Using Mental Simulator for Emotional Rehabilitation of Autistic Patients

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Abstract

It has been discovered about a decade ago that autistic people cannot properly understand and reproduce mental states and emotions. In this study we suggest a particular emotion rehabilitation strategy, based on playing with mental simulator that is capable of modeling the mental and emotional states. We present the model of mental world, approach the formalization of emotions, describe interface and reasoning mechanism of the multiagent mental simulator NL_MAMS. Also, we discuss the case studies of substantial improvement of emotional and mental reasoning skills of two patients.

Introduction

Resent psychological studies have revealed that autistic children can neither reason properly about mental states of themselves and others nor understand emotions (Perner 1991, Pilowsky at al 2000). Autism is a multifactor disorder that is characterized by impaired social interaction and communication, combined with repetitive and stereotyped patterns of behavior, and affects up to 0.1% of school-aged children.

In our previous studies (Galitsky 2000, Galitsky 2001), the systematic approach to exploration of the reasoning about mental states by individuals with mental disorders has been suggested, and the adequate formalization of mental world has been built. These studies addressed the peculiarities of autistic reasoning about knowledge, beliefs, intentions, and about other mental states and actions. Involving the formalisms of logical artificial intelligence, BDI model in particular, the system of reasoning about mental states and actions has been built, which is capable of simulating the verbal behavior of autistic as well as control patients (Galitsky 2002b). We developed a set of exercises, teaching autistic patients to reason properly about mental states in accordance to the traditions of axiomatic method, since the natural ways of teaching (by example) usually do not help. Also, it has been shown that the training of reasoning about beliefs, desires and intentions assists the emotional development (Galitsky 2001).

Multiple technologies have been suggested for mental rehabilitation, including playing LEGO, video-clips together with a set of dolls and autonomous mobile robot. Also, asking questions about mental states of the scene characters, textual scenarios and characters of the works of literature (Galitsky 2002a) is a good assistance to parents and rehabilitation personnel in the diagnosis and training of the corrupted autistic reasoning.

In this study, we present the deployment of the natural language multiagent mental simulator NL_MAMS for mental and emotional development of autistic children. Building the adequate model of mental world and emotions is important for teaching the individuals, whose understanding of mental world is (genetically) corrupted. We use the non-humanized (computer) resources, readily acceptable by the autistic children, to introduce them to the mental world (of humans) via formalized reasoning. The paradox of our methodology is that the reasoning in mental world, usually supposed to be irrational and displayed as an emotion, can nevertheless be considered from the abstract perspective, formalized and used as a training means. Such the hypothesis (Galitsky 2002a) is used to form the skeleton of our rehabilitation strategy to develop the emotional behavior in a real mental world.

Our model of the human agent is based on the supposition that there is a number of standard axioms for mental entities, including emotions; these axioms are genetically set for normal children and are corrupted in the autistic brain (Galitsky 2002b). The patterns of corruption vary from patient to patient and are correlated with the specifically outlined groups of autistic children. They have to acquire these axioms explicitly, by means of direct training, using the specific scenarios. The methodology of using mental simulator for rehabilitation is based on teaching autistic kids the "mechanical" forms of emotional behavior, because the attempts to directly introduce the emotional interaction with the others in a natural manner (teaching by examples, imitating) frequently fail.

From Knowledge and Intention to Emotion

In our formal description of the real mental world, we follow its natural language representation as close as possible, however obeying the restrictions of a formal language, we use the entities with multiple possible interpretations. Acquiring mental entities, autistic trainees are expected to reproduce them in their behavioral patterns and to reveal them in verbal communication of the others. Therefore, both natural language and formal language (user interfaces of a software) representations need to accompany each mental scenario. Sometimes, autistic children prefer to operate with the latter: user interface of a software system seems to be more attractive than reading or talking in natural language.

Building the simulator of mental world, we need to extend traditional BDI implementation of reasoning, based on modal logics that are not well suited for practical applications, as we are going to show. We believe that using such logical means as, for example, default logic for semantic disambiguation, reasoning about action and time in application to mental world, or constraint satisfaction machinery for mental states, taken together, do not provide the solution that is ready for the design of educational software. Multiagent simulation and case-based system need to come into play in addition to pure reasoning means to build the environment, adequate for teaching the laws of mental world. A mental simulator should be capable of producing a sequence of consecutive mental states given an arbitrary initial one.

Adequate description of mental world can be performed using mental entities and merging all other physical actions into a constant predicate for an arbitrary physical action and its resultant physical state (for simplicity). It is well known that humans can adequately operate with the set of natural language mental expressions containing not more then four mutually dependent mental entities. In natural language, each mental entity has a variety of meanings. At the same time, a set of meanings which are expressed by a lexical unit has a lot of common features. Therefore, we will use the formal representation of mental entities by metapredicates with multiple interpretations such that we do not pose explicit constraints on the possible meanings of a mental entity (metapredicates are the predicates whose arguments range over arbitrary well-written formulas).

The set of mental metapredicates, formed in accordance to the respective totality of natural language mental entities, can be divided into three categories:

- Metapredicates for basic mental states;
- Metapredicates for derived mental states and actions. They are expressed via basic metapredicates using mental formulas. For example, there are families of definitions for *inform, pretend, cheat, reconcile, explain, convince* etc.
- Metapredicates for **emotions.** Emotions are the formally independent entities, which are semantically close to one or another derived ones, but contain additional meaning.

Indeed, almost any entity for mental state or action can be defined within these basic mental entities (Galitsky 2000), unless the author of the mental expression wants to use additional parameters of the agent who is characterized by that mental state. Usually, this parameter specifies the mental state of an agent irrespectively on the consecutive mental state, unless this parameter explicitly points to the preference in the choice of action. This parameter does not typically affect the decision-making in terms of the reaction choice of an agent that is described by such mental entity.

For example, we can approximate *to be afraid (of something)* by *not want (something),* when we talk about an agent that chooses an avoidance behavior. If such the agent has two choices – to avoid or not to avoid, it does not matter for his choice of action whether he does *not want* to be with another agent or experiences fear with that agent. Therefore, a derived mental entity forms the class of equivalence of mental entities (emotions) with respect to the choice of action (mental or physical, from the fixed set). The reader can easily construct mental formulas for *forgetting* (lack of a *belief* that follows its presence at some point in time), *dreaming* (*intention* of some physical or mental state to occur), *imagining* (believing that something holds knowing that the belief is wrong), *feeling guilty* (*intention* that some action that has been committed should not has been done and *belief* that it depended on the agent's physical or mental state), *infatuation, fascination, anger, surprise, embarrassment, shame, anxiety, etc.,* approximating their meanings for particular situations.

We have experimentally verified that one neither has to enumerate all possible meanings nor approach them as close as possible to teach *applicability* and *reasonability* of these emotions to an autistic individual. Hence our model of emotions in the mental world is adequate in terms of mental rehabilitation, but may be far from optimal for building agents that impress the audience with intelligent behavior with emotions (compare with (Scheutz 2001, Breazeal 1998, Sloman 2000)).

NL_MAMS inputs natural language descriptions of the initial states of interacting agents and outputs the deterministic scenarios of the intelligent behavior of agents, capable of analyzing and predicting the consequences of mental and physical actions of themselves and others (Galitsky 2002a, www.dcs.bbk.ac.uk/~galitsky/ Nl_mams/).

NL_MAMS is capable of understanding the messages from its user and other agents in natural language, extracting the expressions, which mention explicitly or assume implicitly mental states and actions. Modeling of multiagent interaction takes into account possible ambiguity of messages that is inherent to natural language dialog. NL_MAMS imitates the multiagent behavior that is caused by possible misunderstanding of one agent by another. Under the search of optimal action or reaction, the set of meanings for received entities is (exhaustively) analyzed with respect to avoiding the least wanted state (assuming this state may be achieved as a result of a particular understanding of a message).

The input of NL_MAMS is an arbitrary (possibly, inconsistent) set of mental formulas, obtained by the natural language understanding unit of NL_MAMS. The output is the set of consecutive mental formulas, reflecting the states, which are the results of the committed actions (the behavior), chosen by the agents. The simulator can be viewed from the game-theoretic perspective if the mutual beliefs of agents are absent (the trivial case).

To choose the best action, each agent considers each action he can currently possibly perform. For each such action, the agent assumes he has committed it and analyzes the consequences. They include the actions of other agents and various states, some of which the given agent does not want to occur. The agents either decides to perform the action delivering the least unwanted state or action by another agent, or to do nothing. If there are multiple possible actions which do not lead, in the agent belief, to unwanted consequences, this agent either chooses the preferred action, if there is explicit preference predicate, or the action, which conjectures use the beliefs concerning the other agents in the least degree.

The complexity of scenarios NL_MAMS can handle significantly exceeds that of the textual information on mental attributes of human and automatic agents, comprehensible by a human user. The simulator was tested using a variety of scenarios that were suggested, in particular, by different authors to illustrate certain peculiarities of reasoning about mental world inherent to humans (frame problems, defaults, circumscription, belief updates, reasoning about knowledge, time and space, etc.) The system extracted mental entities and reproduced the described agents' behavior for more than 20 natural language scenarios from various sources. As we discovered, NL_MAMS is capable of adequate processing more than 70 scenarios, selected so that they accent mental interaction between their characters. Usually, agents' behavior that is generated by NL_MAMS is perceived by its user as a sequence of natural and expected choices. If it is not the case, NL_MAMS backs its scenario up by providing the motivation and the protocol of exhaustive search through the manifold of available actions. A user may disagree with the selected form of behavior, but at least understands the motivations.

Note that the particular advantage of NL_MAMS over the traditional systems of automatic reasoning in mental states domain is that NL_MAMS merges various forms of search and a fuzzy match of formulas and deduction patterns together with conventional mechanisms of reasoning about mental states. Furthermore, handling manifold of meanings caused by the necessity to represent NL input increases system flexibility and makes it closer to the real world in imitation of human reasoning and human behavior.

There are three friends: Mike, Nick and Peter.
Nick knows that if Mike gets the toy (asking for it) then Nick's parents will give him his favorite candies. But Mike and Peter are not sure that the toy is good… The initial situation is as follows:

Nick's mental state	Peter's mental state	Mike's mental state
Nick(*n*) wants Mike to get the toy. Nick knows that the toy is bad. Nick wants that both Peter and Mike believe that the toy is not bad. Nick believes that Peter does not know that the toy is bad. Nick knows that initially Mike does not know that the toy is bad. *want(n, get(m,t)).* *know(n, tb).* % *tb*- toy is bad *want(n, believe(p, not tb)).* *want(n, believe(m, not tb)).* *believe(n, not know(p, tb)).* *know(n, not know(m, tb)).*	Peter(*p*) wants Mike to get a toy. Peter does not want Nick to know that Peter wants Mike to get a toy. Peter believes that Mike would get the toys if Mike believes it is not bad. Peter believes Mike would get a toy if Nick informs Mike that the toy is not bad. Peter wants Nick to believe that Mike gets the toy if Peter informs Mike that the toy is not bad. *want(p, get(m,t)).* *want(p, not know(n, want(p, get(m,t)))).* *believe(p, (get(m,t) :- beleive(m, not tb))).* *believe(p, get(m,t)):- inform(n,m, not tb).* *want(p, believe(n, (get(m,t):- inform(p,m, not tb)))).*	Mike(*m*) wants to get the toy if Peter informs Mike that the toy is not bad. Mike wants to get the toy if Peter informs Mike that the toy is worth getting. Mike wants Peter to believe that Mike will not get the toy Mike wants Nick to believe that Mike believes that the toy is not bad. Mike wants that Peter informs Nick that Mike will not want the toy *want(m, get(m, t)):- inform(p,m, not bt);* *inform(p,m, get(m, t)).* *want(m, believe(p, not get(m,t))).* *want(m, believe(s, believe(m, not bt))).* *want(m, inform(p,n, not want(m, get(m, p)))).*

Form the statement using combo boxes below

Nick ▾ | want ▾ | inform ▾ | Peter ▾ | toy is bad ▾ | None ▾

None ▾ | Nick ▾ | None ▾ | None ▾

or input in natural language

Nick wants Peter to inform Nick if the toy is bad.

What will the children do?

Nick asks Peter to tell Mike that the toy is good. Peter asks Mike to ask Nick if the toy is good. Mike informs Nick that Mike believes that the toy is not bad.	Nick asks Mike if Mike believes the toy is bad. Peter informs Mike that the toy is good. Mike asks that Peter inform Nick that Mike will not get the toy.

Fig.1: User interface of NL_MAMS for learning the mental entities by autistic patients.

User Interface for Autistic Training

In this section, we present the user interface of NL_MAMS for autistic rehabilitation (Fig.1). A child is encouraged to understand the initial mental state that includes the initial emotions of agents. Then this child is suggested to compose a story of the multiagent behavior and compare it with what NL_MAMS generates. Doing this, the trainees actively use a variety of mental entities, including basic, derived ones and emotions. Each column represent a mental state of an agent (in natural language on the top row, in the formal language – on the bottom row). Mental sates can be modified either in the text area, or using the row of combo boxes for each predicate name and its arguments. NL_MAMS builds the resultant scenario, and the trainee can analyze it and compare with his own vision of the possible scenario.

Since the majority of autistic children feel very comfortable with a computer (unlike with other humans), these children can exhaustively run through combination of scenarios for the story characters. NL_MAMS suggests the children to memorize both natural language and formal language representation of initial mental state and the scenario. Modifying the parameters of initial mental state, the trainees demonstrated good skills in revealing the cause-reason links in multiagent behavior. Being frequently capable of inductive and abductive reasoning, the children build the rules for agent's actions and emotions rather then performing these actions and displaying emotions, copying other people as controls do. We observed that for the mental world deductive, inductive and abductive kinds of reasoning take autistic patients less efforts to perform, than analogous reasoning, easily conducted by controls in the similar environment.

Case Studies and Conclusions

In this paper, we mention two children whose emotion capabilities are believed to be developed by the suggested approach in addition to the traditional rehabilitation methodologies. This pair was chosen from the group of eight children (from 5 to 12 years old, diagnosed with one of the autism syndromes) because the training seemed to better fit their mental age. Alexandra (F) and Leon (M), 10 years old, has attended the rehabilitation center "Sunny World" on a regular basis, participating in common games with other children, speech therapy, animal-assisted therapy and general training for reading, writing and math. We perform the progress of their emotional capabilities from the winter of 2001/2002 to the autumn of 2002 (Table 1). Five other patients of "Sunny World" have participated in the emotional rehabilitation training using NL_MAMS.

We can see that both children dramatically improved their overall skills of the emotion-related behavior. As we can judge given the data for two children, each has his/her own problems that were the direct or implicit targets of the training. However, certain capabilities have been developed insignificantly; they may be weakly affected by the suggested methodology of emotional rehabilitation. The reader might notice that a lot of additional training has to be performed so that the mental and emotional development proceeded towards the normal skills for their age. As to the other trainees, each of them improved certain emotional skills and capabilities of reasoning about mental states to a various degree. Statistical estimates of results of the NL_MAMS-based treatment are the subjects of the further studies.

Also, various kinds of emotions are built up at different speeds for the same patient. As we discovered, training of each kind of emotion and mental reasoning should be conducted starting from the earlier ages, because for each mental task there is an age when this task becomes adequate to the current patient understanding of the mental world. Therefore, the training toolkit is assumed to be suggested starting from the age when a patient is able to read, till the full (possible) mental recovery in terms of interaction with other people.

Currently, we are investigating the peculiarities of autistic reasoning about actions, revealing whether the children can clearly distinguish fluents from actions and from states. Also, frequent inability of autistic children to distinguish the essential facts from the details, which seem insignificant for a normal individual, is well known. We explore the correlation of such inability to separate *important / unimportant* facts with the intuition for inertia of physical and mental world.

The phenomenon of *computational autism* has been introduced to explore the theoretical and practical issues of the mental disorders: www.dcs.bbk.ac.uk/~galitsky/AU/Computational_autism.htm. Current study shows that the abstract formalism of reasoning about mental states, intended to model the human behavior by a technical system, found an emergent application in the simulation of human agents. The reader is suggested to consult (Graham-Rowe 2002) for a popular analysis of how studying logical constructions assists in the mental development of autistic patients.

There is a series of multiagent systems where agents are designed to implement emotions (Breazeal 1998, Velasques 1998). Also, a number of formalisms have been developed that handle the notion of emotion quite adequately (see e.g. Oatley and Jenkins 1996, Parameswaran 2001, Scheutz 2001). However, the target of our model for mental world, that includes emotions of participating agents, is quite different. As we experimentally discovered, to stimulate the emotional development of autistic patients, the interface of the rehabilitation system does not have to display the emotional behavior explicitly; instead, the canonical explanation of the strict rules for emotions is required. We have learned the following from our experimental studies. When children start better operate with basic entities of knowing and believing and then proceed to the derived entities like deceiving and pretending, the further step to more explicit emotional behavior frequently comes easier and quite naturally.

Ability to understand or to perform a mental action or state	*child*	Alexandra		Leon	
Testing date		2001	2002	2001	2002
Good will deception		Unable	Deception on a wide spectrum of topics	Deception on limited number of topics	Deception on an arbitrary topic
Pretending		Unable	Pretending concerning a subject and concerning her own mental state	Pretending on limited number of topics	Pretending on a wider, but still limited number of topics
Being surprised		On rare occasions	Systematically with proper timing, playing with the teacher	Randomly	Systematically with proper timing, playing with the teacher
Feeling sorry for another person		Non-systematically	Almost always when appropriate	Never	Sometimes, when logically deduced
Feeling happiness for another person		Randomly	Frequently when appropriate	Sometimes, when appropriate and inappropriate	Frequently when appropriate, seldom when inappropriate
Understanding jokes		Unable	Irregular understanding of some kinds of jokes	Randomly	Randomly, but with clear reaction
Cooperating with others when performing a collaborative task		Willing to cooperate without understanding the common goal	Cooperation on different matters with responsiveness and understanding intentions of others	Avoiding any cooperation	Cooperation on demand from the teacher without
Understanding of intention of others		Understanding of only her own intentions	Can understand intentions of others of a limited complexity	Can understand intentions of others, but ignores them	Able to mutually analyze own and other's intentions
Understanding of knowledge and beliefs of others		Mostly misunderstanding	Can understand beliefs of others in practical situations; still confused with own and others' knowledge	Fully understands knowledge and belief of others up to solving the "muddy children" problem. Mental age with respect to understanding knowing is therefore 20 years old!	
Understanding derived mental states		No recognition of pretending	Understands pretending if it affects her wishes	Understands pretending if it affects his wishes	

Table 1: The progress of mental development for two patients.

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