A first prototype of a space model of cultural meaning by natural-language human-robot interaction

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ABSTRACT

When using assistive systems, the consideration of individual and cultural meaning is crucial for the utility and acceptance of technology. Orientation, communication and interaction are rooted in perception and therefore always take place in material space. In our understanding, a major problem lies within the differences between the human and the technological perception of space. Cultural policies are based on meanings, their spatial situatedness and rich relationships amongst them. Therefore, we have developed an approach, where the different perception systems share a hybrid space model generated in a joint effort by humans and assistive systems by means of an artificial intelligence. The aim of our project is to generate a spatial model of cultural meaning, which is based on the interaction between human and robot. The role of the humanoid robots is defined as "companion". This should allow for technical systems to include so far ungraspable human and cultural agendas into their perception of space. In an experiment, we tested a first prototyp of the communication module, allowing a humanoid to learn cultural meanings by means of a machine learning system. Interaction is done by non-verbal and natural-language interaction between the humanoid and testpersons. It leads us to further understanding on the developement of a space model of cultural meaning.

CCS Concepts

Human-centered computing → Human computer interaction (HCI) → HCI theory, concepts and models

Keywords

Humanoid robots; space model of cultural meaning; interaction design; language game; machine learning.

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1. INTRODUCTION

Human day to day life is increasingly enriched by a variety of technologies. Artificial intelligence is already used in areas such as the stock market, face detection or in control of mobile phones. The fusion of A. I. with robotics will provide services for the everyday life which at the same time satisfy individual desires and solve social problems. These assistive systems are developed for areas like, sale, entertainment, communication as well as elderly and health care. Concerning care taking, the hope of our aging society is increasingly set on humanoid robots. Anthropomorphic machines are most likely to support humans and arouse confidence, when they move "naturally" in the intimate physical and social space, where care taking and assistance takes place. Their physical, humanoid shape does not require major changes within a human environment. Social skills and the capability to learn independently from their environment are crucial for the acceptance of assistive robots [1,2].

2. Perception – Space relation

Social robots are in contrast to existing domestic engineering or ubiquitous computing systems mobile and partly autonomously operating technologies. We are currently living in spaces permeated by technology, whereas the degree of technology is constantly increasing. In modern buildings, basic utility and domestic engineering systems for building automation such as electricity, wireless networks, ventilation and connected lighting systems are already provided. The innovative functions of humanoid robots are ranging from the access to physical objects, to digital objects from other technical systems, to the movement in the room and social interaction with humans. Mobil robots introduce new possibilities where place bound technologies reach their limits. At the same time they do not only move in physical space but simultaneously operate in virtual space through their digital inter-connection; thus they represent a form of node in a network between these different types of spaces; a mobile and autonomous node.

In the contemporary technology development two technological approaches complement each other. The concept of the so called ubiquitous computing, conceptualized by Mark Weiser in the early nineties [3] and the development of social robotics [4] are basic elements of the direction of technology development in the twenty-first century. Weiser's approach assumes that technology is woven into everyday life and eventually becomes indistinguishable. While some technologies discreetly seep into the living space, robots explicitly appear as artifacts of the social robots approach. Due to their simulation of isolated human skills and their human appearance humanoids are the most expressive form of robots. The technical performance of both directions of development is achieved through a network of automated operating sensors and algorithmic processing of the data in models by software. The collaboration of these components represents a technical perception system. The tasks of this type of technology can range for instance from the trivial regulation of room temperature to enabling autonomous behavior of hyper-complex machines such as humanoid robots. These examples show the expediency of different technical perception systems, whose different objectives produce different forms of space of perception. While with the first example simply air temperature is connected with heating, the second example projects “the world“ for an artificial intelligence-system. The complexity and un-predictability of the everyday world in which we humans move rather effortlessly constitutes a major challenge for hyper-complex technical systems. All technical perception systems show essential differences compared to the human perception systems. Their quantitatively technical-abstract parameters are opposed by personal meaning embedded in a cultural context. Thus humans and humanoid assistants act in very different perception spaces.

The technological development is currently faced with a paradox: some robots are developed for the most intimate areas of human existence - however they cannot participate in human perception space. Artificial intelligences are limited by their technological perception systems and data models. Data is only recorded according to their perception systems and processed according to the model; which defines the characteristic of the performance of the technological system. Thus, technical systems exist in other spaces of perception than humans. The various technical perception systems have essential differences to the human system, after all they conceive space through geometries, numbers and images. Whereas for humans space is only marginally defined by technical-abstract factors, but rather mainly through personal experiences, associations and habits, each rooted in cultural meaning. These meanings are never fixated. Rather a permanent negotiating takes place between intersubjective meaning and individual meaning. A negotiation between individuals, and between individuals, objects and processes. Even though robots are equipped with the most advanced technical perception systems and they are not equipped to grasp humane meaning at all, as well as they are not able to share the same perception space as humans; this is where the problems motivating our research culminate.

The state of research in this field is for instance defined by concepts such as “Object Recognition“ [5], “Semantic Scene Labeling“ [6] and “Intention Recognition“ [7]. “Object Detection” allows for a technical system to recognize material objects which consequently are labeled by means of “Object Recognition“ or “Scene Labeling“, however this is only possible for objects which do not deviate too much from the common typical form for this object class. Furthermore “Intention Recognition“ considers a functional connection between recognized objects and their related actions. These existing concepts share the fact, that they solve the given problem according to the technical possibilities. Thereby the cultural meanings of objects are marginalized, individual meanings can’t be introduced, by the technological representation of data and tend to disappear.

2.1 Theory towards human – humanoid relations

The term language game [8] coined by Ludwig Wittgenstein implies that every verbal expression is rooted in human life, because the various human language games only make sense there. Each word, each term and each sentence have meanings which are dependent on the context of the action and situation in which they are uttered. Also for example, mathematics and formal logic belong to language games. Referring to the philosophical language game our architectonic space-game makes use of the relation between verbal expressions and human practices. Although in contrast to the language game the space game aims to negotiate cultural meaning between humans and humanoids in order to constitute a shared cultural meaning of space. Through a natural-language human-machine communication a mutual construction of space and meaning becomes possible in a dialog. With the possibilities of the humanoid shape human gestures and postures are imitated in order to enrich this setup with non-verbal communication. Using this interaction, a perception space for humanoids evolves which was formed interactively from meanings exceeding technical parameter.

It was a relatively simple and everyday situation from which the French philosopher Jacques Derrida developed his complex thoughts and profound reflections. One day when Derrida just got out of the shower he realized that he was standing naked in front of his cat which had sneaked into the bathroom. What fascinated him about the situation was the simple observation that he had felt ashamed to be exposed to his cat’s glance. Although the cat certainly did not have any idea what nudity meant and most-likely also was not interested in his nudity, Derrida still felt observed by the gaze of his cat. “How can an animal look you in the face?“ Derrida asked in the lecture “The Animal That Therefore I Am“, in which he describes this very situation [9]. Humanoid robots for domestic needs are built to look us into our face. It nearly seems as if this skill was their main purpose, even one of the reason they were invented, namely because these robots have a face which we can look at, one that can look back, which is able to return our gaze [10, 11, 12]. With cameras as their eyes humanoid robots do not only have the ability to “see“, but can also film. Additionally, they possess a number of further sensors which constantly monitor and evaluate their environment. Furthermore, they are connected with numerous other helping and assistive technical artifacts. All this generates a completely different perception of space, time and actions as present in humans who are socioculturally conditioned and architectonically influenced. In a time when humanoid robots advance more and more into our private and most intimate rooms and are thereby able to look at us - should we feel ashamed? Or are these robots simply an accumulation of technically based offers in a system they represent, merely technical servants whose glances are not touching us? Or are they rather a kind of companion, hybrid creatures who share our most intimate rooms, while at the same time potentially able to share what they see worldwide via the internet?

Which principles make sense for creating a relationship between unique, human individuals and some kind of serial, distorted, technical “mirror image of a human”, namely a humanoid?

All too often the relation between humans and robots is understood as one of many different variations of master and servant, different yet always relations of hierarchy. But we developed a very different concept for the relation, by integrating its spatial context.

In her book “When Species Meet“ [13] the American philosopher and theorist Donna Haraway criticizes Derrida’s approach because he did not take the possibilities of the cat’s gaze seriously and overlooked the various opportunities and meanings of the cat’s glance. This gaze of the cat is - according to Haraway - an invitation to a “becoming with“, what she calls “companion species“, because each glance is always a reciprocal process, each living with such a creature is a becoming with. According to Haraway this becoming with requires a different approach to ethics, an ethics of shared responsibility. Just as a guide dog is responsible for its owner the owner is likewise responsible for the dog. A life together is based on a shared responsibility. This is a principle which is not only valid for relationships between humans and dogs: “Responsibility is a relationship crafted in intra-action through which entities, subjects and objects, come into being.“ [13].

Based on Haraways approach, we understand the humanoid robot as some kind of “companion species” to the humans who live closely with these technical devices. How can a shared responsibility between humans and robots look like? Based on a similar understanding of shared responsibility, we want to reflect upon ethical, political and spatial consequences and develop a technical system in which humans take care of their robots which likewise support humans in everyday life.

Furthermore it always has to be considered in which power structure these humanoids are developed, explored and applied. As Langdon Winner asked in his Essay “Do Artifacts have Politics?“ [14], we also want to question which cultural, ethical and political conceptions should be installed in such robots, especially related to architectonic space forming the domestic environment.

It is state of the art that technical perception systems express objects and users in numbers, register spaces geometrical and present them visually. However they are not capable of associating, variating and contextualizing meaning. Hence they are not capable to put those objects in a meaningful relation to each other. In contrast to this we have developed an approach in which the creation of a space model of cultural meaning is based on the interaction between human and robot. The machine is thereby considered a “companion“.

2.2 Theory on Cultural space production

The human lifeworld is essentially spatial. Hereby space is mainly a holistic substrate of meanings and their positioning, from which all relations which are discussed in social and cultural space theories emerge [15, 16]. Architecture devotes itself especially to the aspects of space to live in. Changes lie ahead of the domain, that will transform behavior concerning the creation and use of space that had been conserved culturally for a long time. Buildings as we know them will thereby be increasingly extended by mobile parts and sophisticated control. We are standing on the cusp of a development with which in the near future technological artefacts like a house and a robot will form everyday perception spaces through their interaction.

Space, the basis of the relational lifeworld of humans, is fed into the managing algorithms of specific technical systems by technical perception systems through numbers, geometries and images. However they are neither able to detect the meanings, nor to put these parameters of the surrounding in culturally meaningful relations to each other. Thus technical systems exist in other spaces of perception than humans do. The powers of each space of perception competes for the interpretational sovereignty concerning the actual everyday world. This structural otherness of human and technological realties contains potential conflicts and risks. Often users feel bossed around, pressed or unchallenged by assistive systems hence feel alienated and denaturalized in a lifeworld that’s no longer theirs’s and therefore reject them.

The social and cultural spaces of humans are diverse. Whereas culture is understood here as the context of values and knowledge that informs the social as the realm of communications, acts and organizations of humans. Humanoid robots should be applied in private households, semipublic premises or public malls. Social space is not a permanent fixed space, but is in fact constantly “produced“ [17] and is therefore in permanent change. The production of space is thereby never a neutral process, but rather determined by power structures, economic interests and cultural hegemonies. We call such an understanding of space, a cultural concept of space. Just as space technologies should not be considered neutral, because even these power structures are in-scripted, our project tries to address those questions of power and furthermore wants to support the empowerment of the users over the artificial intelligence. Thereby “technical objects“ [18] are thematized as active protagonists. Thus also humanoid robots are not only simple objects or neutral actors, but have to be theorized and examined as active designers of such spaces.

How spaces are designed, modified and produced and how we move and interact with each other in these spaces is mainly influenced by perception. What we see, hear and feel is co-determined by our environment. However the way objects, spaces and humans are seen, felt and heard is significantly influenced by cultural factors. Which cultural meanings spaces and objects have is also constantly renegotiated and transformed. Hence we consider humanoids are co-producers of social spaces and interact equally with the space and the humans in it. In order for these machines to perform tasks such as care-taking, selling products or other assistive services and also in order to interact appropriately with humans, they have to learn to cope with these cultural meanings, i.e. this cultural concept of space. Therefore the cultural meaning cannot simply be programmed. Not only because meanings change but likewise they constantly have to be renegotiated and can be individually very different. Thus humanoid robots should not only learn to recognize those cultural meanings, but should also be able to co-create those meanings. Thereby they will hold a new position between existing technologies and humans.

Through this approach technical systems should be enabled to develop a concept of space by an interactive requisition of cultural meanings; humanoid robots and artificial intelligence are being domesticated. The intended space model of cultural meaning is understood as an adaptive system. Through interaction it adapts to its environment and different individual and spatial conditions.

3. HYPOTHESIS AND QUESTIONS

Summarizing section 2, the overall context of our research questions is how to develop a space model of cultural meaning, in a machine learning system, as the operational basis for human as well as humanoid perception systems. As a hybrid spatial model it is conceived to mediate between humans and humanoids by integrating cultural meanings into human-robot interaction on the intersubjective and the individual level. Hence a kind of medium will be created, that is informed by the different perception systems. The humanoid robot and its artificial intelligence can thereby be involved in a shared context of meaning with us humans. For this we use the skills of a humanoid robot for human-like interaction as an approach for both, data-acquisition and model-generation. In the space model discussed here the meanings of objects and there relations are determined through verbal interaction and interconnected using the algorithms of machine learning. Through gathering and connecting of located meanings a space model is developed, which is no longer reducible neither to technical parameters nor to human perception. Instead, a hybrid space model based on interaction is created together.

Our approach follows the hypothesis that in the natural language communication between humans and robots, and with the help of the particular features of a humanoid robot (body language, autonomous movement, guiding a very intuitively designed conversation) a space model of cultural meaning can be developed. This model is neither reducible to technical quantifiability nor to human spatial perceptions, but it introduces a third hybrid interpretation of space based on the cultural meaning of objects and room parts.

The realization of the concept for our space model of cultural meaning is developed in three modules of prototypes: (I) Verbal and non-verbal communication of humanoid robots with humans for the learning of meanings with the machine learning system, (II) Technical system for autonomous object definition from recognition and location, (III) Generation of verbal and non-verbal responses of the humanoid by combining the outputs of the machine learning system and object definitions.

The most important research questions for this first stage of development of our prototype are:

1) Can the interactive creation of a space model of cultural meaning be technological robust, even in a bustling environment and be successful in real-time?
2) Will the generated model be accepted as a representation by users? (narrative interviews)
3) Will Users consider this representation as a relevant abstraction of individual and intersubjective meaning of space and objects? (narrative interviews)
4) Reaction of users on the humanoid as a dialog partner, the kind of acceptance, e.g. terms uttered, usage and modulation of speech like adult versus child, dominance versus subordination. (observation and filming)

4. Artistic research Methodology

These questions will be addressed under the use of trans-disciplinary methods in artistic research and reflected philosophically; thereby new trans-disciplinary approaches and methods ought to be developed and intervened in the current debates and discussions concerning robot ethics [19].

To research on humanoid robots as possible future "companion species", also means to integrate the above-mentioned questions of new kinds of perception. The ascription of meanings to objects, rooms, components, people and machines is a network-like reference system, which consists of geometric, figurative, social and cultural relations. Thereby meanings of single parts and their relations constitute each other mutually and are thus constantly transformed dynamically in negotiations. Integrating/Using sensors, which technically produce completely different images of the environment than the human perception system, the trans-disciplinary, artistic research can especially help to make these special kinds of perception visible and can furthermore show opportunities how an interaction of humanoids with the human perception system can be interwoven, in order to generate a cultural model of lifeworld from individual and intersubjective meanings. A space model which is neither reducible to the human nor to the humanoid perspective.

The research on problems of the lifeworld requires a methodical course of actions which integrates approaches of different disciplines. The transdisciplinary approach of this project consists of the merging of expertise from architecture, automatization technology and philosophy. Synergies develop through the overlapping and sharpening of questions like ours in search of a space model of cultural meaning. In addition we use methods of artistic research to widen our approach. Artistic research is already being used in HRI-studies, like in the case of the Theatrical Robot [2]. Thereby the artistic implementation of human-robot interaction is applied in a performance in order to accomplish social scientifically studies. In contrast to this, in our project artistic research is not used as an artistic tool for a social-scientific purpose, but to apply artistic research methodology.

The variety of complexity in our life-world persists in detail of a surprisingly large number of singular objects and processes. The permanent every-day discourse about operations in and about these objects and processes is only partly graspable with teleological methods. Artistic research methods do not follow explicit targets but are developed rather open-ended and yet goal-oriented. They do not necessarily need to be developed along cause-effect relations and can apply non-causal effects. They explicitly apply vagueness, intentional misreading and superpositions of established concepts, furthermore references and sources and from different disciplines as well as non-scientific bodies of human knowledge can be integrated in the research. Original phantasies and deductive argumentation are considered equally "[…] where logical thinking is naturally intertwined with associative and intuitive conceptualization." [20] For this project it is necessary to work with artistic research methodology. As it does not focus on efficiency but on the aesthetics of interaction, not on reproducibility but on the variability of the interaction, not on precision but on cultural depth of the interaction. Artistic research accompanied by social scientific methods, enables us, to develop, evaluate and reflect the questions concerning the cultural meaning of space, the different kinds of perception of space and spatial relations of robots and non-robots. These specific kinds of interactive and reflective processes [21, 22, 23] are applied for the actualization of a space model of cultural meaning. The findings and insights will not be rated with social and technical targets in a cause-effect relation, but are evaluated as an open result in context of the life-world.

5. Prototype (I), verbal and non-verbal communication of humanoid robots with humans for the learning of meanings with the machine learning system

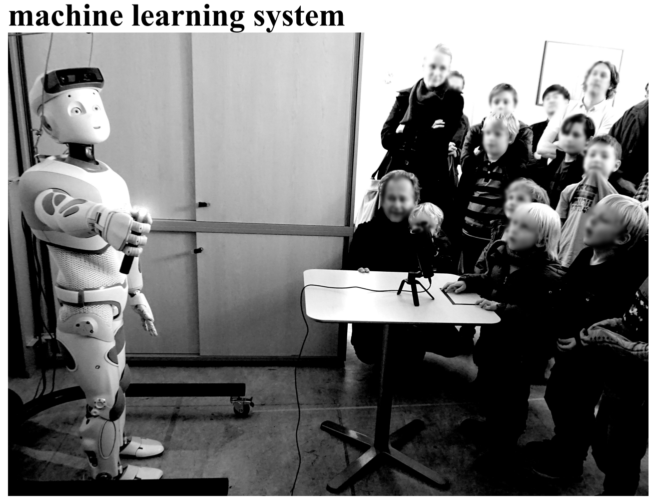

Figure 1. Robot Romeo in the experimental setting at the "Long Night of Robots" at the Vienna University of Technology.

As first attempt of implementation we developed a prototype (I), that has been tested in a first experiment with different people of all ages, unfamiliar with machine learning and robots, as well as different kinds of experts. Based on the experience of these preliminary experiments, this paper presents the first considerations on how the prototype of a space model of cultural meaning can be further developed, and which problems and questions still have to be solved.

5.1 Experimental setting

The principial elements for the setting to generate a space model of cultural meaning consists of the following elements: (a) humanoide robot, (b) machine learning system, (c) test persons, (d) objects and areas of the room.

(a) humanoid robot: A stationary humanoid robot, the model "Romeo" by the company Aldebaran, is equipped with our machine learning system. Besides sound input and output, the most crucial ability of the robot is to extend the verbal communication by various gestures. We consider it of crucial importance to create a communication experience, similar to a conversation amongst humans. The robot was trained to use various non-verbal gestures and common sense phrases of small talk, in order to enrich the interaction. In order to clearly communicate the gestures of the robot in the turbulent and completely crowded room, the robot pointed on the objects with a flashlight to enquire their name, function and meaning (Fig.1).

(b) machine learning system: Through the cloud-based speech recognition of Google the voice input is converted into text. The access to the Wordnet through LibLeipzig enables the definition of the particular grammatical infinitive and thus a first categorization of each term by its word class. The specific categorization of the entire input is made by the library of machine learning by Orange in Python. The machine learning system contextualizes the meanings generated through the interaction with certain areas of the room in relation to the position of the robot. Terms were categorized and reduced to their basic form. The answers of the visitors were itemized for each of the six objects in the categories name, function and features (Fig.2). Our machine learning system generates a hierarchy of meanings but without letting the individual meanings vanish. On the contrary, the individual meanings are especially used as part of the further exchange by an individual user with the machine. As an important aim is to correspond also to the individual range of meanings of the users of the assistive technology. With this prototype (I) individual meanings are captured and counted, but (they) are not yet set in relation, in order to accurately develop the accumulation of intersubjective meanings.

Through the different conversations the machine learning system culminates a variety of terms for each item requested by the robot and also for all the other items which might have been thematized. These terms are evaluated by the artificial intelligence depending on the frequency.

(c) test persons: In order to make the technical system transparent to the visitors, the inclusion of the human statements and the placing of the meanings are presented to the visitors on a screen. Since both happen in real-time, the visitors can follow how their stated meanings are included into the system.

We were invited to make a contribution to the "long night of robots", which took place on the 25th of November 2016 in Vienna, as part of the "European Robotics Week". We used the opportunity to do a first experiment with our first prototyp of (I) verbal and non-verbal communication between the humanoid and the visitors in order to generate cultural meaning in the machine learning system. We expected the visitors to have very different foreknowledge, social and cultural backgrounds and interests, but nonetheless being interested layman in robotics. Our contribution offered the visitors a "conversation" with a humanoid robot: a natural-verbal interaction supported by gestures about the space and the meanings of the some surrounding objects.

Due to the invitation to a public event in Vienna the robot communicated in German language. Modifying the speech recognition from German to English, and change the LibLeipzig library to TextBlob, would make the experiment reproducible in English.

(d) The setting of the interaction was a 60m2 large room in the robotic laboratory, divided into an experiment area and a visitor area, including several objects and parts of the room: a cabinet, an overhead light, a fire extinguisher, the floor, a window and the robot Romeo itself. The objects were spread out in the room.

5.2 Experiment process

The robot points at objects and parts of the room and asks the visitors about personal meaning (Fig. 1). Four types of questions in different variations were asked about six predefined objects in the room. Questions are stated in natural language with common sense phrases and accompanied by distinct non-verbal gestures. The responses of the visitors are registered by the machine-learning system. Parallel to communication with the robot, visitors could also observe on a screen, how their voiced answers were allocated to a specific location within a floor plan of the room and weighted by the answers before (Fig. 2).

5.3 Experiment RESULTS

Evaluation of research question 1: Within the "European Robotics Week" our projected invited the public along with other projects through press releases to the "long night of robots" at the Vienna University of Technology. The organizers were overwhelmed by the rush of more than 1000 interested visitors. This visitor frequency overstrained the prepared setting several times. We had the opportunity to do narrative interviews with mainly layman, but also with a philosopher specialized inphilosophy of technology, a psychoanalyst, and several researchers in in the field of robotics. However, in total 258 interactions between visitors and the robot Romeo could be stored.

Evaluation of research question 2: In the narrative interviews that we conducted with some of the visitors, nearly everybody accepted the representation of the model at an instance. The reason was the familiarity with a floor plan and the text which was shown on the screen. This simple fact overwrote the strangeness of the humanoid and the abstractness of the invisible machine learning system. Hence it was mostly understood as relevant.

Evaluation of research question 3: The level of abstraction was understood and considered relevant for matters of the everyday lifeworld.

Evaluation of research question 4: In this first experiment, the robot was set up to ask questions and store the answers in a machine learning system. The interviewed persons reacted with different modes of speech to the robot and his questions: some spoke slowly and over articulated, almost as if they were speaking to a toddler. Others used only single words. Another group of visitors spoke as if they were answering the question of a human vis a vis. Although the visitors were aware that the robot could not reply in context, they still tried to change the questions-answer-dialog into a complex conversation. Counter questions were often

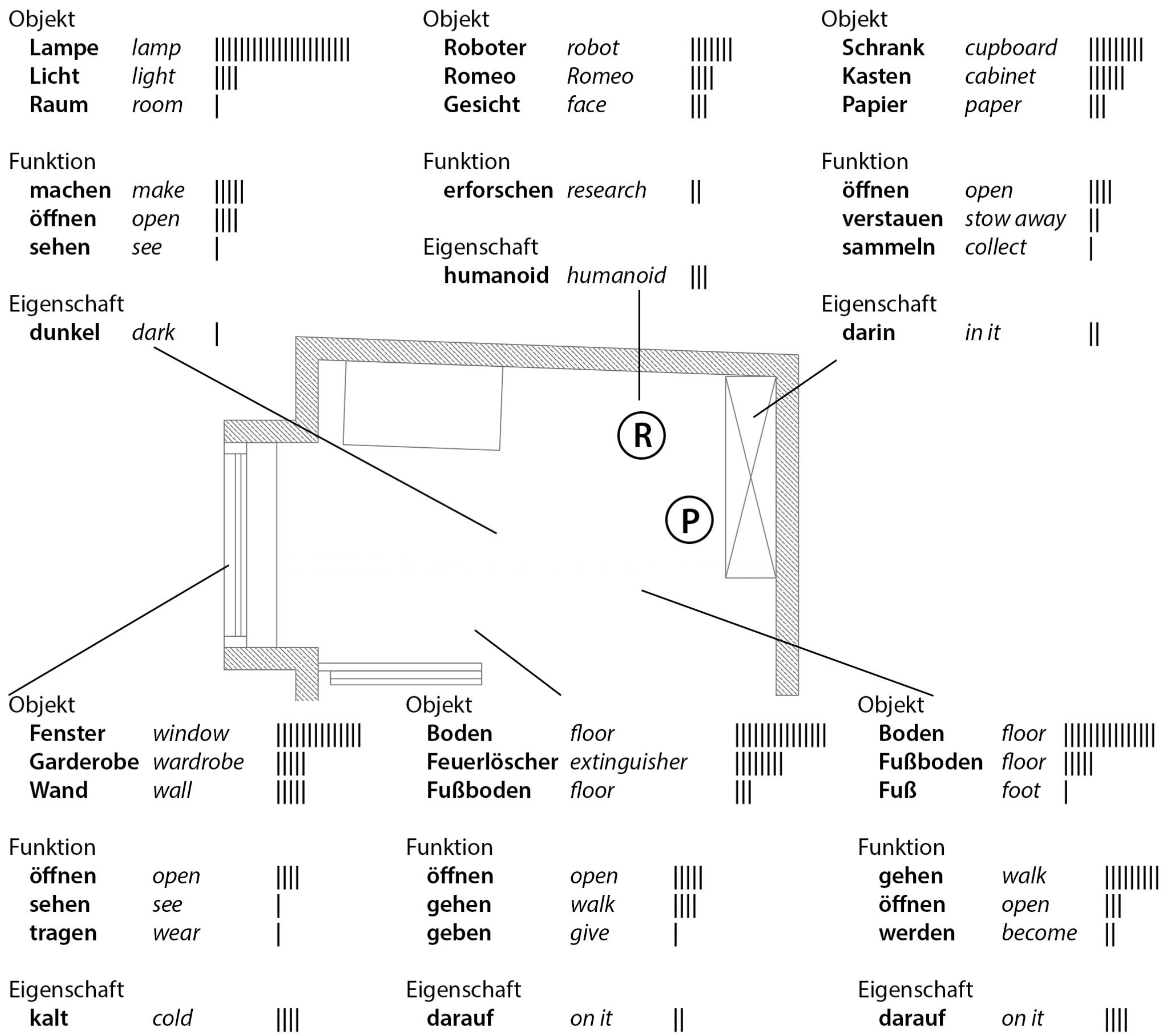

Figure 2. Floor plan of the experimental area with the location of the six objects, translated to english, the Robot (R) and the interview partner (P). Naming of object, function attributed to object, property associated to function and object. Bars indicate the number of mentionings.

asked and the comprehensions of the robot were inquired. Many people tried different modes of speech in their conversation with the robot, and changed therefore their modes of speech as the conversation developed.

Evaluation of prototype (I): Our system achieved reliable terms for most of the objects and areas of the room. Only for the object “fire extinguisher“, “floor“ was mentioned more often as a result of equivocal pointing and its interpretations. In this case the attribution of “fire extinguisher“ got succeed by “floor”.

Additionally, unexpected connections occurred. As an example, “wardrobe“ was associated with the feature “cold“ and “overhead light“ with “dark“. This was not obvious at the beginning, exemplifying therefore the before mentioned constant negotiation process, with variables like “cold” for the season. The object “cabinet“ was connected to the feature, that something is “in it“, just like the floor is a part of the room “on which“ something is situated. The examples “wardrobe“ and “floor“ show, that inherent features and concepts from the verbal analysis were filtered out correctly. Within the machine learning system our space game maps cognitive connections between objects. For example, the term wardrobe is directly associated with the terms "wear" and "cold". Other systems, like mentioned in section 2, would have to bring these terms into context. Our system has to solve the challenge to separate the context (future work 2). A combination with the field of Scene Labeling might be promising.

Our expectation was that intersubjective and individual meanings could be mapped and related with a non-verbal and natural-language dialog. In this respect the prototype (I) worked. Indeed, a space model of cultural meaning started to develop.

6. FUTURE WORK

1. An experiment with 150 test persons will be held in controlled setting by mid-march. The evaluation of this experiment will be available in mid-april. Inputs in the machine learning system are thus related to each other and categorized. This will be done with the classification- and regression algorithms by Orange in Python, like for example with the simple method: “k-nearest-neighbors“. (I)

After the evaluation of the interaction and the thereby generated space model the results will be applied to the development of further modules in several prototypes, as mentioned above:

2. Relation of the meanings of the objects and areas of space. (III)
3. Recognition of objects and building parts by the robot and simultaneously location of specific meaning in combining the pointing direction of the robot and expanding the robots sensors by ultrasound measurement. (II)
4. Generation of answers by means of the machine learning system (III)
5. Additionally to intersubjective meanings the individual meanings get processed by the machine learning system. (III)

Once a robust prototype of the three modules has put to work as a space model of cultural meaning, further goals are:

6. Ethical problems of privacy on at least two levels: usage of meanings in the system in different situations of the everyday, and usage of individual data in the machine leaning system.
7. The introduction of time as a dimension in the model. The planned approaches consider time as the fourth dimension or cinematically as the third dimension in a two-dimensional space.
8. After the assessment, interconnection and categorization of the meanings generated, we will test the placing of whole networks of meanings and their categories.
9. Applying of the meanings and the diverse concepts of space in different cultures like e. g. the Japanese.
10. Prediction of meaning through the classification- and regression methods mentioned above.
11. Extending the natural-verbal communication with non-verbal elements like human gestures in connection to facial expressions and brainwaves of moods.

7. REFERENCES

[1] Duffy, B. R.: Anthropomorphism and the social robot. Robotics and autonomous systems, 42(3), (2003), 177-190.Ding, W. and Marchionini, G. 1997. *A Study on Video Browsing Strategies*. Technical Report. University of Maryland at College Park.

[2] Dautenhahn, K.: Methodology and themes of human-robot interaction: a growing research field. International Journal of Advanced Robotic Systems, (2007).Tavel, P. 2007. *Modeling and Simulation Design*. AK Peters Ltd., Natick, MA.

[3] Weiser, M.: Ubiquitos Computing. Computer 10, (1993), 71-72.

[4] Brooks, R. A.: Intelligence without representation. Artificial intelligence, 47(1), (1991), 139-159.

[5] Varvadoukas, T.; Giannakidou, E.; Gomez, J. V.; Mavridis, N.: Indoor Furniture and Room Recognition for a Robot using Internet-derived Models and Object Context. 10th International Conference on Frontiers of Information Technology, (2012), 122-128.

[6] Koppula, H. S.; Anand, A.; Joachims, T.; Saxena, A.: Semantic Labeling of 3D Point Clouds for Indoor Scenes. Neural Information Processing Systems, NIPS, (2011).

[7] Krauthausen, P.: Learning Dynamic Systems for Intention Recognition in Human-Robot-Cooperation. KIT Scientific Publishing, Karlsruhe, (2013).

[8] Wittgenstein, L.: Philosophische Untersuchungen. Wissenschaftliche Buchgesellschaft Frankfurt, (2001).

[9] Derrida, J.: "The Animal That Therefore I Am (More to Follow)". Critical Inquiry, Vol. 28, No. 2 (Winter, 2002), 369-418.

[10] Coeckelbergh, Mark.: Humans, Animals, and Robots: A Phenomenological Approach to Human-Robot Relations. International Journal of Social Robotics 3, (2011), 197–204.

[11] Coeckelbergh, M.: Growing Moral Relations: Critique of Moral Status Ascription. Palgrave Macmillan, (2012).

[12] Coeckelbergh, M., Gunkel, D. J.: Facing Animals: A Relational, Other-Oriented Approach to Moral Standing. Journal of Agricultural and Environmental Ethics 27, (2014).

[13] Haraway, D.: When Species Meet. University of Minnesota Press, (2008).

[14] Winner, L.: "Do Artifacts have Politics?". The Whale and the Reactor: A Search for Limits in an Age of High Technology, Chicago: University of Chicago Press, (1987).

[15] Dünne, J.: Raumtheorie: Grundlagentexte aus Philosophie und Kulturwissenschaften (suhrkamp taschenbuch wissenschaft), Suhrkamp, (2006).

[16] Günzel, S.: Raumwissenschaften (suhrkamp taschenbuch wissenschaft), Suhrkamp, (2008).

[17] Lefebvre, H.: The Production of Space. Blackwell, (1991).

[18] Simondon, G.: Die Existenzweise technischer Objekte. Zürich, diaphanes, (2012).

[19] Lin, P. et al. (Hg.): Robot Ethics. MIT-Press, (2015).Dyrssen, C.: Navigating in Heterogeneity: Architectural Thinking and Art-based Research. Biggs, H., Karlsson, M. The Routledge Companion To Research In The Arts, (2011).

[20] Klein, J.: Was ist künstlerische Forschung. kunsttexte.de/Auditive Perspektiven, Nr. 2/2011, www.kunsttexte.de. (2011).

[21] Rey, A.; Schöbi, S. (Hg.): Künstlerische Forschung – Positionen und Perspektiven. Museum für Gestaltung Zürich (2009).

[22] Badura, J. et. al (Hg.): Künstlerische Forschung. Ein Handbuch, diaphanes, (2015).