Behavioral Design Patterns for Social, Assistive Robots

Insights from the NIKA Research Project

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ABSTRACT

The growing body of research in human-robot interaction (HRI) is still mainly focused on technical aspects of the interaction. There are no defined guidelines that describe how social, assistive robots need to be designed to be accepted by human interaction partners. The NIKA project is aimed at developing generic design solutions for reoccurring interaction situations in HRI. The developed solutions will be documented as behavioral design patterns to make them accessible for interaction designers and software developers in the field of robotics. This paper describes the framework of the pattern language that was developed in the NIKA project and outlines the steps that are necessary to create new behavioral design patterns within this framework.

CCS CONCEPTS

• Human-centered computing~Systems and tools for interaction design

KEYWORDS

Social human-robot interaction, behavioral design patterns, pattern language

1 Designing Social, Assistive Robots

There is an increased interest of applying robots not only in industrial contexts, but bringing them to the homes of people where they are expected to support and assist humans in their daily lives.

Particularly older adults benefit from domestic assistive robots, as such robots can help them maintain an independent, active and self-determined life. To make robot applicable in everyday situations, researchers in human-robot interaction (HRI) are constantly developing and improving robotic skills to enable a smooth cooperation with humans. Such skills are, for example, handing over objects, accompanying humans, as well as context, speech or face recognition. Although theses technical developments found the basis of any interaction between robots and humans, they are not sufficient to render this interaction successful: It also important to make sure that a robot's action is understood intuitively by the human interaction partner and that the interaction is experienced as pleasant.

Although HRI is a growing field of research, until now, no comprehensive proposition has been made on how exactly a robot's behavior needs to be designed in order to be experienced positively by humans.

While design knowledge and best practices have been well researched and documented for graphical user interfaces, this is not the case for robots. In the domain of HRI, design knowledge is often fragmented or focused on very specific aspects of the robot's appearance or behavior. There are no design guidelines that provide explicit instructions for designer and software developers how to design robot behavior that leads to a positive perception of the robot and the interaction.

2 A Pattern Approach to HRI Design

The research project "NIKA – User-Centered Interaction Design for Context-sensitive and Acceptable Robots" is aimed at developing *design suggestions for reoccurring interaction situations*, i.e. behaviors of the robot that humans encounter frequently and in different interaction scenarios. Such reusable design suggestions will reduce the effort for the design team and support the design of consistent robot behavior, thus promoting the development of user-friendly and trustworthy robots. The ultimate goal of NIKA is to create guidelines for HRI design that are generic enough to be used for assistive social robots of various appearances (humanoid, animoid, abstract).

The developed design suggestions are documented as *Behavioral Design Patterns*. The concept of design patterns has been first introduced by Alexander [1] in the domain of architecture and since then been transferred to different application areas in the field of human-computer interaction (HCI), such as software design [4], interface design [9] and interactive exhibits [2]. Some proposition have been made to apply the pattern approach to HRI [5, 6, 8], but none of them resulted in structured guidelines for the behavioral design of social robots.

The NIKA project therefore develops a framework that defines the structure and formal documentation of the pattern language as well as a concrete set of behavioral patterns that describes

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solutions to reoccurring design problems in HRI (compare Borcher's definition of a design pattern [2]).

2.1 Framework of the NIKA Pattern Language

The framework of the pattern language was developed based on the existing HCI pattern approaches mentioned above as well as the structure of *ROS Enhancement Solutions* which describes conventions for introducing solutions to re-occuring problems for the Robot Operating System (ROS) [7]. Table 1 shows an overview of the attributes that need to be specified to generate a comprehensible and sufficiently detailed pattern description.

Table 1. NIKA pattern structure.

Attribute		Attribute description
Name		Short, to the point description of the core of the solution
Preamble	Type	Pattern Type (Level 1 | 2)
	Ranking	Indication of how valid the pattern is
	Version	Version no.
	Author	Authors' names (+ e-mail address)
Design Challenge	Interaction Situation	Describes the general situation in which the patter occurs including the expectations and needs in this situation from the user's point of view
	Communication Goal	Describes the design problem at hand, focusing on the communication goal, i.e. what the robot behavior should communicate to the human interaction partner
Design Solution	Solution	Text description of the approach how to solve the design challenge as an instruction for the designer
	Illustration	Visual representation of the solution
	Rationale	Reasoning behind the proposed approach: inspirational examples and scientific references
	Examples	Concrete use cases in which the pattern can be used, visualized as story boards
References & Context		Connections with other patterns

2.2 Eight Steps of Pattern Generation

Existing pattern approaches usually generate pattern by analyzing existing solutions, e.g. software applications, and extracting design propositions that have been proven to be successful. This approach cannot be followed for pattern generation in HRI as there not sufficient solutions that can be analyzed. On the contrary, in this context, patterns are understood as design guidelines for future realization of social, assistive robots. The NIKA pattern approach is therefore based on the idea to generate patterns based on concrete use cases with accumulated knowledge from psychology, social science, HCI and HRI research. This process consists of eight steps.

Step 1: Generation of Essential Use Cases

As a starting point, the most relevant use cases are specified and noted down as *essential use cases* [3]. An essential use case is a formal documentation of the use case, structuring it into abstract *user actions* and *system actions.*

Step 2: Extraction of relevant Micro Interaction Steps

We define each interactions step within an essential use case (user action or system action) and an *micro interaction step.* By extracting all interaction situations that describe the behavior of the robot (system actions) from the essential use cases, we create a collection of those robot behaviors that we need to create patterns for.

Step 3: Specification of Communication Goals

The NIKA project takes a user-centered perspective on HRI and robotic design. To include this perspective in the pattern generation process, each *micro interaction step* of the robot is associated with a *communication goal.* The communication goal describes which message the robot intends to communicate to the human interaction partner with its behavior. Ideally, the communication goal is phrased from the robot's perspective (e.g. "I am currently processing the information you provided.").

Step 4: Desktop Research

The patterns are meant to combine existing knowledge about relevant aspects for the design of a robot's behavior and present them in a structured and usable way. To be able to generate a reasonable design solution for a given communication goal, we first need to gather existing knowledge and research findings from psychology, social science, HCI, HRI and other relevant domains. This is realized in an extensive desktop research. For the communication goal mentioned above this desktop research would, for example, contain ways how human beings, living organisms and technical products convey that they are currently processing information they received.

Step 5: Creation of Inspiration Boards

To communicate the findings of the desktop research within the design team, *inspiration boards* are created. *Inspiration boards* are large posters that contain a collection of the findings as text, sketches or pictures. One board is created for each communication goal.

Step 6: Development of Pattern

Based on the inspiration boards, first pattern are created within the defined framework (Table 1), starting with the description of the *situation*, *communication goal* and *solution.* The *rationale* is added based on insights of the inspiration board.

Step 7: Evaluation of Pattern

Each initial pattern needs to be evaluated with end users to ensure that it serves the intended communication goal. This evaluation should include both, a context-independent and within-context user study that integrates a number of patterns into one complete use case.

Step 8: Revision of Pattern

The initial version of each pattern is, if required, revised based on the evaluation research and tested again.

2.3 Future Challenges

Within the NIKA project the four first steps have already been carried out and the extracted micro interaction steps (and communications goals) have been prioritized, in order to make an informed decision for the first patterns to be created. Steps 5 and 6 have been performed for three selected communication goals as a test run, which resulted in the first three NIKA patterns. The next steps will be to produce more patterns to have a sufficient set to start with the first evaluations.

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