SRS

Multi-Role Shadow Robotic System for Independent Living

Small or medium scale focused research project (STREP)

SRS Scenario Revision

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Overview

This document presents the SRS consortium's strategy for bringing the workload associated with the SRS scenarios into a realistic scope and to focus development work more clearly on user needs and on the central SRS innovations.

In *section 1,* as a basis for the subsequent scenario assessment, a consolidated illustration showing the most relevant results of the SRS user requirement study carried out as part of work package 1 is presented.

In *section 2,* the SRS concept is explained briefly in one page in order to provide the relevant background for the scenario selection process (section 3) and the scenario descriptions (section 5).

Section 3 carries out the scenario assessment. It provides a reason-based process for scenario selection by setting choice criteria and evaluating how each possible scenario conforms to these criteria.

Section 4 explains the SRS phase concept of pre-deployment, deployment, and normal usage which is necessary to understand the subsequent scenario descriptions.

Section 5 describes the proposed scenarios to be implemented, highlighting for each step the related technological innovation in the right column.

1. SRS User Survey: Compacted Results on Demands

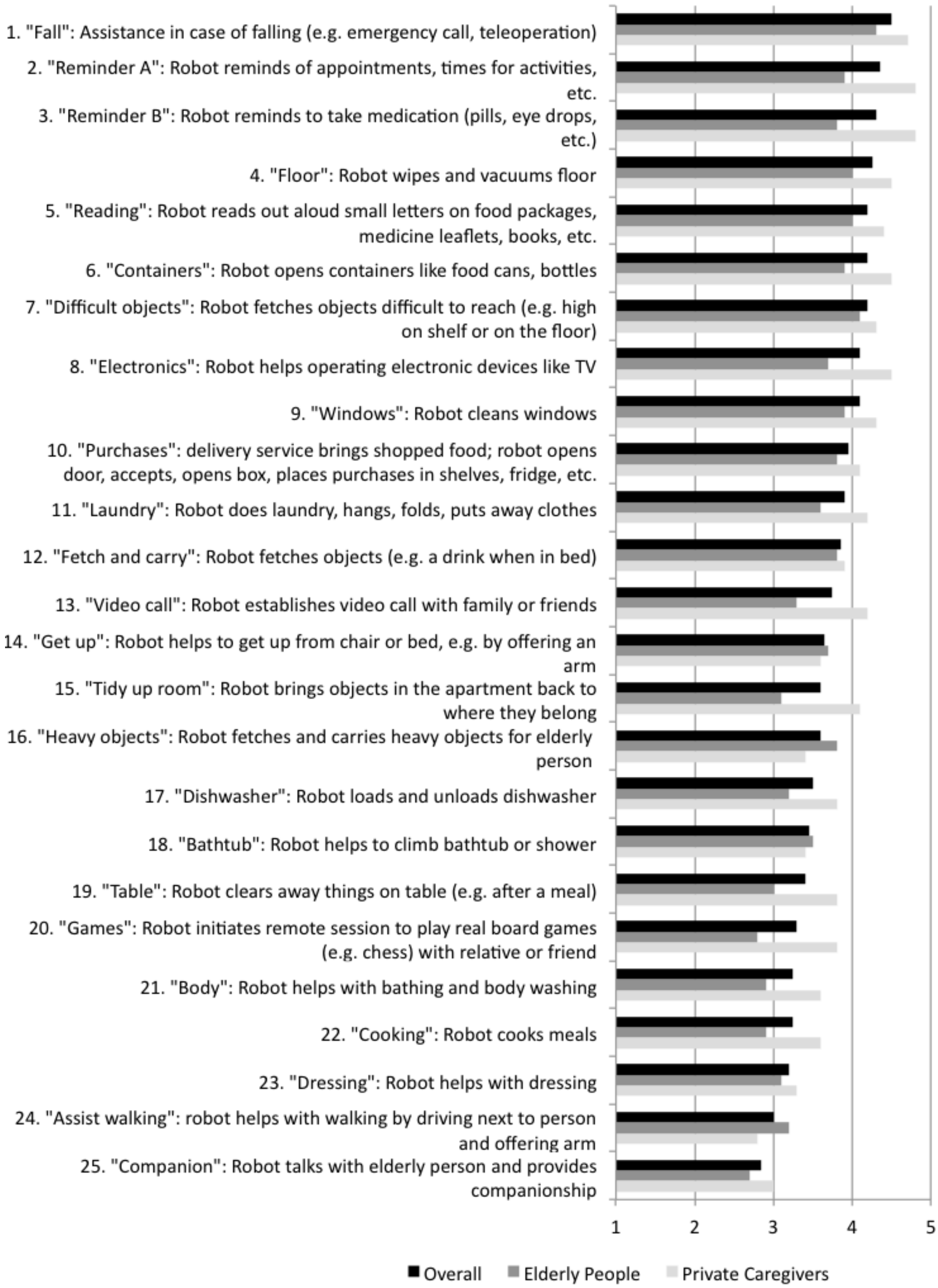


Figure 1: Responses by elderly and private caregivers on usefulness of tasks to be performed by a robot in their home (1: not useful at all; 5: very useful) sorted by overall usefulness (average value between elderly and private caregivers); result of SRS survey in work package 1 (83 respondents)

2. SRS Concept

With aging populations, many developed countries in Europe and worldwide are facing a situation where young people have to support an increasing number of old people. Personal service robots could be an interesting option for addressing the resulting bottleneck in healthcare, supporting independent living of elderly people in their familiar home environment. Personal service robots can be divided into two groups – able and unable to manipulate objects in the environment. Robots unable to manipulate are mainly focused on providing information. Apart from providing information, people would like robots to physically alter the world (Kemp et al., 2007). While such manipulation robots have been implemented successfully in controlled environments (mainly in factory settings), the heterogeneous and unstructured domestic environment poses substantial technological challenges in many areas of artificial intelligence. To address this problem, the research project "Multi-Role Shadow Robotic System for Independent Living" (SRS) aims to supplement robotic intelligence with human intelligence. When the robot encounters an unknown situation it cannot handle autonomously, a teleoperator is contacted. Through automated learning from the teleoperation and active teaching, human involvement decreases over time. This way, the robot's functional range gets extended and its behavior increasingly adapted to the local context.

There are three main user groups (for details see SRS user specification):

- Elderly person in the home
- Private caregiver (mainly sons and daughters of elderly but could also be friends, etc.)
- 24-hour teleassistance staff

In the long run, eldercare facilities could also benefit from using SRS but these are not primarily targeted. If the robot encounters a problem, first the private caregiver is called for remote assistance. If the private caregiver is unavailable or cannot solve the problem, the request is forwarded to a professional 24-hour teleassistance center. The assistance staff is specially trained and has more sophisticated means of controlling the robot. Teleoperation requests can also be initiated by any user.

There are various modes of operation in SRS:

1) **Autonomous mode:** This is the favored mode but it will often not be possible because it is technologically challenging. In this mode, the user issues a single high-level command such as "lay the table" and the robot executes all necessary actions autonomously.

2) **Semi-autonomous mode:** If autonomous task execution is not possible, semi-autonomous mode is the next best choice. In this mode, the teleoperator operates the robot but the robot assists as much as possible with its own intelligence. For example, the user could assist navigation by clicking on a position on a map and the robot navigates there autonomously. Or the user could assist manipulation by selecting an object in a video image and the robot grasps it autonomously. This mode takes away effort from the user, reduces operation errors, and reduces the network traffic, which is advantageous for teleoperation over real-word networks like DSL, Wireless LAN or 3G. There may be further variants of the semi-autonomous mode requiring more user input. These may be fallen back on in case the favored, most user-friendly semi-autonomous mode fails in the unstructured environment. One approach could be that the user places a 3D model of an object on the screen for SRS to find appropriate grasping points. Another approach could be that the user reduces the search space for object detection by specifying an area in the video image.

3) **Manual mode:** In this mode, the least robotic intelligence is used. The teleoperator directly controls the robot, e.g. the user may navigate the robot similar to driving a car and operate its arm and gripper directly with up/down commands. This mode requires the most user interaction effort and can be technologically challenging in real-world communication networks. This mode is used if all other semi-autonomous modes fail or are not feasible from the beginning. It is thus considered the last alternative.

SRS learns autonomously from semi-autonomous and manual teleoperation by deriving hypotheses on user intentions and transforming them into task knowledge. Also, users can teach the robot new objects, how to grasp objects, or action sequences. Due to this learning system, it may only be necessary to teleoperate SRS a few times for a given task and after an analysis of the usage pattern, SRS will execute this task autonomously.

The SRS framework is designed generically so it can be applied to a large number of robots. The concrete capabilities of SRS depend on the specific robot used. SRS is also not limited to a specific task like preparing food or helping a person to stand up. The SRS framework is useful in cases where technologically challenging autonomous task execution can be improved by the input of a human teleoperator. For example, if the robot's hardware capabilities allow, it could be used to fetch objects, to load and unload a dishwasher, to prepare food, or to clean windows. The demonstration scenario implemented during the SRS project was determined by considering user demands, the capabilities of the robot used as prototype, and suitability for demonstration of the SRS innovations.

3. Assessment of Scenarios for SRS Implementation

The overall goal of SRS is to provide an adaptable, manipulating robot not limited to a specific scenario. However, certain demonstration scenarios are chosen for implementation during the project runtime. They aim to serve as a proof of concept for the SRS innovations of semi-autonomous operation and learning. Each of these demonstration scenarios must fulfill all of the following requirements:

1) **Demanded by prospective users:** Those scenarios are prioritized which showed the highest demand by elderly and private caregivers (see Figure 1).
2) **Within SRS scope:** (a) The scenario will benefit from the SRS innovations of semi-autonomous teleoperation and learning. (b) A robot is required for the scenario. (c) The scenario can be accomplished in a standard private home with a robot only and no other changes to the home (e.g. installing sensors).
3) **Achievable workload:** Because basic hardware component development is not supported for the objective, only such scenarios can be considered that can be accomplished with the existing hardware of the SRS prototype or minor changes to it. Also, major AI development that does not relate to the SRS innovations of semi-autonomy and learning is not foreseen.

While user needs (1) are the general guideline for scenario selection, only such scenarios can be considered that are also in line with (2) and (3).

In addition, there is a fourth factor which is considered beneficial but not obligatory for selecting a scenario:

4) **Enabler capability:** Extensibility of a scenario to enable implementation of further scenarios is considered beneficial.

On the following pages, three tables consider possible SRS application scenarios for suitability according these three criteria:

- Table 1 considers the extensive list of scenarios that emerged from the SRS focus groups and were subsequently rated for usefulness in the SRS survey.
- Table 2 considers the previous list of scenarios that were selected in SRS before the first EC project review. Some of these are similar or identical to the scenarios in Table 1.
- Table 3 considers additional scenarios found in literature. This literature review considered 13 scientific papers on user needs for robotic and assistive solutions (for details on the papers considered, see Mast et al., 2010). Only papers with family caregivers and/or elderly people as participants and where participants rated scenarios for perceived usefulness were considered for inclusion in the table. Application scenarios were included if they were (a) not already covered by our own study or similar to our own preliminary scenarios, (b) not of low perceived usefulness by the criteria of the publication. In general, there was rather high consistency between the results of the SRS user survey and results found in literature, e.g. emergency scenarios being ranked highly, household assistance scenarios ranked higher than socially interactive scenarios, or scenarios related to a need for respite for family caregivers (e.g. Boissy et al., 2007). Therefore, not many additional scenarios from the literature could be identified.

Table 1. SRS implementation suitability of scenarios that emerged from the SRS user survey (cf. Fig. 1); user demand scale: very low (1 - 1.49), low (1.5 - 2.49), below average (2.5 - 2.99), above average (3 - 3.49), high (3.5 - 4.49), very high (4.5 - 5)

Scenario	User Demand	Within SRS Scope Benefits from semi-autonomy, learning, and teleoperation Requires a robot Requires no other technology in the home Requires no changes to user environment	Achievable Workload Technically achievable Requires no basic component development and no major hardware changes to existing prototype platform Requires no major software development outside of central SRS innovations	Enabler Capability Helps implementation of other scenarios (only scenarios within SRS scope are evaluated)
1. “Fall”: assistance in case of falling (e.g. emergency call, teleoperation)	High	To some degree. It depends on the implementation (see preliminary SRS scenarios 1.4 and 1.5 on page 9 which were both derived from this user demand)	To some degree. It depends on the implementation (see preliminary SRS scenarios 1.4 and 1.5 on page 9 which were both derived from this user demand)	To some degree. It depends on the implementation.
2. “Reminder A”: robot reminds of appointments, times for activities, etc.	High	No. See preliminary scenario 2.4 (page 12) for reasons.	No. See preliminary scenario 2.4 (page 12) for reasons.	
3. “Reminder B”: Robot reminds to take medication	High	No. See preliminary scenario 2.4 (page 12) for reasons.	No. See preliminary scenario 2.4 (page 12) for reasons.	
4. “Floor”: Robot wipes and vacuums floor	High	Yes, probably to some extent.	No. Prototype hardware is not able to accomplish this task.	No. Requires dedicated hardware limiting extensibility.
5. “Reading”: Robot reads aloud small letters on food packages, medicine leaflets, books, etc.	High	No. Robot not necessary for this scenario; could be done by e.g. smartphone. It is also questionable if this task could benefit from the central SRS innovations.	No. Development here would have to focus on OCR, speech synthesis, etc. which is not within the SRS innovations.	
6. “Containers”: Robot opens containers like food cans, bottles	High	Yes, to some extent. While it may not be absolutely necessary to have a robot perform this task (other machines are thinkable), it would make sense. There is also a chance that the task could benefit from semi-autonomy and learning.	No. Would require substantial hardware changes (e.g. a new gripper) and has high dexterity requirements that the prototype hardware is not capable of.	No. Requires dedicated hardware limiting extensibility.

7. “Difficult objects”: Robot fetches objects difficult to reach (e.g. high on shelf or on the floor)	High	Yes. A robot is required, it makes sense to do it or teach it remotely, and various types of learning (object grasping points, visual object recognition, object positions) are thinkable. Semi-autonomous navigation and grasping makes sense. No other technology in the home is required and no changes to the home.	Yes, probably to some degree. The lowest and highest possible grasping positions would have to be determined. So far, the robot has not been used in a way that its height limits would be reached. Additional development work might be necessary. Challenges would need to be identified but could result from maximum field of view of stereo vision and time-of-flight cameras, or a combined adjusting of camera positions and body posture. Installing a camera in the gripper could be an option.	Yes. But can be derived from fetch and carry scenario.
8. “Electronics”: Robot helps operating electronic devices like TV	High	Yes, potentially to some extent.	Prototype hardware does not have the precision to operate small buttons precisely or to pull or plug in cables. Also, there is only one arm but this scenario would often require two arms, e.g. when moving a Hi-Fi system to plug in new cables. However, a scaled down version could be feasible where no manipulation is used but only the robot’s cameras and the elderly person carries out the physical actions.	Yes. But can be derived from fetch and carry scenario.
9. “Windows”: Robot cleans windows.	High	Yes, potentially to some extent.	No. Prototype hardware cannot perform the necessary movements and reach high enough.	No. Requires dedicated hardware limiting extensibility.
10. “Purchases”: delivery service brings shopped food; robot opens door, accepts, opens box, places purchases on shelf, fridge, etc.	High	Yes. See preliminary SRS scenario 2.5 “shopping management” on page 12 for details.	No. See preliminary SRS scenario 2.5 “shopping management” on page 12 for details. It is an ongoing research topic in research challenge 2. Technology is not available.	Yes. But can be derived from fetch and carry scenario.
11. “Laundry”: Robot does laundry, hangs, folds, puts away clothes	High	Yes.	No. Prototype object recognition does not work for objects that change their shape and appearance like a towel. Also grasping of such objects is not feasible.	Yes. But can be derived from fetch and carry scenario.
12. “Fetch and carry”: Robot fetches objects (e.g. a drink when in bed)	High	Yes. A robot is required, it makes sense to do it or teach it remotely, and various types of learning (object grasping points, visual object recognition, object positions) are thinkable. Semi-autonomous navigation and grasping makes sense. No other technology in the home is required and no changes to the home.	Yes. Can be done with one arm. Many useful objects can be recognized and grasped. Also, this scenario would enable many other scenarios in the present table which are a variation of fetch and carry.	Yes. The technology developed for the scenario can be reused in other manipulation related scenarios.

13. “Video call”: Robot establishes video call with family and friends	High	Not directly but the consortium sees this as a supportive scenar-io, i.e. video communication is necessary because the elderly person needs to know what is going on when the teleoperator operates the robot. Communica-tion will be necessary or at least useful for many other scenarios (e.g. the elderly person needs to tell the teleoperator which ob-jects to fetch for the fetch and carry scenario) and is therefore considered essential.	Yes.	Yes. The technol-ogy developed for the scenario can be reused in other scenarios related to communication and remote pres-ence.
14. “Get up”: Robot helps to get up from chair or bed, e.g. by offering an arm	High	Yes, to some degree. See pre-liminary SRS scenario 2.2 “Stand up assistance” in Table 2 for details (page 11).	Uncertain. See preliminary SRS scenario 2.2 “Stand up assis-tance” for details (page 11).	Yes. The technol-ogy can be re-used for getting out of bath tub, etc.
15. “Tidy up room”: Robot brings objects in the apartment back to where they belong	High	Yes. This is a variation of the fetch-carry scenario (12). See scenario 12 for scope assess-ment.	Yes. Bringing an object back to its standard location is an exten-sion of the fetch-and-carry sce-nario that can be done without much extra development effort. Bringing all detected objects in a scene or even apartment back to their standard locations should also be achievable.	Yes. But can be derived from fetch and carry scenar-io.
16. “Heavy ob-jects”: Robot fetches and carries heavy objects for the elderly person	High	Yes. This is a variation of the fetch-carry scenario (12). See scenario 12 for scope assess-ment.	Yes. Care-O-bot can lift up to 5 kg which is heavy enough to be problematic for an elderly per-son. However there are some limitations regarding the tactile sensors which would have to be determined. They might imply a reduced maximum weight.	Yes. But can be derived from fetch and carry scenar-io.
17. “Dishwasher”: Robot loads and unloads dish-washer	Higher than neutral	Yes.	No. Prototype hardware not capable of recognizing and grasping the necessary objects (e.g., objects too small and not enough space between them)	Yes. But can be derived from fetch and carry scenar-io.
18. “Bathtub”: Robot helps to climb bathtub or shower	Higher than neutral	Yes, to some degree the task could benefit from semi-autonomous operation (e.g. if elderly person is equipped with a teleoperation device or private caregiver operates). It is however questionable how much SRS could learn from the interaction in this task as it mostly consists of navigating the robot.	No. Prototype hardware does not allow direct contact with people due to safety. A safety frame-work that would allow this is out of scope. Also, space restrictions due to small bathroom and con-tact with water are problematic.	Yes. But can be derived from get up assistance scenario (14).

19. “Table”: Robot clears away things on table (e.g. after a meal)	Higher than neutral	Yes. This is a variation of the fetch-carry scenario (12). See scenario 12 for scope assessment. It represents a sequence of fetch-carry actions.	No. Typical objects on the table are: plate, fork, knife, spoon, glass, bottle, food in various containers or without containers (e.g. bread). Only a fraction of these could be grasped with the prototype hardware so that the scenario could not be sufficiently completed.	Yes. But can be derived from fetch and carry scenario.
20. “Games”: Robot initiates remote session to play real board games (e.g. chess) with relative or friend	Higher than neutral	No. Scenario does not require a robot and can be done with standard video conferencing systems. Also, it would not benefit from the SRS innovations.	No. Objects of typical board games too small to grasp.	
21. “Body”: Robot helps with bathing and body washing	Higher than neutral	Yes, potentially to some degree.	No. Robot prototype hardware not suitable for body contact. Movements too difficult. Contact with water not possible.	Yes. But it is far outside of present state of the art.
22. “Cooking”: Robot cooks meals	Higher than neutral	Yes. This is a variation of the fetch-carry scenario (12). See scenario 12 for scope assessment. It represents a sequence of fetch-carry actions.	Yes, to some degree. While cooking is not feasible (e.g. unpacking a pizza, opening containers), heating and serving of prepared meals in microwave or oven is.	Yes, if it does not use special grippers. Otherwise no.
23. “Dressing”: Robot helps with dressing	Higher than neutral	Yes, potentially to some degree.	No. Dexterity and AI requirements are too high. Prototype hardware not suitable for body contact.	Yes. But it is far outside of present state of the art.
24. “Assist walking”: Robot helps with walking by driving next to person and offering arm	Lower than neutral	No, probably not substantially. The task seems more suitable for fully autonomous robots or manual teleoperation and not so much for semi-autonomous operation. Also the robot could not learn substantially from the interaction on this task.	No. Adaptation and coordination of robot movement with the person and direct contact of person with robot is not achievable. No handles can be attached to the robot.	
25. “Companion”: Robot talks with elderly person and provides companionship	Lower than neutral	No. While a robot could make sense, the scenario does not benefit from the SRS innovations.	No. For example, very high requirements in natural language processing.	

Table 2. SRS implementation suitability of preliminary SRS scenarios (as in SRS deliverable 1.1); user demand scale: very low (1 - 1.49), low (1.5 - 2.49), below average (2.5 - 2.99), above average (3 - 3.49), high (3.5 - 4.49), very high (4.5 - 5)

Scenario	**User Demand**	**Within SRS Scope** Benefits from semi-autonomy, learning, and teleoperation Requires a robot Requires no other technology in the home Requires no changes to user environment	**Achievable Workload** Technically achievable Requires no basic component development and no major hardware changes to existing prototype platform Requires no major software development outside of central SRS innovations	**Enabler Capability** Helps implementation of other scenarios (only scenarios within SRS scope are evaluated)
Preliminary SRS scenario 1.1: “Fetch and carry” (= scenario 12, Table 1)	High (scenario 12, Table 1)	Yes. A robot is required, it makes sense to do it or teach it remotely, and various types of learning (object grasping points, visual object recognition, object positions) are thinkable. Semi-autonomous navigation and grasping makes sense. No other technology in the home is required and no changes to the home.	Yes. Can be done with one arm. Many useful objects can be recognized and grasped. Also, this scenario would enable many other scenarios in the present table which are a variation of fetch and carry.	Yes. The technology developed for the scenario can be reused in other manipulation related scenarios.
Preliminary SRS scenario 1.2: “Setting table” (derived from scenario 19, Table 1)	Unknown (user study only asked about scenario 19: clearing table (higher than neutral)	Yes. This is a variation of the fetch-carry scenario (12). See scenario 12, Table 1 for scope assessment. It represents a sequence of fetch-carry actions.	No. Typical objects on the table are: plate, fork, knife, spoon, glass, bottle, food in various containers or without containers (e.g. bread). Only a fraction of these could be grasped with the prototype hardware so that the scenario could not be sufficiently completed.	Yes. But can be derived from fetch and carry scenario.
Preliminary SRS scenario 1.3: “Heat and serve meal” (derived from scenario 22, Table 1)	Higher than neutral (scenario 22, Table 1)	Yes. This is a variation of the fetch-carry scenario (12). See scenario 12, Table 1 for scope assessment. It represents a sequence of fetch-carry actions.	Yes, to some degree. While cooking is not feasible (e.g. unpacking a pizza, opening containers), heating and serving of prepared meals in microwave or oven is.	Yes, if it does not use special grippers. Otherwise no.
Preliminary SRS scenario 1.4: “Night monitoring without smart home” (derived from scenario 1, Table 1)	High (scenario 1, Table 1)	Yes. This scenario should rather be called “emergency” since no actual monitoring is involved. While it does not directly address the learning innovation, semi-autonomous operation makes some sense, e.g. when opening the door or bringing medication to the fallen person on the floor.	Yes. One challenge is how SRS would find the person on the floor. Developing such technology would be out of scope but a workaround could be manual localisation. Also, the person would not be able to reach as high as the height of the Care-O-bot tray to fetch an interaction device as currently outlined in D1.1. This aspect needs to be changed.	Yes, the “emergency” scenario can be extended to other security related tasks like prevention of break-in, checking if the windows are properly closed, etc.

Preliminary SRS scenario 1.5: “Night monitoring with smart home” (derived from scenario 1, Table 1)	High (scenario 1, Table 1)	No. This would require a smart home environment and cannot be done in a normal home. Smart homes are rare today and their capabilities widely differ. It cannot be assumed that a smart home would offer person localization and fall detection so this would have to be developed by the SRS team. Also, having to buy a smart home in addition to SRS would be a substantial economic obstacle. The scenario would not substantially benefit from learning. Semi-autonomous operation makes sense only to some degree, e.g. when opening the door. A robot would not be required for realizing the important aspects in the scenario (emergency call and video conference could be done with a smartphone and fall detection with a smart home). A robot would be useful for opening the door in this scenario but it could also be done by a smart home.	No. Significant workload is associated that is outside of the central SRS innovations: e.g. integration with smart home sensors and development of a fall detection algorithm for the smart home.	
Preliminary SRS scenario 2.1: “Day monitoring” (derived from scenarios 1 and 13, Table 1)	Unknown but derived from scenarios 1 and 13, Table 1 (high)	Yes. Task does not benefit from learning and only potentially to a lesser extent from semi-autonomy. The task is essentially a video call plus semi-autonomous navigation in the apartment. It would not necessarily require a robot (video call could be done with smartphone and checking the apartment with home cameras). However, since video calling has to be implemented anyway (see scenario 13, Table 1, for reasons) and semi-autonomous navigation too, this task can be covered with no additional development effort.	Yes. Authorization of the teleoperation request may require a device for the elderly person. Automatic localisation of the elderly person could be useful in the future but avoided initially.	Yes. Similar to scenario 1.4.

Preliminary SRS scenario 2.2: “Stand up assistance” (derived from scenario 14, Table 1)	High (scenario 14, Table 1)	This task could be done with a combination of semi-autonomous and manual modes (remote user controls robot, navigates by map, finds person, adjusts robot orientation so elderly person can reach handle, then drives robot forward). However, it is unclear what SRS could learn in this interaction for subsequent autonomous task execution. If SRS was to do this autonomously after a learning process, technology to localize a person and algorithms for detecting a person would have to be used so the robot can approach the person and turn around so the person can reach the handle (find room, position in room, orientation of person). This would require moderate changes to the home (e.g. installing 3 Wi-Fi base stations for localization by signal strength).	Uncertain. Offering an arm is not feasible due to the safety concept of Care-O-bot not allowing humans within the vicinity of the arm. Attaching a handle to the robot is not feasible due to the necessary free space for manipulator and tray movement. However, it might be possible to attach a strap which a seated elderly person could grasp to be pulled up. It needs to be determined if this scenario would be feasible and useful. Developing person localization technology for autonomous execution after learning would be out of scope but there may be workarounds. If the elderly person is equipped with a teleoperation device or we assume that this task can only be done with help of the remote caregivers, the scenario becomes more feasible because the teleoperator could steer the robot to the right position. Extending this scenario to walking assistance would involve adapting the robot speed to a person’s walking speed. This is not within the scope of SRS.	Yes. The technology can be reused for getting out of bath tub, etc.
Preliminary SRS scenario 2.3: “Difficult objects” (= scenario 7, Table 1)	High (scenario 7, Table 1)	Yes. A robot is required, it makes sense to do it or teach it remotely, and various types of learning (object grasping points, visual object recognition, object positions) are thinkable. Semi-autonomous navigation and grasping makes sense. No other technology in the home is required and no changes to the home.	Yes, probably to some degree. The lowest and highest possible grasping positions would have to be determined. So far, the robot has not been used in a way that its height limits would be reached. Additional development work might be necessary. Challenges would need to be identified but could result from maximum field of view of stereo vision and time-of-flight cameras, or a combined adjusting of camera positions and body posture. Installing a camera in the gripper could be an option.	Yes. But can be derived from fetch and carry scenario.

Preliminary SRS scenario 2.4: "Reminder" (derived from scenarios 2 and 3, Table 1)	High (scenarios 2 and 3, Table 1)	No. This is an entirely autonomous task. It does not at all benefit from any of the SRS innovations. Also, a robot would not be required. Neither is tele-operation. Reminders can be implemented by many other means such as watches.	No. It would require substantial additional workload such as implementing a calendar UI for configuring and editing of alarms (e.g. daily, weekly) and user rights because not all private appointments should be visible to all users (elderly, family, teleassistance centre). In case this scenario was implemented as described in D1.1, it would also require connecting to the supermarket's product system to retrieve product information, a payment and ordering system, a product recommendation system, etc.	
Preliminary SRS scenario 2.5: "Shopping management" (= scenario 10, Table 1)	High (scenario 10, Table 1)	Yes, potentially in case of robots with very advanced capabilities in environment perception and grasping dexterity this could make sense and it could also benefit from learning and tele-operation. For such a robot it might also be possible to not alter the environment.	No. The scenario cannot be realized to an acceptable degree (i.e., a delivery service delivers a closed package or bag of any shape with any kind of product inside and SRS will accomplish the task autonomously after a learning process). Small objects cannot be grasped and there may be problems recognizing independent objects in a box when there are many other objects around it. Also, grasping an object autonomously or in semi-autonomous mode may be problematic if many other objects are in the vicinity and when seen from above only. It would require a special type of delivery packaging for the robot to be able to accomplish the task. Overall, it seems that the utility for users from a drastically scaled-down version of this scenario would not be sufficient. To some extent this scenario is also covered by the "difficult objects" scenario.	Yes. But can be derived from fetch and carry scenario. Some ongoing research projects under research challenge 2 are dedicated to the grasping problems associated with this scenario. If a solution can be found in those projects, the scenario can be easily built upon the "fetch and carry" scenario.

Table 3. SRS implementation suitability of additional scenarios found in literature

Scenario	**User Demand**	**Within SRS Scope** Benefits from semi-autonomy, learning, and teleoperation Requires a robot Requires no other technology in the home Requires no changes to user environment	**Achievable Workload** Technically achievable Requires no basic component development and no major hardware changes to existing prototype platform Requires no major software development outside of central SRS innovations	**Enabler Capability** Helps implementation of other scenarios (only scenarios within SRS scope are evaluated)
Scenario A from literature review: "Robot warning about dangers: break-in, fire, carbon monoxide, water damage" (Harmo et al., 2005)	3.8 out of 5 (highest rating among robotic scenarios)	No. An extensive amount of sensors would be required throughout the apartment. A robot would not be required. This is a typical smart home scenario with focus on monitoring. It is also unlikely that this scenario would benefit substantially from the SRS learning capabilities. However, a scaled down version would come close to scenario 1.4 in Table 2. Therefore, no need to be considered separately.	No.	
Scenario B from literature review: "Remotely monitor loss of autonomy and the patient's abilities in everyday life" (Boissy et al., 2007)	No rating (qualitative study)	No. An extensive amount of sensors would be required throughout the apartment. A robot would not be required. This is a typical smart home scenario with focus on monitoring. It is also unlikely that this scenario would benefit substantially from the SRS learning capabilities.	No.	
Scenario C from literature review: Supervision of patients after they left hospital, e.g. remote visits by healthcare professionals and doctors, follow-up with the family, monitoring of injuries (Boissy et al., 2007; Faucounau et al., 2009)	No rating (qualitative study) in one study, 80% "yes" responses in other study	Yes. This is another application case of the preliminary SRS scenario 2.1 "day monitoring" (see page 10) and also related to scenario 13 "video call" (see page 7)	Yes.	Yes.
Scenario D from literature review: "Cognitive stimulation program" (Faucounau et al., 2009)	93.3% "yes" responses	No. This is the topic of dedicated research projects and requires very different approaches than a semi-autonomous teleoperated robot.	n/a	

Scenario E from literature review: "Automatic help call" (Faucounau et al., 2009)	93.3% "yes" responses	To some degree (no automatic help call but assistance during a manual help call). Robotic assistance in an emergency call would have to be largely be under human control by the teleoperator (therefore it would not benefit from learning). Applications could range from opening a door to bringing medicine or checking the health status.	A scaled-down version without automatic calling (which would require sophisticated sensors in the home) could be a variation of the fetch-carry scenario combined with video communication.	Yes. But can be derived from fetch and carry scenario.
Scenario F from literature review: "Abnormal positions detection" (Faucounau et al., 2009)	93.3% "yes" responses	No. Detection and interpretation of body postures (e.g. in case of a fall) would be a dedicated research project of its own. Also, it seems more suitable for smart homes than a robot.	No.	

Conclusion

The scenarios in the tables were derived from demands and everyday life difficulties of potential future users (elderly and family caregivers). The assessment leads to the conclusion that 21 out of the 31 scenarios (excluding preliminary SRS scenarios as they are near-duplicates of surveyed scenarios) would be within the SRS concept. This shows the wide reach and high future potential of the SRS concept. When looking at feasibility for implementation with the available robotic platform, 11 scenarios remain which could be achievable or partially achievable:

- 1. "Fall": assistance in case of falling (e.g. emergency call, teleoperation)
- 7. "Difficult objects": Robot fetches objects difficult to reach (e.g. high on shelf or on the floor)
- 8. "Electronics": Robot helps operating electronic devices like TV
- 12. "Fetch and carry": Robot fetches objects (e.g. a drink when in bed)
- 13. "Video call": Robot establishes video call with family and friends
- 14. "Get up": Robot helps to get up from chair or bed, e.g. by offering an arm
- 15. "Tidy up room": Robot brings objects in the apartment back to where they belong
- 16. "Heavy objects": Robot fetches and carries heavy objects for the elderly person
- 22. "Cooking": Robot cooks meals
- Scenario C from literature review: Supervision of patients after they left hospital, e.g. remote visits by healthcare professionals and doc-tors, follow-up with the family, monitoring of injuries (Boissy et al., 2007; Faucounau et al., 2009)
- Scenario E from literature review: "Automatic help call" (Faucounau et al., 2009)

In order to reduce the development workload in line with the European Commission reviewers' recommendations and to come to a more realistic selection of scenarios, the original list of scenarios to be implemented is changed from what was described in Deliverable 1.1. The goal behind the new selection was to address user demands by covering many highly rated scenarios while at the same time ensuring that the development work remains realistic and that the chosen scenarios benefit from the central SRS innovations.

The scenario assessment revealed that many of the scenarios within scope of SRS and feasible with the robotic demonstrator either build upon the fetch and carry scenario or are largely covered by it. Since fetch and carry was also rated highly by the prospective users, it is therefore defined as the main scenario of the SRS project that other scenarios will build upon. This way, a high number of user needs can be addressed. Implementation of fetch and carry will be the first priority.

The scenario revision leads to the following new list of scenarios which will be implemented in the priority order listed.

First Priority Scenarios (Base Scenarios)

The following two scenarios are key to achieving a large number of further scenarios feasible with the robotic demonstration platform. They ensure that the base functionality of a manipulating semi-autonomous teleoperable robot like SRS is available. This base functionality is then taken a step further in subsequent second-priority scenarios. The functionality is varied and will be subject to learning algorithms for increasing the spectrum of robotic applications and adapting the robot to the local context.

1. **Fetch and carry:** By implementing this scenario SRS's semi-autonomous navigation and object manipulation can be demonstrated. In a wider sense, this scenario can be considered semi-autonomous manipulation in general, i.e. also including associated manipulation tasks like opening a fridge or door. Covered by this scenario and the subsequent "video communication" scenario with no further development effort is the former "day monitoring" scenario (Deliverable 1.1) as it only involved a call and navigation in the apartment.

2. **Video communication:** This can be regarded an independent scenario but is also necessary in order to realize other scenarios because communication is necessary during manipulation tasks. The functionality includes face-to-face communication through an interaction device as well as availability of the robot's own cameras. Video communication can be used for checking the health status of the elderly person remotely by the family members or for telesurveillance or remote doctor visits. It could also be used as a scaled-down version of scenario 8 (robot helps operating electronic devices like TV or phone). For example, the elderly person could direct a family member to a room so the robot's camera sees the TV screen's content and the elderly person could hold the TV remote in the camera's field of view. The remote operator could then tell the elderly person which buttons to press to solve the problem. Or cable connections could be checked or the status of a telephone display. In other scenarios, video communication will be a necessary supporting scenario to converse with the elderly person during teleoperation because the elderly person needs to know what is happening (e.g. why does the robot move around in the apartment now) and because the elderly person needs to give advice (e.g. where to find a certain object).

Second Priority Scenarios

Once the base scenarios are implemented (first priority), the focus will turn to the following scenarios which can be realized with moderate modifications:

1. **Emergency assistance:** The elderly person places an emergency call (e.g. in case of a fall) using a device carried on the body and a teleoperator uses video calling and robot navigation, e.g. to assess the health status and type of injury, to calm down the elderly person, or to make the elderly person keep talking in case of an instable health condition. The operator can also use fetch-carry, e.g. to bring medicine. Initially, the position of the elderly person will be determined either by the remote operator searching in the apartment using the robot or by the elderly person indicating the current position, e.g. through video or audio calling or entering it in a UI. In the future, it could be extended to use localization through wireless LAN signal strength measurement as the development (integration of localization technology is out of the scope of the SRS project and subject to other research projects).

2. **Prepare food:** This scenario represents an action sequence of consecutive fetching tasks that remains stable across occasions (e.g. putting away shopped goods from a box varies with different objects on each occasion and is therefore more challenging). It is necessary to implement this scenario in order to demonstrate SRS's ability to learn fetch-carry procedures (action sequences) autonomously. This is also the reason why its implementation priority is higher although it was ranked lower in the user survey than some of the subsequent scenarios.

3. **Fetch and carry difficult objects:** For elderly people, objects low on the ground and high up are often difficult to reach (approx. lower than 0.5 m or higher than 1.50 m). Also, heavy objects can be problematic (approx. >3kg). Reaching and carrying such objects is a key benefit of a manipulating in-home robot. This scenario is therefore a suitable showcase for SRS. The prototype hardware has certain limitations regarding maximum weight and lowest and highest object that can be reached. These limitations have to be determined in detail throughout the project as the robotic platform has so far not been used that way. The goal is to implement and demonstrate at least one of the three applications (low, high, heavy).

Third Priority Scenarios (Optional)

The following scenarios could be feasible but will be implemented only if time allows and are treated with lower priority:

1. **Tidy up:** For each object, a user-specifiable standard location can be set and a list of previous object locations (where the object was fetched or placed before) is kept by the system. The scenario is realized by two functions: (1) The user can choose to have a specific object returned to a previous location. (2) SRS can scan a scene and autonomously return all recognized objects to their standard location.
2. **Stand up assistance:** It is not possible to attach handles to Care-O-bot due to the necessary free space for manipulator and tray movement. However, it might be possible to attach a strap which a seated elderly person could grasp to be pulled up. It needs to be determined if this scenario would be feasible. Challenges are e.g. the navigation precision during remote operator control, the grip strength of COB's wheels on various types of floors, or the reachability of the strap in a seated position. If implementation is feasible, this scenario would not benefit from learning. It would always rely on a teleoperator. Also, this scenario would only assist to stand up but not assist when the elderly person wants to walk around the apartment because that would require autonomous adaptation of the robot's movement speed to a person's walking speed. From a technical viewpoint, this scenario would only involve semi-autonomous navigation and manual navigation. Nevertheless, it would allow the robotic system to help with mobility issues not only indirectly (fetch and carry based scenarios), but also in direct interaction with the robot.

Scenarios no longer pursued

The following preliminary scenarios as in D1.1 are no longer pursued:

- "Reminder function" (2.2) for reasons listed in Table 2
- "Night monitoring with smart home" (1.5) for reasons listed in Table 2
- "Setting table" (1.2) for reasons listed in Table 2 and because a procedural scenario is already included with the "prepare food" scenario. Also, user demand is not known for this scenario because the user study only surveyed clearing away objects on a table.
- "Shopping management" (2.5) for reasons listed in Table 2. Only a scaled-down version could be implemented which would be of questionable advantage for the user. Also, a procedural scenario for demonstrating SRS's procedure learning ability is already included with the "prepare food" scenario.

4. Phases of SRS System Usage

To understand the SRS demonstration scenarios that will be described subsequently, it is necessary to distinguish three phases. Pre-deployment (1) is the phase before the robot is deployed to an individual home. This phase specifies the knowledge SRS comes equipped with when it leaves the factory. This knowledge is general and not adapted to the local context. The deployment phase (2) is the “first day” of the robot in the individual home where it is to be deployed. In the deployment phase, the robot gets taught basic information like important objects expected to be needed during normal usage and a map of the apartment. This information is required later for autonomous and semi-autonomous navigation and manipulation. Finally, the normal usage phase (3) is the phase after deployment when the robot is used in the home of the elderly person. This is the main phase focused on for SRS demonstration and evaluation.

Pre-Deployment Phase

Every SRS system comes equipped with certain knowledge about its application scenarios before it is deployed into a specific local environment. In particular SRS is shipped with:

- **Library of action sequences:** This library contains action sequences and relevant parameters for all application scenarios SRS comes equipped with and can be extended with further action sequences after deployment. If SRS was to be used for preparing food, it would know the basic procedure for this, e.g. first the fridge or locker needs to be opened to fetch a food package, then it might have to be opened in some cases, the oven might need to be pre-heated next, etc.
- **Library of objects:** This library is just a data structure and all entries can be considered placeholders that will be filled with real object data (textures, shapes, names of specific objects) during the deployment and normal use phases. However, categories and object names for all of SRS’s expected application scenarios can be pre-filled. For example, if SRS was to be used for cooking and baking, the library would contain certain moveable objects (e.g. pot, jug), certain fixed facilities (e.g. tap to fetch water, kitchen sink for waste water, oven which has buttons for on/off and setting the temperature, stove with certain buttons), and certain surfaces for placing things (table, kitchen worktop). The objects have features. E.g. moveable objects like a cup have a standard position in the apartment and several additional positions where they were previously placed or fetched by the user (this is e.g. necessary for the tidy up task where the robot brings back an object to a previous position).
- **3D object model library:** for “mixed reality 3d model” approach to object manipulation. This library contains the shapes of typical objects needed for the application scenarios (e.g. cup, bottle, etc.). This library will be used for deforming objects over the live video as an approach for semi-autonomous grasping. The library could be joined with the library of “object names and features”.

Deployment Phase

On the first day of SRS in a new apartment, an initial setup routine is run. The robot gets taught the basics of its new environment. The user interface could be a wizard-style interface asking the user to help the robot acquiring the requested information. The user interface for this phase will not be developed during the runtime of the SRS project as the project focuses on the normal usage phase. SRS acquires the following information:

- By the SRS deployment personnel a 2D map of the apartment is supplied which will be shown in the user interface and used for navigation and information purposes during normal usage.
- By visiting every room in the apartment SRS builds a 3D map for future autonomous and semi-autonomous navigation (navigable area can bee seen on this map and it can be overlaid in the UI with the 2D map)
- SRS learns to recognize all door handles so it can open doors during normal usage.
- SRS learns important objects necessary to execute the application scenarios it ships with. E.g. in the case of cooking it would learn the position and visual features of one or several pans, the position of the fridge and the visual features of its handle, position and visual features of oven (including buttons for turning it on and off or setting the temperature), etc.
- SRS learns the positions of fixed (e.g. fridge) and standard positions of movable (e.g. sauce pan) objects necessary for executing its main scenarios
- Adapt the standard action sequences if necessary

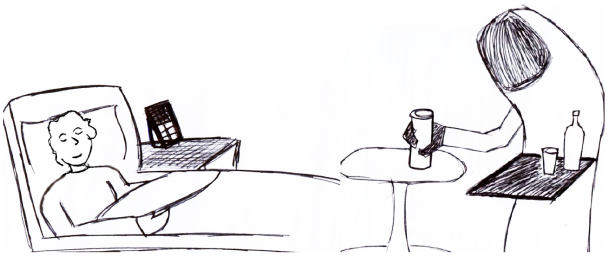
Normal Usage Phase (Post-Deployment)

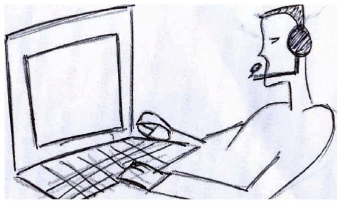
This phase is the everyday operation and interaction with the robot in its specific home environment. See the following section for a description of the functionality provided during normal use.

5. SRS Demonstration Scenarios

The subsequent scenario descriptions represent goals for SRS development. The final demonstration of the SRS system will take place in a standard home or simulated standard home (no smart home, no special objects and changes like barcodes or RFID tags on objects). The starting point of the demonstration will be <u>after</u> deployment, i.e. the deployment phase will assumed to be finished. It is assumed that SRS has undergone the standard process for deployment and was taught important objects for its applications scenarios, a room plan for map-based navigation, etc. This is because no user interface will be developed for the deployment phase for now within SRS to keep development work in a realistic scope. The focus is on everyday use where new objects and action sequences are also still learned.

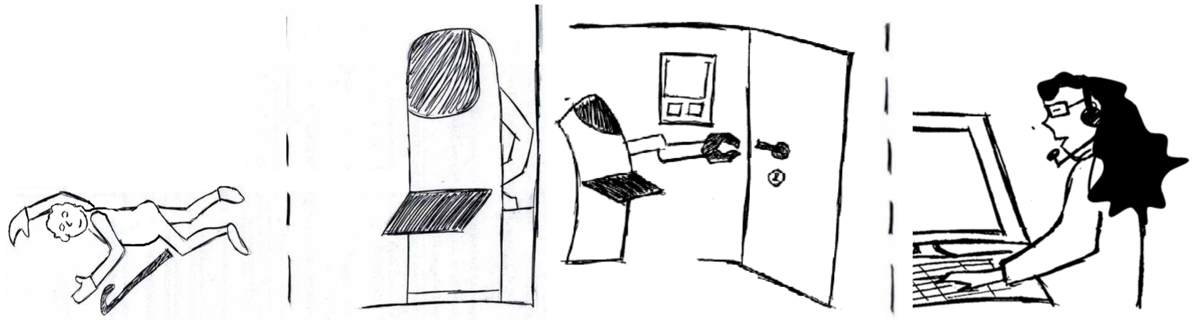
1. Fetch and Carry + Video Call (Base Scenarios)





Scenario	**Technological Background** Major SRS innovations in red
Elisabeth Baker (84) lies at home in bed due to a cold. To check if everything is alright, her son Martin initiates a request for a remote session from his workplace. Elisabeth accepts the request on her portable communication device and a video communication is established. Martin asks if he could do anything for his mother.	Authorization of local user for remote session Video call functionality
Elisabeth answers that she feels a bit thirsty. Martin therefore wants to fetch a bottle of water and a glass from the kitchen. He uses a room plan to specify that SRS should go to the kitchen.	Semi-autonomous navigation by room plan
Having arrived in the kitchen, Martin switches to manual navigation mode to drive SRS to the specific place where the bottle and glass are located.	Manual navigation
SRS indicates by a rectangle that it recognizes the bottle. This bottle has previously been taught to SRS. However, the glass is not indicated to be recognized. It is a new glass that SRS has not been taught before.	Recognition of previously taught objects and user-friendly indication in the user interface
Martin clicks on the bottle and SRS puts it on the tray.	Grasping of recognized objects
Because the glass is not recognized, Martin switches to user-assisted grasping mode. From a library of 3D object models, Martin selects from the category “glasses” a cylinder-shaped glass similar to the one to be grasped. He adjusts its shape (height, width, position) so that it matches what he sees on the video picture. He then clicks “GO” and SRS grasps the object and puts it next to the glass on its tray.	User-assisted 3D object model approach for teaching the robot grasping of objects
Having finished the grasping, SRS asks Martin if this object should be saved for future grasping. SRS suggests to save it in the category “glasses”. Martin confirms and assigns a name: “long IKEA glass”.	Teaching of new objects remotely
Martin directs SRS back to the bedroom of his mother. While SRS drives back, Elisabeth asks Martin what he is doing and why it takes so long. Martin speaks with his mother telling her that SRS will be there soon.	Simultaneous video calling and teleoperation
Martin and his mother agree to end the conversation and speak again tomorrow. After ending the call, SRS autonomously drives back to its charging place.	
Next day: Martin calls again and again wants to get his mother a glass and bottle. Today, Martin can just click on the glass to grasp it.	Demonstration of SRS handling the object taught
However, today grasping the bottle fails even though this is an object taught to SRS. There are many other objects in the scene. Martin uses the “reduce search space” approach and SRS successfully grasps the bottle.	“Reduce search space” approach to enhance chance for successful object recognition

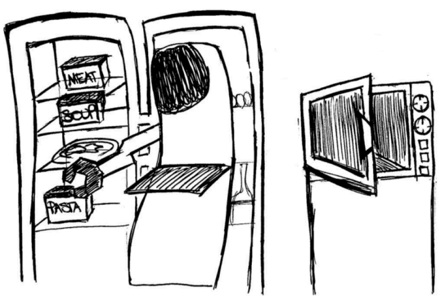
2. Emergency Assistance

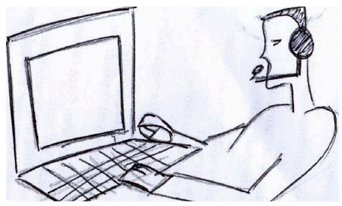


Scenario	**Technological Background** Major SRS innovations in red
Elisabeth Baker (84) watches TV. In the commercial break, she wants to go to the bathroom but falls on her way, unable to get up again.	
With a device she always carries attached to her belt, Elisabeth presses a button “emergency”.	Implementation of an emergency device
Right away, a call is placed to her son and daughter as well as to the 24-hour teleassistance center.	Multi-user system implementation
The device asks Elisabeth for her current position and she selects the room from a list.	Localization of elderly person: Development of localization technology is not within the scope of SRS. Localization will be achieved through manual position indication by the elderly user in the device’s UI, or alternatively, in spoken form during the video call, or by the operator navigating the robot and searching.
SRS starts moving from its charging station to the room where Elisabeth fell.	Autonomous navigation
The 24-hour center first accepts the call. Through SRS’s camera, Claudia, the teleoperator, can see Elisabeth on the floor and asks what happened. She uses manual navigation to further drive the robot to the place where Elisabeth lies and to point the robot’s camera more downwards.	Video calling Robot camera transmission Manual navigation and camera perspective control
Then Martin, Elisabeth’s son joins the remote session.	Multicast video streaming to several users simultaneously
Because Elisabeth can no longer move her legs due to strong pain, the three decide to call an ambulance. Martin logs off to come over in person and Claudia from the 24-hour service keeps talking to Elisabeth.	
The ambulance arrives before Martin and rings the door bell. As Elisabeth cannot move, the teleoperator navigates SRS to the door to open it. *Note: In case door opening should turn out to bee too risky from a safety perspective, SRS could fetch medication for Elisabeth.*	Semi-autonomous navigation by room plan
SRS fails to find a suitable grasping point. Claudia tries to use user-assisted grasping mode (3D model approach) but it fails too. Therefore, she changes to professional manual mode and uses the force-feedback device to open the door. The ambulance personnel enters and helps Elisabeth.	Force-feedback based advanced manual manipulation

3. Preparing Food

This scenario primarily aims to demonstrate SRS's ability to learn action sequences.





Scenario	Technological Background Major SRS innovations in red
Because Elisabeth Baker (84) recently neglected to eat, stating she has no appetite, she and her son Martin have agreed that Martin would prepare lunch for her daily for a while and they would have a chat while he does it. Therefore, Martin today during his lunch break at work calls his mother. Elisabeth accepts the call and they talk about how her day went. Martin asks her what she would like to eat and Elisabeth chooses pasta.	Authorization of local user for remote session Video call functionality
During the conversation, Martin directs SRS to the kitchen. Through SRS he opens the microwave oven, then the fridge, fetches the pasta microwave meal package, puts in the microwave, closes fridge and microwave oven, turns on the microwave by setting it to 5 min, fetches some water and puts it on the table, and after 5 min fetches the food and places it on the table.	Remote execution of a sequence of fetch-and-carry tasks
At the end of the process, Martin receives a message from SRS notifying him that a similar action sequence as today has been carried out 2 times before. SRS displays the recognized sequence and asks if it should be saved for future autonomous execution: 1. Open microwave 2. … 16. Place object *pasta microwave meal* on *living room table*.	SRS self-learning mechanism of action sequences (learning from semi-autonomous operation)
Martin is also given the option to edit the action sequence before saving it. E.g. he can shorten it, delete elements, or define variable elements that SRS should ask for before executing the sequence. Martin thinks to himself "This is nice, so next time I can fully focus on my conversation with Mum and I will simply wait for SRS to finish preparing the meal, only intervening in case SRS encounters a problem." Martin cuts the segment "Fetch object *water bottle;* bring to location *living room table*" because his mother often has some water sitting there already. Also, Martin sets the sequence object *pasta microwave meal* a variable object so SRS will next time ask what kind of food to prepare.	User editing of action sequences
Next day: Martin again calls his mother. However, today, SRS prepares the meal autonomously and Martin and his mother chat on how her day has been.	Demonstration of learned behavior

4. Fetching and Carrying of Difficult Objects

Note: The object high on the shelf may be replaced with an object low on the ground or a heavy object, depending on what is most feasible with the robot prototype platform.

Scenario	**Technological Background** Major SRS innovations in red
Francesco Rossi (78) is mentally still quite fit. However, he does not feel safe climbing a ladder and has fallen before. He has an SRS system to help him with difficult objects. Since he has no cognitive deteriorations, he usually handles SRS himself, only falling back to a teleoperator in case it fails to execute an interaction with SRS.	
Francesco wants to find some information in an old book located on a high shelf. He uses his interaction device to navigate SRS by map to the shelf.	Semi-autonomous navigation by room plan, system usage by elderly person themselves (demonstrating usability for elderly)
Since Francesco knows that SRS has never before seen this object, he switches to 3D object model approach of grasping. However, after several failed attempts, he gives up (the book is surrounded by other books causing problems with the collision-free path planning for the arm).	
Recognizing the failed attempts, SRS suggests to forward the interaction request to Gianni, his son. Francesco agrees. Gianni does not answer how-ever, so SRS suggests forwarding the interaction request to the 24-hour service. Francesco agrees.	Call priority chain function
Claudia from the 24-hour service answers the call and sees on her screen the steps that lead SRS to suggest to call him (failed manipulation attempts). She greets Francesco and asks him to explain what he would like to do. Francesco explains it and shows her the book.	Video call function
Claudia uses the professional manual mode with the force-feedback interac-tion device to grasp the book, moving aside the other books.	Force-feedback based ad-vanced manual manipulation
Knowing that Francesco will later want to return the book on his own, Claudia teaches SRS the book by the “rotate-on-gripper” approach. Francesco says thank you and the two agree to end the remote session.	Rotate-on-gripper approach for teaching objects
Francesco searches the book and finds what he was looking for. He now uses the standard semi-autonomous grasping mode to return the book. He simply taps the object on his device (it is highlighted by a rectangle) and places it back on the shelf by tapping the desired place on the shelf.	Demonstration of SRS han-dling the object taught

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