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Towards Creative Humanoid Conceptualization Learning from Metaphor-Guided Pretense Play

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Abstract

This paper describes a newly proposed approach towards investigating how social humanoid robots can learn creative conceptualizations through interaction with children in *metaphor-guided pretense play* using a componential creativity framework. We describe this metaphor-guided pretense play approach and then illustrate it by describing a social robot interaction pretense play scenario between a child and a humanoid robot.

Introduction

Creativity in humans has not only been a subject of interest by researchers but the topic of robots that are endowed with creativity has also been of interest in science fiction. It is believed that the ability of a robot to exhibit creativity will demonstrate a characteristic of true intelligence. This paper describes how we propose to enable cognitive agents to teach each other how to be creative through the use of metaphors. In particular we seek to enable a humanoid robot to learn new creative conceptualizations by observation of a child creating new metaphors. We describe this approach in the context of a socially interactive game conducted by a humanoid robot with a child to promote healthy eating habits. The rest of this paper is organized as follows. We begin with providing background research in creativity using metaphors and discuss related work in human-robot interaction, pretense play and developmental robotics. Finally we synthesize topics from these areas to describe our approach to enabling humanoid robots to learn creative concepts and behaviors through social interaction with children.

Background

Creativity is the quality that is marked by the ability or power to produce through imaginative skill. (As a related aside, it is interesting to note that a key word used in this definition, *imaginative*, has an etymology based in the word *image*.) A dictionary definition of imagination is the ability to form a mental image of something not yet present. Boden (2009) defines creativity as the ability to generate novel, and valuable, ideas (e.g. concepts, theories, interpretations, stories). In describing novel, she defines two distinctions: psychological novelty, or P-creative, and historical novelty, or H-creative. A P-creative idea is one that is new to the person who generated it while an H-creative idea is one that is P-creative and has never occurred in history before. She describes how novel ideas may be produced by combination, exploration, or transformation (Boden 2004). Transformational creativity involves transforming the space or style by altering or eliminating one or more of its defining dimensions.

Scientists have different definitions of what constitutes creativity and may be categorized based on the product, process, or a conceptual definitions (Amabile 1983). Early artificial intelligence researchers, Newell, Shaw, and Simon (1962), suggested that a mechanism, or agent, is creative if it could exhibit behavior just like that of a human performing creative activity. In this case, there needs to be operational specifications for the behavior of the agent and a demonstration that the agent could show phenomena that are thought to be creative. Examples of phenomena they thought would accompany creative thinking included illumination or formation and change in set.

In the product-based definition, creativity is defined as an observable outcome or response that appears novel but appropriate. Amabile (1983) argues that an operational definition based on the product definition is dependent upon the extent that appropriate observers indicate that the product is creative. However, she then explains that a conceptual framework that draws from these two types of creativity is based on two necessary elements (Amabile 1983):

A product or response will be judged as creative to the extent that (a) it is both a novel and appropriate, useful, correct, or valuable response to the task at hand and (b) the task is heuristic rather than algorithmic.

A Framework for Creativity

Amiable (1983) describes a componential framework for creativity that is based on three factors for creativity: domain-relevant skills, creativity relevant skills, and task motivation. She presents a schematic for the creative process based on these skills and motivation that includes:

1. Problem or task representation
2. Preparation
3. Response generation
4. Response validation
5. Outcome

These steps in the creative process are influenced by the creative factors she describes in various ways to increase (or decrease) learning, set-breaking, or task motivation. Task motivation effects problem or task representation and response generation. Task motivation affects the learning of domain-relevant skills as well as set-breaking for creativity-relevant skills. Other relationships among the creative process steps and factors exist that are described further by Amiable. However, of particular interest are the impact of set-breaking and the affect of creativity-relevant skills to response generations.

Creativity-relevant skills have several components including a) breaking perceptual set (Boring 1954), b) exploring new cognitive pathways (Newell et al. 1962), c) using broad categories (Cropey, 1967), and d) breaking out of well-used algorithms, or scripts (Schank and Abelson 1977). The creativity-relevant skills component includes knowledge of heuristics for generating novel ideas (Ambiable 1983; Newell et al. 1962). One of the heuristics provided by McGuire (1973) include generating hypotheses by analyzing previous related cases, using analogies, accounting for exceptions and investigating paradoxical incidents. Amiable argues creative heuristics such as this one that uses analogies can lead to set-breaking and novel ideas. We show how a metaphor heuristic can be used to generate a creative, or novel, product or design.

Metaphors and Creativity

In this section we describe how metaphor is related to creativity. Genter (et. al. 2001) writes that metaphors are critical for problem-solving and describes the steps of using metaphors in this manner. First, one must extract a variety of unfamiliar concepts from remote domains where possible relationships with the current task may not be initially apparent. Second, there must be a mapping of high-level or deep relationships between the metaphor concept and the problem. Performing generalization and abstraction techniques may make this matching possible. Third, secondary relationships may be discarded leaving only structural correspondence between the metaphor source and the problem. Finally, the structural matches, or correspondences, associated with the metaphor source are transferred and applied to the problem, which leads to a novel solution. Using metaphors is an example of a creativity-relevant skill of generating hypotheses that can lead to set-breaking and novel ideas. These metaphors can be used as heuristics to organize problem solving or design thinking to solve loosely defined design problems (Rowe 1987, Antoniades 1992).

According to Indurkhya (1992), a "metaphor is an unconventional way of describing (or representing) an object, event, or situation (real or imagined) as another object, event or situation". The target is the object that is being described and the source is the object that is being used to unconventionally describe the target. A cognitive agent exhibits creativity by creating similarities between two objects that do not have existing similarities (Idurkhya 1992). We will describe in a subsequent section how we design a cognitive agent, i.e. humanoid robot, to interact socially with another cognitive agent, a child, to learn novel solutions to a design problem by seeding the human-robot interaction with an image containing a source metaphor concept. In the next section we show how a child interacting with a humanoid robot can create new solutions using the metaphor heuristic.

Pretense Play and Human-Robot Interaction

Children can create meaning from their social interactions collectively through pretense play (Janes 2002). They can creatively take on imaginary roles, act out stories, and change toys into tools or instructions. Golomb and Kuersten (1996) describe pretense as the ability of the mind to create and recognize the worlds of fantasy and reality without confusion. Children often play "make-believe" and use their imagination to act as though they were taking on an adult or imaginary role. For example, a child may make-believe they are an astronaut and turn a couch into a rocket seat by sitting upside down in it while counting down from ten before "blasting off" into outer space. A shoe can become a radio that the child talks into in order to speak with another child who represents an engineer back at mission control. In this scenario, the children use the metaphor of space flight in pretense play to transform ordinary living room objects into tools for space exploration. We hypothesize that pretense play between a child and a humanoid robot can be used to create and learn new concepts via metaphor. This will involve human-robot interaction scenarios and algorithms, which we introduce by giving a brief overview of related human-robot interaction research.

In the past decade, the field and interest in human-robot interaction has grown dramatically. Research in social robots (Breazeal 2004) is occurring in assistive robotics (Mataric 2006) and rehabilitation (Brooks and Howard 2009). We acknowledge by combining ideas from human-robot interaction and social robot interactions with children, we intersect with work in developmental robotics (Lungarella et. al. 2003). Our humanoid robot takes on the role of a "child", or a developmental robot with intelligence levels of a child in early childhood. We are interested in child-humanoid robot interaction and the ability of humanoid to learn creative conceptualizations through these interactions. We assume that we have the basic tools for humanoid-child interaction including a humanoid robot with fundamental computer vision, speech generation and recognition, and motion capabilities (Pot et. al. 2009).

Approach

Semantic Concepts of Cognitive Agents

In order to describe our approach we first define how concepts are represented and organized for our cognitive agents (Williams 2004). Cognitive agents are either humans or computational beings (e.g. artificially intelligent humanoid robot) that possess some or all of the following cognitive capabilities in varying degrees: autonomy, reasoning, social skills, learning, communication, and mobility. Other models for agency are being researched including interactivist representations where agents are modeled as action systems (Stojanov et. al. 2006). A cognitive agent has a conceptualization of the world, which only exists in a human or agent's mind and an ontology, which is a mapping of language symbols to that conceptualization and provides meaning to the symbols of the language. A conceptualization consists of all the objects and their interrelationships with each other that an agent hypothesizes or presumes to exist in the world and is represented by a tuple consisting of a universe of discourse, a functional basis set, and a relational basis set (Genesereth and Nilsson 1987).

An agent's ontology consists of the specification of a conceptualization, which includes the terms used to name objects, functions, and relations in the agent's world (Gruber 1991). An object is anything that we can say something about. An object can be concrete or abstract, primitive or composite, fictional or non-fictional. A set of objects can be grouped to form an abstract object called a class.

An agent's invention of its conceptualization is its first step towards describing knowledge about the world. Declarative knowledge can be used to represent an agent's environment and guide it in making intelligent decisions regarding its behavior in the environment (Russell and Norvig 1995). This knowledge is represented by describing the world in sentences composed of a language such as natural language or first-order predicate calculus. Declarative semantics gives a precise way of defining meaning for an agent. The particular meaning defined for objects in a conceptualization are specified by elements in the representational language. The object constant is the label given to a particular object using the language. A semantic concept is a term in a language that represents the meaning of a particular set of objects in the conceptualization. A semantic concept is an abstract object constant for a particular agent that is mapped to a set of concrete objects in the universe of discourse. A semantic object is an object taken from the universe of discourse and mapped to a particular semantic concept for an agent. The semantic concept set consists of all the semantic objects in a particular agent's semantic concept.

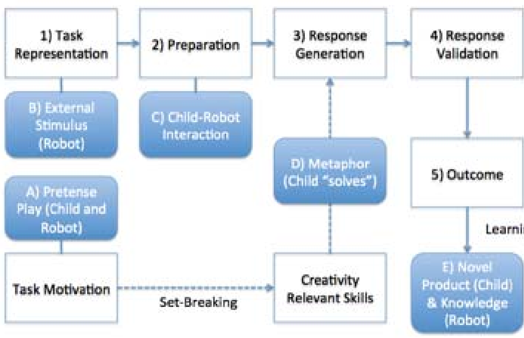
Cognitive Agents Using Metaphors for Creativity

We build on the algebraic approach to modeling creativity using metaphors (Indurkhya 1999) and the ability of agents to learn to share meaning from diverse ontologies (Williams 2004). We view two cognitive agents who share diverse theories of their environment, or model. We assume that one of the agents, R, has a very limited and simplistic structured theory including an ontology of semantic concepts that describe its environment. The other agent, C, has a very complex but hidden ontology and possesses a very high skill in identifying cognitive, or semantic, metaphoric relationships between disparate theories. The model, or environment, consists of a set of (physical) objects and operators that can operate over this set. A theory has a similar algebra but also can have a predetermined set of primitives, various complexity levels, sorts, and structures (Indurkhya 1999).

Metaphor-Guided Pretense Play

The goal of our child-to-humanoid robot interaction is to create new conceptualizations, or semantic concepts in our ontology, for the humanoid through socially interactive pretense play. We introduce metaphor-guided pretense play as a means for the child to teach the humanoid new, creative concepts. We utilize the componential framework of creativity to design our metaphor-guided pretense play (Figure 1). First we describe the process generically and then we describe a concrete example.

We address two of the three factors for creativity: task motivation and creativity relevant skills. The task motivation for the human cognitive agent in Figure 1 is A) pretense play. The child's task is to pretend to take on an imaginary role and interact with the humanoid robot to complete a task. In step 1, the humanoid robot represents the task by presenting an B) external stimulus to the child, e.g. an image depicting a subject. It is important to note that the external stimuli represented and presented to the child is *not* in the same domain of the pretense play. For example, the external stimuli image may be a scene of a tree log with ants on it but the expected outcome of the pretense play is a healthy food snack that may "look like" a tree log with ants but made out of objects represented by a food ontology.



Metaphor-Guided Pretense Play

In step 2, or preparation, the humanoid robot prepares the child for the pretense play task through verbal communication of the goal of the interaction. This may involve simple dialogue exchanges in the form of explanation, and question and answer along with the presentation of visual information. In step 3, or response generation, the child uses a metaphor created by the visual seed image and his own knowledge of the food and snack domain along with his innate creativity, or ability to find cognitive relations connecting disparate concepts from diverse ontologies. With limited visual recognition and metaphor translation understanding, step 4 will require an external response validator, or judge, to measure the child's creative solution. The solution will be evaluated based on a measure of a) how novel the solution is, and b) how appropriate the solution is. In step 5, or the outcome step, the child delivers her novel product to the humanoid robot and the humanoid robot provides verbal feedback to the child. The robot then queries the child to determine what the child created and matches the new, novel concept to the initial external stimuli image concept presented in step 1, or task representation. Next we describe in more detail how metaphor-guided pretense play process is used to exhibit and produce creative knowledge that the robot can learn and incorporate into its ontology.

In metaphor-guided pretense play, the child is given the pretense play role of head chef with a set of healthy food items such as grapes, bananas, celery, peanut (, or soy) butter and raisins. The humanoid robot "customer" presents a "seed" image to the child "chef". However, the seed image is not a picture of food but rather a picture of another unrelated subject, such as a muddy tree log lying on the ground with a line of ants walking over it. The humanoid robot will say to the child, "Make me some food that looks like this!" and then begin observing how the child manipulates the objects and composes them. It will then be up to the child to use her available food objects to create the concept conveyed by the picture. We anticipate and will test in future experiments, that the child will create a new metaphor for the subject using the food items. The resulting metaphors may consist of a stick of celery (, or "log") with soy butter (, or "dirt") to glue the raisins on (, or "bugs"). The child may name the new food item, "bugs on a log". The robot can respond with "Yummy! What do you call it?" and then begin the verbal exchange process to incorporate the novel concept along with the operators to produce the concept for future re-use.

The child unwittingly has created a new metaphor that can be learned by the humanoid robot through observations of the food objects and the operators performed on them. The operators that child uses may include: spread, stack, and place. The humanoid can incorporate the new semantic concept in its ontology located in its theory. The child will have used her concept similarity perception to create a metaphor between previously unrelated concepts, e.g. raisins and bugs in disparate ontologies, e.g. forest scenery and health snack foods.

Conclusions and Future Work

We have described our new approach to enabling humanoid robots to learn new, creative concepts through metaphor-guided pretense play. Our cognitive agent uses observation of another agent that is adept and highly skilled in finding cognitive relations, i.e. similarities between concepts in disparate domains. We provided a concrete example metaphor-guided pretense play scenario in which a humanoid robot and child play the role of chef and food connoisseur, respectively, of healthy, creative snacks. We will utilize the Nao humanoid robot to develop our human-robot interaction algorithms for this work and evaluate our methodology with children as experiment subjects. We anticipate using our outlined method to study the effectiveness of metaphor-guided humanoid-child pretense play in engaging and motivating children to eat healthier food to address childhood obesity.

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