Vetenskapsrådet

Application

2015-03-31

2015-03769	Topp, Elin Anna	NT-2

Information about applicant

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Doctorial degree: 2009-01-27

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Information about application

Call name: Forskningsbidrag Stora utlysningen 2015 (Naturvetenskap och teknikvetenskap)

Type of grant: Projektbidrag

Focus: Unga forskare

Subject area:

Project title (english): Task knowledge based mixed-initiative information acquisition and ambiguity resolution in interactive industrial automation systems

Project start: 2016-01-01

Project end: 2019-12-31

Review panel applied for: NT-2

Classification code: 10207. Datorseende och robotik (autonoma system), 10201. Datavetenskap (datalogi), 10204. Människa-datorinteraktion (interaktionsdesign) (Samhällsvetenskapliga aspekter under 50803)

Keywords: Human-Robot Interaction, Industrial robotic systems, Knowledge based systems, Mixed-Initiative interaction with robots, Hypothesis generation for meaningful communication

Funds applied for

Year:	2016	2017	2018	2019
Amount:	1,541,192	1,583,648	1,627,378	1,672,419

Descriptive data

Project info

Project title (Swedish)*

Blandad initiativ i industriella automationssystem för inhämtning av information och hantering av oklarheter baserad på kunskap om uppgifter och processer

Project title (English)*

Task knowledge based mixed-initiative information acquisition and ambiguity resolution in interactive industrial automation systems

Abstract (English)*

The purpose of this proposed research project is to enhance the communicative skills of industrial robotic applications to contribute to systems that are easier to program, configure and ultimately more intuitive to use than this is (still) the case with today's systems.
This said for the general and rather broad purpose, the proposed project aims to investigate and develop cognitive models and knowledge representations that can be applied to support the communicative abilities of robotic systems, particularly in the context of mixed-initiative information acquisition and learning. Mixed-initiative information acquisition means here to enable a robotic system to handle both information spontaneously given by and information explicitly requested from a user.
The proposed project plan includes the development of application scenarios for industrial robotic systems in realistic settings, as well as user studies that should inform the development of prototypical software systems for interaction monitoring based on bayesian techniques and the application of knowledge representation techniques for the generation of dialogues that can support mixed-initiative information acquisition.
The ideas for the project are based on previous work and results, hence there is some ground to build on, but the idea is to pursue basic research principles, exploring new perspectives on and contexts for human-robot interaction with industrial robotic systems. Further it is planned to maintain ongoing and initiate new cooperations with other groups at Lund University (Particularly in Control, Cognitive Science, and Industrial Design), as well as with researchers in Sweden and at international sites, since the project is targeting not only the fields of Computer Science and Robotics but relies also on Cognitive Science and Human-Robot Interaction (in itself multi-disciplinary). Due to this rather diverse background, it can probably not be assumed that the results will be highly significant to each of the fields, but it is to be assumed that there will be significant contributions to human-robot interaction research in the area of industrial robotics and automation systems, providing a better understanding of how systems can use human-comprehensible models to communicate appropriately.

Popular scientific description (Swedish)*

Att få en industri-robot att veta när den inte vet

En ansats inom människo-robot-interaktion utgår ifrån att det är lämpligt att bygga robotsystem som på ett vettigt sätt kommunicerar med sin användare, så att användaren kan ge systemet nya kunskaper. Vid sådana instruktionstillfällen kan det dock hända att det som roboten får som information inte riktigt passar ihop med bilden den själv har byggt eller utgår ifrån som baskunskap. Dessutom är det lätt hänt att användaren glömmer att ge viss information, eller ger delvis otydliga anvisningar.
Roboten, eller snarare dess styrsystem, borde alltså kunna ta initiativet och fråga användaren efter ytterligare eller tydligare information om situationen. Detta förutsätter att systemet redan har en hypotes, om vad det är som händer, så att frågan kan utformas på ett lämpligt sätt. Projektet ska stödja byggandet av lämpliga frågor för industriella robotsystem genom att tillhandahålla modeller, som fungerar som bas för kommunikationen med användaren. En del av det är att modellera och undersöka människans agerande i en situation då hon interagerar med en robot i ett lämpligt och realistiskt scenario. Det finns redan resultat som tyder på att användare visar upp vissa mönster i interaktionen med en robot när de ska visa olika platser och föremål för en mobil robot. Utgående från dessa resultat ska det undersökas, vilka mönster man kan hitta och utnyttja för byggandet av passande representationer för industrirobotar - som i sin tur kan stödja formuleringen av lämpliga hypoteser och frågor.
Med hjälp av system som analyserar data från olika sensorer, som t.ex. kameror och distansmätare, och med hjälp av sparade kommandon kan en "interaktionshistoria" byggas för en viss period i interaktionen. Baserat på historien ska systemet kunna känna igen interaktionsmönstren som eventuellt relaterar till information som ska ges till roboten. Roboten ska sen kunna knyta ihop det den hittills förstått med information som ges direkt från användaren - eller kan efterfrågas. Därmed ska en bättre uppfattning om situationen kunna byggas än vad det är möjligt enbart utifrån det som användaren säger eller enbart genom autonoma tolkningar av situationen.
En annan del är att modellera kunskapen som systemet behöver för att kunna utforma frågorna. Denna kunskap antas kommer från redan kända beskrivningar för olika produktionsprocesser. Också här ska det undersökas, om det finns mönster i beskrivningarna som gör det möjligt för robot-systemet att jämföra observationer från interaktionen med användaren (t ex en sekvens av operationer som användaren planerad för) med tidigare sparade sekvenser - för att kunna hitta oklarheter och avvikelser.
Under projektets gång ska det alltså byggas (protoypiska) system, som sedan ska testas i så realistiska förhållanden som möjligt, antingen i kooperation med lämpliga företag, eller som explorativa laboratoriestudier.

Project period

Number of project years*

4

Calculated project time*

2016-01-01 - 2019-12-31

Deductible time

Deductible time

	Cause	Months
1	Parental leave	10
2	Other approved reason*	5
	Total	15

Career age: 59

Career age is a description of the time from your first doctoral degree until the last day of the call. Your career age change if you have deductible time. Your career age is shown in months. For some calls there are restrictions in the career age.

Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

SCB-codes*

1. Naturvetenskap > 102. Data- och informationsvetenskap (Datateknik) > 10207. Datorseende och robotik (autonoma system)

1. Naturvetenskap > 102. Data- och informationsvetenskap (Datateknik) > 10201. Datavetenskap (datalogi)

1. Naturvetenskap > 102. Data- och informationsvetenskap (Datateknik) > 10204. Människa-datorinteraktion (interaktionsdesign) (Samhällsvetenskapliga aspekter under 50803)

Enter a minimum of three, and up to five, short keywords that describe your project.

Keyword 1*

Human-Robot Interaction

Keyword 2*

Industrial robotic systems

Keyword 3*

Knowledge based systems

Keyword 4

Mixed-Initiative interaction with robots

Keyword 5

Hypothesis generation for meaningful communication

Research plan

Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

Reporting of ethical considerations*

The project plan includes user studies and experiments that might involve third parties. It is planned to handle expected data in appropriate anonymised form (using coding systems), while study subjects will be informed about their rights to withdraw from the study at any point and to withdraw their data from further handling after a conducted experiment. Subjects will have to sign an according form of consent.
For contacts with the target robot systems all necessary means of precaution will be taken, e.g., in the form of options for manual override of commands through an experiment leader. Studies will be focused on systems designed for interaction or co-existence with humans to avoid hazardous circumstances up front.

The project includes handling of personal data

Yes

The project includes animal experiments

No

Account of experiments on humans

No

Research plan

Research plan

Task knowledge based mixed-initiative information acquisition and ambiguity resolution in interactive industrial automation systems

1 *Purpose and aims*

The purpose of this proposed research project is to enhance the communicative skills of industrial robotic applications to contribute to systems that are easier to program, configure and ultimately more intuitive to use than this is (still) the case with today's systems. Recently, several projects have targeted interactive industrial systems in different ways. However, in many cases these projects lack the opportunities to provide a deep analysis of the actual interaction one could expect to observe in a setting with an industrial robot on the shop floor, simply because the prototypical or demonstrator systems needed for such investigations were rather the goal of these projects than the tools to start out with. One assumption for this project proposal is thus, that prototypical systems resulting from previous projects can be applied for more fundamental research on Human-Robot Interaction with industrial robotic systems, which in turn aims to provide results that future, rather practically oriented projects can benefit from.
This said for the general and rather broad purpose, the proposed project aims to investigate and develop cognitive models and knowledge representations that can be applied to support the communicative abilities of robotic systems, particularly in the context of mixed-initiative information acquisition and learning. Mixed-initiative information acquisition means here to enable a robotic system to handle both information spontaneously given by and information explicitly requested from a user.
While the user's initiative to provide information to the robotic system can initially be based on the task or general purpose of the robotic system, the robot needs a broader base of knowledge to rely on to generate sensible hypotheses about surroundings and situations. In other words, the robotic system needs to find out in a given situation what it needs to know to complete its knowledge or disambiguate its current understanding of the situation, since it cannot be expected of the user to provide the needed information at all times without being explicitly prompted for it.
An example for a disambiguation request would be a situation in which an industrial robotic system is instructed to perform a certain task, e.g., to assist during the assembly of a certain workpiece, but the operator (instructor in this situation) omits to explicitly parameterise a particular step of the presumably existing assembly plan. For instance, the plan assumes in "step 3" that piece "A" has to be mounted on top of piece "B". During the instruction the operator uses the "Programming by demonstration" mode of the system and shows, how to fixate the piece but she does not make this information explicit. The system now notices that the operation description "mount" is ambiguous (it could be to snap-fit, glue, position for later screwing, etc.) and asks for a clarification. To support the operator in giving a useful answer, the system provides a clear hypothesis, generated through a reasoning process that considers, e.g., a priori knowledge about the task domain and extracted from previous processes, as well as the actually observed task demonstration: "Please confirm or correct: Piece A is to be snap-fitted onto Piece B". For this type of scenario, the proposed project aims to provide the means, i.e., the

knowledge and communicative tools, to generate useful hypotheses than can be used to form, e.g., in a graphical dialogue, requests for completion, confirmation or correction of the hypothesis in question. To this end the following questions need to be answered: a) What general knowledge about task sequences, plans and processes is needed to generate useful hypotheses for communication in a specific situation? How can it be represented?, b) Are there specific patterns re-occurring in such plans that can be exploited for the detection of ambiguities as described in the above example?, and c) Are there patterns observable in the behaviour of assumed users who are interacting with an industrial robot or its control system in different production scenarios, that can be exploited?
Some indications towards more general answers to the above questions were derived from results of previous and ongoing projects the hosting group for Robotics and Semantic Systems is or was involved in. However, these are mainly EU-funded projects with a strong connection to (industrial) applications, i.e., the main focus is often shifted towards practical demonstrations rather than fundamental research. This project would thus aim to strengthen the basic research efforts in the group, trying to find rather general answers to the above questions, which in return could contribute to other, more applied efforts. The ideas for the project are based on previous work and results, hence there is some ground to build on, but the idea is to pursue basic research principles, exploring new perspectives on and contexts for human-robot interaction with industrial robotic systems. Further it is planned to maintain ongoing and initiate new cooperations with other groups at Lund University (Particularly in Control, Cognitive Science, and Industrial Design), as well as with researchers in Sweden and at international sites, since the project is targeting not only the fields of Computer Science and Robotics but relies also on Cognitive Science and Human-Robot Interaction (in itself multi-disciplinary).

2 *Survey of the field*

As indicated above, the proposed project will integrate different aspects of cognitive modeling, human- robot interaction, situation understanding and situation awareness in robotics, and knowledge management and learning. Hence, this survey covers or touches several fields, while it seems impossible to claim completeness for all of them. Related or relevant approaches and projects are described in the following paragraphs, while the immediate background for the project idea and the direct connections to ongoing projects and related investigations will be described in section 3.

Mixed-initiative or symbiotic interaction The idea and benefits of mixed- initiative approaches to disambiguation and information acquisition have been discussed in the context of human-robot interaction with service robots [9, 6], and the idea of perspective taking, i.e., hypothesis generation based on understanding of physical limitations and pose configuration of interaction partners has also been investigated in a series of works targeting more general applications [e.g., 21, 7]. Investigations in the area of more general situation awareness, robot system driven exploration, and ultimately interactive information acquisition were, for example, part of the EU-commission funded project CogX [3]. The idea of "robots that can ask for help" or symbiotic human-robot interaction [11, as an example] is related in the sense that a robotic system can determine that it needs some form of collaboration or input to be able to solve a certain task - and

both, robot and user can benefit from and provide to the solution.

Probabilistic methods for learning and classification The preliminary results that could be achieved so far (see below), are based on the application of probabilistic representation, classification and learning techniques such as Bayesian Networks and suitable algorithms like Expectation Maximisation (EM). Recently, those techniques have become quite popular in the areas of situation assessment or scene understanding [e.g., 15], and the proposed project aims to explore them further.

Action representation Several recent and ongoing projects deal with representations of actions and objects and their correspondence (e.g., PACO+ [8], ACat [1]). Very often those approaches have a focus on the object that might be subject to a certain action, whereas the proposed project aims to focus on the observable (inter)action with the robotic system to identify (ultimately) the communicative goal (which might very well involve particular objects). Hence, the work in these projects has to be considered strongly related, and the applicant hopes to be able to strengthen existing and establish further contacts to relevant research groups in this area.

Knowledge representation and management A number of recent projects dealt with knowledge management, building models of space, objects, workspaces and tasks, to facilitate flexible and adaptive task execution [12, 5]. These projects target both service robots and industrial systems, which is certainly relevant to the proposed project. Two recent projects investigate the representation of robot skills (and tasks) in industrial settings [18, 16].

Psycholinguistics and common ground in communication The idea of enhancing the communicative abilities of a robotic system is strongly connected to the concept of common ground in communication [2], as well as research in the field of psycholinguistics [e.g., 4] seems to be a foundation for the investigations of *interaction patterns* to be conducted. The proposed project is assumed to offer the opportunity of investigating in particular the latter relation further.

Related projects Other projects with strong involvement of the applicant's group are SMErobotics [14], in which investigations within both knowledge representation and management as well as in Symbiotic Human-Robot Interaction with industrial robots play a central role, the recently concluded EU-funded project PRACE [10], which assumes an industrial robot as an "apprentice", supposed to be learning from observations, and finally the recently started project SARAFun [13], which investigates high-level programming approaches for industrial robotic systems.

3 *Project description*

The project idea covers several subtopics, which are described in the following paragraphs.

Knowledge representations for workspaces and tasks For a system to be able to form hypotheses about a given situation, it needs to have general knowledge about its environment and tasks. Hence, the workspace of an industrial robot and its tasks are going to be modeled, so that reasoning about needed information based on such models can be provided. Here, the current involvement of the group (including the applicant) in the ongoing project SMErobotics [14] and results regarding the representation of (workspace) knowledge relevant to industrial robotic systems, obtained in previous projects [17] can contribute to the proposed project. The general models for surroundings and tasks will then provide one of the information cues needed to generate hypotheses about the overall situation an assumed interactive industrial robot might find itself in.

Interaction monitoring A central question is in how far the observation of particular "(inter)action patterns" can be exploited to substitute pre-coded (a priori) knowledge or, if a priori knowledge is available, can be used to interpret an ambiguous situation. Based on previous studies (see paragraph on preliminary results), it seems possible to extract meta-information (at least in form of a hypothesis) about the information explicitly given by a user from observing the users actions before and during en explanation is given to the robotics system, e.g., an object is presented and explained. The project will initially investigate the existence of particular patterns observable in the interaction of a human user with industrial systems. This work will benefit from the work carried out within the mentioned project SMErobotics (see below). Further steps will include the investigation of the applicability of such patterns by applying machine learning and data mining approaches to clustering and categorisation, (including appropriate tracking approaches to extract user actions and an "interaction history" for a given situation) to understand their potential correspondence to the assumed models and general knowledge the robotic system has. In preliminary investigations specifically Bayesian Networks and respective techniques for learning proved an appropriate line of research to pursue and will be evaluated further in this context.

Mixed-initiative information acquisition Particularly for industrial systems it can be assumed that they will still work on a rather low level of autonomy and also for personal service robots it can be assumed that it must be possible to "switch them off". Consequently, it is supposed that the human user will in both cases be responsible for getting involved in an interaction with the robotic system in the first place, e.g., by starting up the system and specifying the task at hand. However, while working, and also for the configuration or programming of the system, it has to be assumed that the user will not necessarily give perfectly complete information. With the help of the knowledge provided through the general situation and workspace models, and information about the current situation provided through the interpretation of (potentially observable) interaction patterns, the robotic system can be enabled to generate a hypothesis for which a request for confirmation can be expressed to the user.
In the course of the project a suitable dialogue management mechanism for the generation of such requests and later the processing of the user response will be investigated and developed. Here it is assumed that this should be done by integrating access to the previously provided workspace-specific knowledge the system needs, not only to build a suitable hypothesis about a situation but also to formulate requests to the user in a

suitable manner. For example, it needs to be investigated whether it is most suitable to formulate an open question ("I do not understand, what do you mean?") as opposed to applying a more guiding type of formulation ("Do you mean A, B, or C?") or even stating a clear hypothesis ("I assume you mean B, right?"). The obtained response can, depending on the given situation, mean to revise the currently assumed representation. Hence, a strong focus of the project will be on this aspect; i.e., generating requests from currently assumed hypotheses and revising the underlying knowledge and representations if necessary. The applicability of existing knowledge representations and memory based architectures will be investigated, to find the optimal balance that is needed for mixed-initiative information acquisition, as this requires both a short term memory structure for the immediate interaction monitoring (building an interaction history) as well as long term memory (a knowledge base) for adaptation and learning of optimal interaction strategies on the robotic system's side.

User studies with industrial robotic systems The preliminary results could be obtained mainly from studies in the area of (mobile) service robotics. It is obvious, however, that the issue of providing robotic systems with the means to pose meaningful questions also applies to other scenarios that go beyond these examples. Regarding the targeted industrial systems, the potential scenarios to deal with would then not only have to handle conceptual but also semantic knowledge (functional understanding), once it is possible to find adequate cues in the interaction between robot and human user. This would then apply particularly to industrial settings in which a user might be in the situation to refine the robotic system's knowledge about a given workpiece and the task to be performed with it. Further, error prevention in terms of erroneous assembly of two parts of a workpiece might be possible when the robotic system is aware of a potential uncertainty or weakness in the original task description. It has to be assumed, that even with a strong contact to real-world applications, the project work has to be carried out (at least initially) with prototypical setups and realistic but limited scenarios. For the proposed project those target scenarios will be developed with a strong focus on industrial systems, while the experiences from studies with service robots can inform this work. It is assumed for the proposed project that there will be the opportunity to carry out user studies in real application scenarios, if not on-site in a presumed end-user facility, then with a realistic experimental setup in the robot laboratory the applicant has access to (see section 8).

Ethical considerations The project plan includes user studies and experiments that might involve third parties. It is planned to handle expected data in appropriate anonymised form (using coding systems), while study subjects will be informed about their rights to withdraw from the study at any point and to withdraw their data from further handling after a conducted experiment. Subjects will have to sign an according form of consent. For contacts with the target robot systems all necessary means of precaution will be taken, e.g., in the form of options for manual override of commands through an experiment leader. Studies will be focused on systems designed for interaction or co-existence with humans to avoid hazardous circumstances up front.

Timeframe and milestones Assuming a possible period of four years (48 months, m01 to m48) and the opportunity to apply the grant as funding for about one (full-time) PhD student, up to 40% of the applicants salary for supervision and direct involvement in the research, and presumably some salary for project assistants (or student workers paid on hourly basis for implementation and maintenance work) the discussed research activities are planned over this period as listed in the following table. Since some preliminary results might be expected even before the official start of the project, these are referred to as well. As the assumed steps and key activities are expected to be rather intertwined than sequential, there is a certain overlap in the periods dedicated to them.

Time period (estimate)	Planned activity
ongoing - m0	Further analysis of previously acquired study material on *interaction patterns*, based on probabilistic methods (bayesian networks). Prototypical work on a dialogue management and interaction monitoring approach to support mixed-initiative information acquisition.
m01 - m12	Investigation of typical situations and potential patterns observable in industrial settings, with particular focus on potential application scenarios for robotic systems. Based on surveys of preliminary results and potential visits to respective sites (in conjunction with other projects of the group).
m07 - m18	Further investigation of appropriate methods and algorithms (tracking, clustering, learning, reasoning) for Interaction pattern-detection, their interpretation, and application to hypothesis generation in the obtained scenarios.
m13 - m24	Further development / implementation of prototypical interaction monitoring and dialogue management system for hypothesis generation regarding the current interaction related situation. Preparation of a prototype system for an experimental user study.
m19 - m30	User study / Technical experiments to evaluate the benefit of the prototypical mixed-initiative approach in an industrial setting, preferably on-site, otherwise in realistic laboratory settings. For a potentially funded PhD student a clear milestone would be a licentiate thesis publication.
m25 - m40	Analysis of study material, extraction of generalisable knowledge, investigation of potential long term learning opportunities (adaptation to specific users, development of particular, situation dependent interaction strategies, etc). Further development of the prototypical dialogue management with deeper coupling to knowledge bases. Establishment of a long term memory structure to allow for the mentioned learning and adaptation in terms of interaction strategies on the system side.
m31 - m48	Evaluation of the proposed strategies for mixed-initiative information acquisition in the identified industrial target scenarios. A potentially funded PhD student should conclude the work on the respective thesis around this time.

4 *Significance*

The project will contribute to the research and development of robotic systems that are easier and more intuitively to use than that is the case today. While autonomous, cognitive, and intelligent systems are quite far developed in the area of (mobile) service robotics, there are still open issues to be handled when dynamic environments and the interaction with human users are concerned. The proposed project aims to investigate one of these issues by working before a multi-disciplinary background. Hence, it can probably not be assumed that the results will be highly significant to each of the fields, but it is to be assumed that there will be significant contributions to human-robot interaction

research in the area of industrial robotics and automation systems, providing a better understanding of how systems can use human-comprehensible models to communicate appropriately.
As the background of the applicant lies in the area of service robotics, while the project concerns mainly industrial robotics scenarios, one interesting aspect will be to investigate whether the same frameworks, generic cognitive models and principles in the context of mixed-initiative human-robot interaction for information acquisition can be applied to both service robotics and industrial systems. This in itself can be considered a significant contribution which will (if the question can be positively answered), open new possibilities for knowledge transfer from usually easier accessible mobile service robotic research systems to industrial applications.

5 *Preliminary results*

In previous work, a framework for "Human Augmented Mapping", or interactive robotic mapping in a "guided tour scenario", was proposed [19]. Within the respective work, several studies and experiments were conducted that ultimately resulted in open questions to be handled in currently conducted work in projects the applicant's group is involved in. The work suggested a partially hierarchical environment representation for mobile robots that supported intuitive communication between user and robot about indoor environments, while it could at the same time be improved itself through this communication. In particular the idea of *interaction patterns* [20] has been further investigated. The term *interaction patterns* refers to patterns in the user behaviour that can give indications for the user's intentions when presenting different items in the environment. Recently, the existence and potential for identification and application in an interactive scenario could be shown, and respective publications are planned for the near future.
The concept of *interaction patterns* was also transferred to the realm of industrial robotics research within the EU-funded project SMErobotics [14] and adapted to the idea of *task patterns* that can be applied to monitor the events in a production process and to identify situations where the user should be requested to fill in a gap of knowledge or simply confirm or correct a hypothesis about the situation to prevent an error. Within that project, some prototypical results regarding the modelling of such task patterns, their identification and application for mixed-initiative interaction have been achieved, that form the basis for the investigations within this proposed project.
In another line of research different aspects of high-level programming of industrial robotic systems are investigated, with prototypical results that have recently been summarised in a respective licentiate thesis [17]. Also in this area, a more thorough investigation of the actual needs and applicability of the proposed approach in realistic interaction situations involving industrial systems seems appropriate, while the prototypical systems described in that work can be beneficial to the proposed project, as previously pointed out in the project description.

6 *Independent line of research*

The applicant joined the group for Robotics and Semantic Systems of the Computer Science department at Lund University in May 2009 which was about the time for the

group to actually being established. Before the applicant joined the group the following areas were covered by the senior members of the group: Natural Language Processing (Pierre Nugues), Artificial Intelligence (focusing on reasoning under constraints and knowledge representation) (Jacek Malec), Software Systems for Robots and Automation Systems (Klas Nilsson). As of today the group consists of six senior members and two full-time PhD students, covering the areas of Software Systems for Robots and Automation systems (Klas Nilsson, senior lecturer, docent, head of the group and grant holder for the larger part of the groups projects, Mathias Haage and Sven Robertz), Knowledge representation and reasoning (Jacek Malec, professor, supervising one of the PhD students), Natural language processing (Pierre Nugues, professor, supervising the second PhD student affiliated with the group, grant holder for one VR-funded project), and Human-Robot Interaction (Elin A. Topp, applicant for the proposed project). Hence, the applicant contributes to the group with the formerly not covered area of Human-Robot Interaction and Cognitive Modeling for Interaction. During the initial period as postdoctoral researcher in the group the applicant established an independent collaboration with a former project partner institution (Cognitive Interaction Technology - Centre of Excellence (CITEC), Bielefeld University, Germany), and hosted a visiting PhD student for three months in spring 2010. This collaboration resulted in the study material the preliminary results for the proposed project are based upon. However, this specific line of research could not be followed as intensely during the following years due to the applicant being offered and accepting a tenure position as senior lecturer (in combination with several periods of parental and sick leave). It is assumed though, that similar contacts can be (re-)established and lead to fruitful collaborations and project ideas. The grant applied for with this proposal would thus contribute to strengthening the applicants position both within the group (by providing funding for further PhD students) and towards the research community to allow a more continuous work on the proposed investigations (carried out by herself and supported by the prospectively funded staff) than this is currently possible due to the teaching and other departmental duties that are immanent for a lectureship. The applicant plans to achieve docent status as one central step towards being able to apply for promotion to full professor. The described project lies exclusively in the responsibility of the applicant.

7 *Type of employment (Anställningsform)*

The applicant is since July 2012 employed as Senior Lecturer (Universitetslektor) with approximately and on average per year 50% of the actual working time spent on teaching and departmental duties, the other 50% spent on project work and research. As this is a tenured position, there is no change expected in the type of employment for the period assumed for the proposed project. The grant would then be used to (at least partially) cover the funding for a PhD student to be co-supervised by the applicant, and to strengthen the research involvement of the applicant herself.

8 *Equipment / Need for infrastructure*

The group for Robotics and Semantic Systems is through the department of Computer Science part of the Lund University Centre for Applied Software (LUCAS), and shares through this collaboration the responsibilities for the Robotics Laboratory hosted by the

department of Automatic Control, which provides access to different types of robotic systems, including the target industrial systems. The budget for the proposed project includes merely consumables and costs for general use and maintenance of the Robotics Laboratory, as it is assumed that the equipment and infrastructure already available will cover the immediate needs.

9 *International and national collaboration*

The different members of the group are involved in several ongoing national and international projects, some of which have a strong focus on industrial applications of robotic systems. This would allow the applicant to establish further contact to relevant Swedish industry (i.e., beyond the today established international contacts through the project SMErobotics where the applicant currently has the focus of her research efforts) to identify potential scenarios and specific application areas on a national level. Some of the personal (university internal as well as external national and international) contacts of the applicant other than those mentioned here can be found in the applicant's CV, which is part of the overall proposal.

10 *Other grants*

The group for Robotics and Semantic Systems is currently involved in two larger projects, the EU seventh framework programme (FP7) project [14], and the EU programme Horizon 2020 project SARAFun [13].
The applicant is directly involved in two potential new projects within the EU programme Horizon 2020 (one under evaluation, the second to be applied for shortly). These projects can be seen as complementary to the project applied for here, as they could provide insights into additional cases of applications and use-case scenarios where the proposed research could benefit from and later on evaluated against.

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[8] PACO+. Perception, Action and Cognition through learning of object-action complexes. IST-FP6-IP-027657.

[9] J. Peltason, E.A. Topp, F.H.K Siepmann, T.P. Spexard, and M. Hanheide. Mixed-initiative in human augmented mapping. In *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*, Kobe, Japan, May 2009.

[10] PRACE. Prace - the productive robot apprentice. EU FP7-285380.

[11] S. Rosenthal, M. Veloso, and A. Dey. Task behavior and interaction planning for a mobile service robot that occasionally requires help. In *Proceedings of the AAAI'11 Workshop on Automated Action Planning for Autonomous Mobile Robots*, 2011.

[12] ROSETTA. RObot control for Skilled ExecuTion of Tasks in natural interaction with humans; based on Autonomy, cumulative knowledge and learning. EU FP7-230902.

[13] SARAFun. smart Assembly Robot with Advanced FUNctionalities. EU HORIZON 2020 ICT-2014-1.

[14] SMERobotics. Smerobotics. EU FP7, FP7-287787, http://www.smerobotics.org.

[15] D. Song, N. Kyriazis, I. Oikonomidis, C. Papazov, A. Argyros, D. Burschka, and D. Kragic. Predicting human intention in visual observations of hand/object interactions. In *Proceedings of IEEE International Conference on Robotics and Automation (ICRA)*. IEEE, 2013.

[16] STAMINA. Sustainable and reliable robotics for part handling in manufacturing automation. EU FP7-610917.

[17] M. Stenmark. *Instructing Industrial Robots using High-Level Task Descriptions*. Licentiate Thesis, Lund University, Faculty of Engineering, 2015.

[18] TAPAS. Robotics-enabled logistics and assistive services for the transformable factory of the future. EU FP7-260026.

[19] E.A. Topp. *Human-Robot Interaction and Mapping with a Service Robot: Human Augmented Mapping*. Doctoral Dissertation, KTH School of Computer Science and Communication (CSC), Stockholm, Sweden, 2008.

[20] Elin A. Topp. Understanding Spatial Concepts from User Actions. In *Proceedings of the 6th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. ACM, 2011.

[21] J.G. Trafton, A.C. Schultz, D. Perzanowski, M.D. Bugajska, W. Adams, N.L. Cassimatis, and D.P. Brock. Children and robots learning to play hide and seek. In *Proceedings of the ACM Conference on Human-Robot Interaction (HRI), Salt Lake City, UT, USA*, 2006.

Interdisciplinarity

My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

Scientific report

Scientific report/Account for scientific activities of previous project

Budget and research resources

Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

Dedicated time for this project*

	Role in the project	Name	Percent of full time
1	Applicant	Elin Anna Topp	40

Salaries including social fees

	Role in the project	Name	Percent of salary	2016	2017	2018	2019	Total
1	Applicant	Elin Anna Topp	40	361,256	372,093	383,256	394,754	1,511,359
2	Participating researcher	(doktorand)	100	517,404	532,926	548,914	565,381	2,164,625
3	Other personnel without doctoral degree	(projektassistent)	12	55,857	57,533	59,259	61,037	233,686
	Total			934,517	962,552	991,429	1,021,172	3,909,670

Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

Premises

	Type of premises	2016	2017	2018	2019	Total
1	Kontor + allmänna lokaler	74,296	76,370	78,506	80,706	309,878
	Total	74,296	76,370	78,506	80,706	309,878

Running Costs

	Running Cost	Description	2016	2017	2018	2019	Total
1	Driftskostnader	Resor + studiematerial	70,000	70,000	70,000	70,000	280,000
2	Utrustning + förbrukningsmaterial	RobotLab, material, underhåll	20,000	20,000	20,000	20,000	80,000
	Total		90,000	90,000	90,000	90,000	360,000

Depreciation costs

Depreciation cost	Description	2016	2017	2018	2019

Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

Total budget

Specified costs	2016	2017	2018	2019	Total, applied	Other costs	Total cost
Salaries including social fees	934,517	962,552	991,429	1,021,172	3,909,670		3,909,670
Running costs	90,000	90,000	90,000	90,000	360,000		360,000
Depreciation costs					0		0
Premises	74,296	76,370	78,506	80,706	309,878		309,878
Subtotal	1,098,813	1,128,922	1,159,935	1,191,878	4,579,548	0	4,579,548
Indirect costs	442,379	454,726	467,443	480,541	1,845,089		1,845,089
Total project cost	1,541,192	1,583,648	1,627,378	1,672,419	6,424,637	0	6,424,637

Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

Explanation of the proposed budget*

Löner: Projektet antas att kunna vara grunden för en doktorsavhandling, dvs en doktorand skulle då finansieras med en antagen aktitivtetsgrad på 100% över fyra år (eller vid möjligheten att disponera medel under en längre tid än bidragstiden med ca 80% under ca fem år). Projektledaren antas kunna bidra utöver (biträdande) handledning av denna doktorand också direkt i projektet, därav anges an aktivitetsgrad på 40%. Projektet medför en viss del implementerings- och underhållsarbeten, därav planeras för en viss andel (12%) för en timanställd projektassistent.

Driftskostnader:
- Resor (konferenser i området roterar mellan Europa, Amerikanska kontinenterna (mest nord) och Asien), det antas ca 2 resor per år per person med olika höga kostnader. En annan del är studiematerial, så som kostnader till mindre gratifikationer för studiedeltagare, samt förbrukningsmaterial.
- Bidrag till robotik-laboratoriet RobotLab som drivs av både Inst för Datavetenskap och Inst för Reglerteknik.

Lokaler: Här anges det andelen av institutionens allmänna lokalkostnader (kontor och möteslokaler) baserad på personal och dess aktivitetsgrad i projektet.

Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

Other funding for this project

Funder	Applicant/project leader	Type of grant	Reg no or equiv.	2016	2017	2018	2019

CV

Curriculum Vitae

Personal information

Name	Elin Anna Topp	741030-9129
Citizenship	Germany (permanently registered in Sweden)	
Languages	German (native), English, Swedish, French	

1. Higher education qualicifications

11/2003 MSc Computer Science (Diplominformatikerin), Universität Karlsruhe, Germany (now Karlsruhe Institute of Technology, KIT)

2. Doctoral degree

01/2009 PhD Computer Science (Teknologi doktor datalogi), "Human-Robot Interaction and Mapping with a Service Robot: Human Augmented Mapping" (2008), supervisor Prof Henrik I. Christensen and Prof Kerstin Severinson Eklundh, Royal Institute of Technology (KTH), Stockholm, Sweden

3. Postdoctoral position

05/2009–04/2011 Dept. of Computer Science, Group for Robotics and Semantic Systems, Faculty of Engineering, Lund University (see paragraph 6)

5. Current position

from 07/2012 Senior Lecturer (Universitetslektor), tenure position. Dept of Computer Science, Faculty of Engineering, Lund University, Lund Sweden. Research involvement ca 50% of actual working time per calendar year (see paragraph 7).

6. Tidigare anställningar

05/2011–06/2012 Researcher / Teaching assistant (fixed time appointments of 6, 2, and 6 months). Dept of Computer Science, Faculty of Engineering, Lund University, Lund Sweden. Research involvement ca 80% of actual working time (see paragraph 7)

05/2009–04/2011 Postdoctoral researcher (fixed time appointment of two years), Dept. of Computer Science, Group for Robotics and Semantic Systems, Faculty of Engineering, Lund University, Lund, Sweden. (research involvement ca. 85%, teaching involvement ca. 15%)

7. Interruption in research

02/2009–04/2009 Unemployed, looking for postdoctoral position.
09/2009–01/2010 Partial parental leave, summing up to 0.775 full months
08/2011–01/2012 Full time parental leave 6 months
02/2012–03/2014 Partial parental leave, summing up to 2.625 full months
08/2012–12/2012 In practice 100% of actual working time spent with undergraduate teaching involvement due to new position and tasks

03/2014–12/2014	Varying degrees of sick leave (ca. six weeks full time, after that gradual recovery steps), summing up to 5.375 full months.
01/2015–ongoing	Partial parental leave (25%), 0.75 months so far in 2015

9. Other relevant information

Supervision, reviewing, examination

Reviewer conferences and journals	IEEE/ACM HRI, IEEE ICRA, IEEE/RSJ IROS, IEEE Ro-Man, IEEE-RAS Humanoids, IEEE-RAS Robotics and Automation Magazine, IEEE Transactions on Robotics, Elsevier Robotics and Autonomous Systems, ACM Transactions on Interactive Intelligent Systems
Supervision (MSc)	three successful MSc projects and one three-months student project at Royal Institute of Technology (2004–2008)
Supervision (MSc)	four successfully concluded MSc projects (2009–2014), three ongoing promising MSc projects (one exchange student from UPC Barcelona) at Lund University
Hosting / Supervision	visiting doctoral student Annika Peters (now PhD) from the Cognitive Interaction Technology Center of Excellence / Applied Informatics group, University of Bielefeld, Germany (04/2010–06/2010)
External Reviewer	PhD thesis, Annica Kristofferson, "Measuring the Quality of Interaction in MRP Systems using Presence, Spatial Formations and Sociometry" (defended fall 2013, Örebro, University)
Examiner	Licentiate degree in Computer Science, Maj Stenmark, "Instructing Industrial Robots using High-Level Task Descriptions", Dept of Computer Science, Lund University (03/2015)

Cooperations, Contacts

Workshop	(co-organised with Helge Hüttenrauch, at the time Department of Computer and Systems Sciences, Stockholm University) held at the IEEE International Symposium in Robot and Human Interactive Communication, September 2010, Viareggio, Italy
Project involvement	EU Integrated Project "COGNIRON – 01/2004–02/2008.
Project involvement	Swedish (SSF) funded project "ENGROSS" and EU Integrated Project "ROSETTA" (minor contributions 2009–2012)
Project involvement	EU Integrated Project "SMErobotics" (considerable contributions), 2012–ongoing.
Programme	Participation in STINT Sweden–Korea program funded cooperation with Hanyang University, Seoul, South Korea
Study Group	Participation in Advanced Study Group "The meaning of action", Pufendorf Institute for Advanced Studies, Lund University, 09/2011–06/2012

Publication list

List of publications

(*) Mark the five publications most relevant to the proposed project. (**) Mark the five most cited publications with the author being a main contributor over the last ten years (three of them hence dating back slightly longer than requested). Number of citations from Google Scholar, excluding self-citations.
Recent results are currently prepared for submission / publication (see project description, section 5: "Preliminary results")

1. Peer-reviewed articles

2010 (*) (**) Elin A. Topp and Henrik I. Christensen, "Detecting Region Transitions for Human Augmented Mapping", IEEE Transactions on Robotics, ISSN 1552-3098, vol 26(4), pp 715–720, 2010. Number of citations: 13

2009 (*) Helge Hüttenrauch, Elin A. Topp and Kerstin Severinson Eklundh, "The Art of Gate-Crashing: Bringing HRI into Users' Homes", Interaction Studies, vol 10(3), 2009, Special Issue on "Robots in the Wild: Exploring HRI in Naturalistic Environments", pp 274–297. Number of citations: 7

2008 Zoran Zivkovic, Olaf Booij, Ben Kröse, Elin A. Topp, and Henrik I. Christensen, "From Sensors to Human Spatial Concepts: An Annotated Data Set", in IEEE Transactions on Robotics, vol 24:2, pp501-505, 2008. Number of citations: 20

2. Peer-reviewed conference papers

2013 Klas Nilsson, Elin Anna Topp, Jacek Malec, Il-Hong Suh, "Enabling Reuse of Robot Tasks and Capabilities by Business-related Skills Grounded in Natural Language". In proceedings of the International Conference on Autonomic and Autonomous Systems (ICAS) 2013. Number of citations: 3

2011 (*) Elin A. Topp, "Understanding Spatial Concepts from User Actions", in Proceedings of the 6th ACM/IEEE International Conference on Human-Robot Interaction (HRI), 2011. Number of citations: 1

2009 (*) (**) Julia Peltason, Elin A. Topp, Frederic H.K. Siepmann, Thorsten P. Spexard, and Marc Hanheide, "Mixed-Initiative in Human Augmented Mapping", in Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2009. Number of citations: 28

2008 Elin A. Topp, Henrik I. Christensen, "Detecting Structural Ambiguities and Transitions during a Guided Tour", in Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), 2008. Number of citations: 6

2007 Thorsten P. Spexard, Shuyin Li, Britta Wrede, Marc Hanheide, Elin A.Topp, and Helge Hüttenrauch, "Interaction Awareness for Joint Environment Exploration" Special Session on Situation Awareness in Social Robots at the IEEE International Symposium on Robot and Human Interactive Communication (Ro-Man), 2007. Number of citations: 6

2006 (**) Elin A. Topp and Henrik I. Christensen, "Topological Modelling for Human Augmented Mapping", in Proc. of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2006. Number of citations: 31

(**) Elin A. Topp, Helge Hüttenrauch, Henrik I. Christensen, and Kerstin Severinson Eklundh, "Bringing Together Human and Robotic Environment Representation - A Pilot Study", in Proc. of the IEEE/RSJ International Conference on Intelligent Robots and Systems, 2006. Number of citations: 42

2005 (**) Elin A. Topp and Henrik I. Christensen, "Tracking for Following and Passing Persons", in Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2005. Number of citations: 78

3. Monographs

2008 (*) Elin A. Topp, "Human-Robot Interaction and Mapping with a Service Robot: Human Augmented Mapping", Doctoral Thesis, Royal Institute of Technology, Stockholm, Sweden, September 2008, ISBN: 978-91-7415-118-3. Number of citations: 8

CV

Name: Elin Anna Topp	**Doctorial degree:** 2009-01-27
Birthdate: 19741030	**Academic title:** Doktor
Gender: Female	**Employer:** No current employer

Research education

Dissertation title (swe)

Dissertation title (en)

Human-Robot Interaction and Mapping with a Service Robot: Human Augmented Mapping

Organisation	Unit	Supervisor
Kungliga Tekniska Högskolan, Sweden Sweden - Higher education Institutes	CVAP, Datorseende och robotik	Henrik I. Christensen

Subject doctors degree	ISSN/ISBN-number	Date doctoral exam
10201. Datavetenskap (datalogi)	ISBN: 978-91-7415-118-3	2009-01-27

Publications

Name: Elin Anna Topp	**Doctorial degree:** 2009-01-27
Birthdate: 19741030	**Academic title:** Doktor
Gender: Female	**Employer:** No current employer

Topp, Elin Anna has not added any publications to the application.

Register

Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.

Applications with an organisation as applicant is automatically signed when the application is registered.