapes include rectangular, oval, and circular.*

Material features: *The wall mirror is made of mirror glass.*

Moveability: *The wall mirror is not movable.*

Mobility: *The wall mirror is not mobile.*

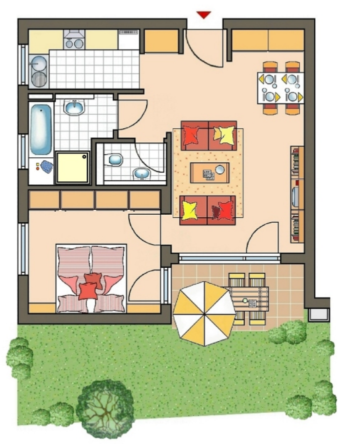
☐ More items to be specified for future revisions. ☐

Appendix B

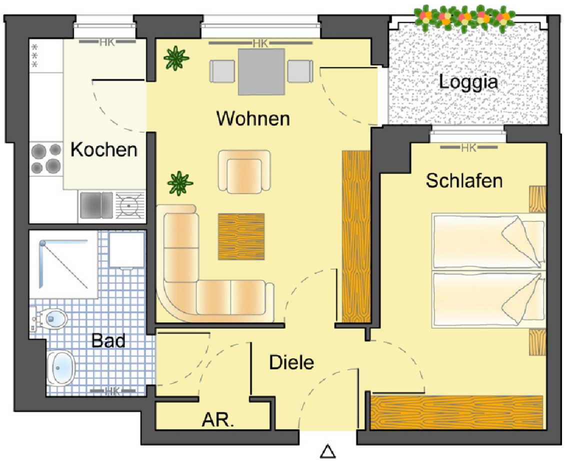
Variations of the Environment

The role of this appendix is to indicate the variability of the scenario by illustrating possible, controllable variations of the environment.

B.1 Alternative Environment Layouts



□ This appendix may be extended in future revisions. □


HK
HK
Loggia
Wohnen
Kochen
HK
Schlafen
Bad
HK
Diele
AR.


Terrasse
4.80 m²
Küche
9.18 m²
Schlafen
13.53 m²
Gast
10.76 m²
Flur
12.51 m²
Wohnen
29.77 m²
AR
4.56 m²
WC
1.87 m²
Bad
6.36 m²
Umkleide
4.62 m²
Bad
6.22 m²
Schlafen
12.35 m²
Flur
2.90 m²
Terrasse
6.24 m²
Flur
5.36 m²
Aufzug
Wohnen
32.02 m²
Küche
6.87 m²
WC
2.61 m²
AR
4.36 m²
Bad
6.36 m²
Wohnen
29.77 m²
Flur
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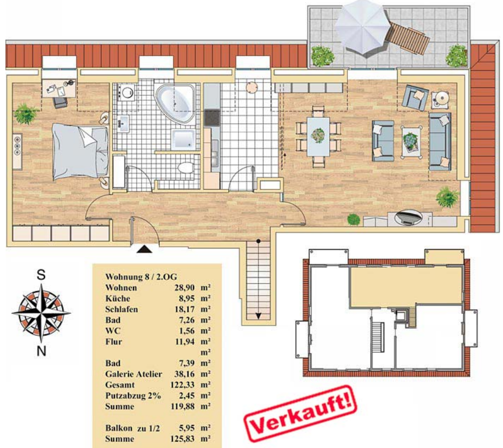
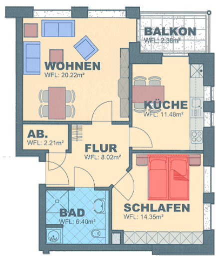
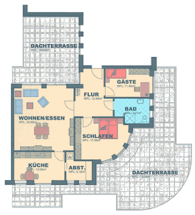
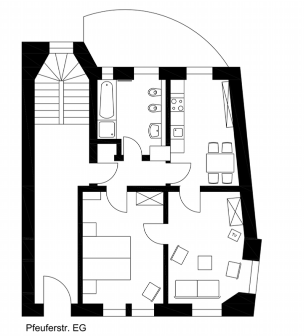
Gast
10.76 m²
Terrasse
4.80 m²
Küche
9.18 m²
Schlafen
13.53 m²

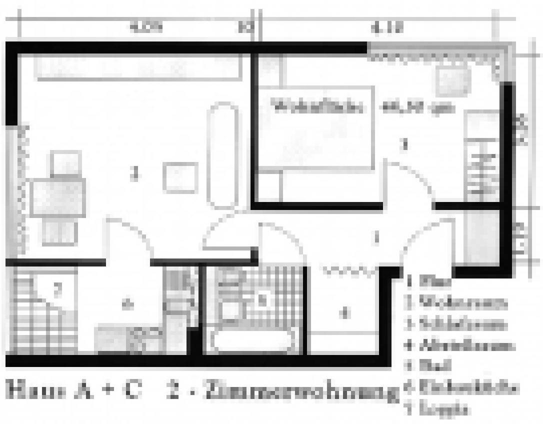

S
N
Wohnung 8 / 2.OG
Wohnen 28,90 m²
Küche 8,95 m²
Schlafen 18,17 m²
Bad 7,26 m²
WC 1,56 m²
Flur 11,94 m²
m²
Bad 7,39 m²
Galerie Atelier 38,16 m²
Gesamt 122,33 m²
Putzabzug 2% 2,45 m²
Summe 119,88 m²
Balkon zu 1/2 5,95 m²
Summe 125,83 m²
Verkauft!


Verkauft!
Wohnung 8 Variante
Wohnen 47,56
Küche 20,60
Schlafen 24,17
Bad 13,82
WC 3,36
Flur 12,97
Flur 4,28
Bad 7,65
Atelier 38,77
Gesamt 173,18
Putzabzug 2% 3,46
Summe 169,72
Balkon zu 1/2 4,38
Balkon zu 1/2 5,45
Summe 179,55
S
N









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Appendix C

RoCKIn@Home Environment Construction

□ This section is planned for inclusion in revision 2.0 □

Appendix D

Benchmarking Infrastructure for RoCKIn@Home

□ This section is planned for inclusion in revision 2.0 □

Appendix E

Library of Functionalities Deemed Useful for RoCKIn@Home

□ This section is planned for inclusion in revision 2.0 □

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