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CHALLENGES IN MODELLING ARTIFICIAL HUMAN-LIKE AGENTS

MĀKSLĪGU CILVĒKIEM LĪDZĪGU AĢENTU MODELĒŠANAS IZAICINĀJUMI

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Human-like agents, cognition, emotion, modelling

1. Introduction

Human mind, intelligence, behaviour and 'mysteries' about what knowledge actually is and what role it plays in human life have been studied and discussed for thousands of years. In this discussion, scientists from many different fields have been involved, including philosophy, physiology, neuroscience, psychology, sociology, computer science etc. This reinforces the idea that human mind can be studied from a large number of different perspectives.

However, it is still not clear how does human brain encode and represent external and internal stimuli (including feelings, desires, memories, and five senses), and how human cognition, conation and affect works together and governs human behaviour.

Direct brain studies, such as, brain scanning or electrical stimulation of the brain, can give answers about the structure of the brain, but tell very little about the function of the brain [1]. More answers about the functioning of the brain can be found in mind studies especially in cognitive science. Mind is defined as "The human consciousness that originates in the brain and is manifested especially in thought, perception, emotion, will, memory, and imagination" [2]. However, cognitive scientists tend to focus on the behaviour of single individuals thinking and perceiving on their own. [3]

Computer Science and Artificial intelligence also tries to understand how human mind works and tries to copy these understandings in artificial life by developing computational models of mind. An agent-based modelling and simulation has become a popular method in trying to understand how an agent perceives and reacts on its environment and how agents interact with each other.

There is a growing realization across the social sciences that one of the best ways to build useful theories of group phenomena is to create working computational models of social units and their interactions, and to observe the global structures that these interactions produce. [3]

Why is it necessary to develop mind models? One reason is that mind models are developed to understand how different individuals work together forming consistent social organizations, which tend to achieve common goals. To understand how the network of networks is forming and existing.

The aim of this paper is to identify main challenges in modelling such a network of networks. It is important to identify these challenges before starting to develop artificial human-like agent's mind and relationships between different agents forming social network of networks.

In this paper, we identify four main challenges that developer needs take into account when developing human-like agents.

Identified challenges will serve as guidelines in our further research on modelling and simulating artificial human-like agents.

2. Humans are emotional beings

The first challenge that we will describe in this paper in more details than three other challenges is that humans are emotional.

Why is this aspect challenging for a human-like agent modeller? First, because there are lot of uncertainties regarding emotion and its role in human cognitive and behavioural processes. Second, because emotion is regarded as something opposite of logic and therefore difficult to formalize.

The traditional model of human mind is that there are three basic human mental processes: cognition, emotion, and conation. The original source of this structure comes from Plato who was arguing for a tripartite structure of the human soul. [4 p.563] Plato created these three concepts and put them in partial opposition to each other. While this doctrine has had many critics, still it profoundly affected modern psychology where cognition is often seen as an antagonist to emotion. [4 p.563]

However, a recent tendency in psychology as well as in computer science is to study the interaction between cognition, emotion and will [4, 5, 6, 7].

Joseph LeDoux, a Professor of Neuroscience and Psychology at New York University, says:

> *"Cognitive scientists previously banned emotion from their field, but are beginning to realize that they don't really have a science of mind as such, but instead a science of a part of the mind. They now want to bring emotion and cognition back together, and that's a good thing. Lots of AI modelling of emotion, and some connectionist modelling, is also going on. [..] We have to put emotion back into the brain and integrate it with cognitive systems. We shouldn't study emotion or cognition in isolation, but should study both as aspects of the mind in its brain."* [7]

Most of the researchers trying to create intelligent computers have focused on problem solving, reasoning, learning, perception, language, and other cognitive tasks considered essential to intelligence. Most of them have not been aware that emotion influences these functions in humans. However, now there is a majority of evidence that emotion plays a vital role in functions considered essential to intelligence. [8].

This new understanding about the role of emotion in humans indicates a need to rethink the role of emotion in computing [8]. Recently research has started on affective computing,

emotional agents and other aspects of emotion in the field of computer science. About a decade ago (in 1997) R. Picard wrote a book on Affective Computing that triggered an explosion of interest in the emotional side of computers and their users. Her motivation was to gain a new understanding about the importance of computers with affective abilities. She claimed that for a computer intelligence computer emotion is needed.

Researchers with an interest to human mind models [6, 9] assert that one aspect of human mind (e.g., cognition, emotion) should not be studied in isolation with other aspects. It is important to study an 'integrated' mind putting all aspects (or at least several aspects) together in one integrated, coherent model.

One of the most important impulses in the computer modelling of emotions comes from the Japanese psychologist Masanao Toda. He stresses the importance of studying whole systems, including perception, action, memory, and learning. In 1962, he proposed a scenario of "fungus eater" - an autonomous humanoid robot. His aim was to illustrate how emotions would emerge in a system with limited resources operating in a complex and unpredictable environment. [10]

One of the most important subjects in integrated human mind studies is to define the relationship between cognition and emotion. What are the cognitive factors eliciting different emotion, what is (if any) the effect of affective states on cognitive processes, what is the perception and cognition of affect [4 p.563-571]

Appraisal theories suggest that people evaluate events in terms of the perceived relevance for their current needs and goals, including considerations of their ability to cope with consequences and the compatibility of the underlying actions with social norms and self-ideals. Based on this evaluation a corresponding emotion is elicited. [4 p.564]

Affective science literature [4 p.567] suggests that there is not just unidirectional connection between cognition and emotion, where cognitive appraisal processes produce emotion, emotion affects cognition, but there is rather recursive chaining interaction between cognition and emotion. That means that cognition and emotion continuously influence each other. Cognition triggers affect and affect, in turn, has a powerful influence on cognitive processes. [4 p.566]

Affective states have a powerful influence on the way people perceive, interpret, and represent social information and the way they formulate attitudes and judgments. Mild everyday affective states can have a highly significant influence on the way people perceive and interpret social situations and the attitudes they form. Affective reactions to social events also play a critical role in how attitudes and social information are cognitively represented and categorized. [4 p.596-618]

The last several years have witnessed a bust of interest in the role of emotions in decision-making. Researchers have shown that even the affect that is unrelated to the decision at hand can have a significant impact on judgement and choice, but emotional deficits can degrade the quality of decision-making. Traditional decision-making theory paid little attention to emotion. Decision-making was viewed as a cognitive process where decision makers dispassionately choose actions that maximized the "utility" of potential consequences of their decisions. [4 p.619-642]

It is regarded that there are two basic kinds of affective influence on decision-making: expected emotions and immediate emotions. Expected emotions consist of predictions about the emotional consequences of decision outcomes. They influence a person to select actions

that maximize positive emotions and minimize negative emotions. Immediate emotions are experienced at the time of decision-making. [4 p.619-642]

Theories of decision-making, if they incorporate emotions at all, typically assume that expected emotions are the only emotions that matter. People are assumed to choose options that they expect will maximize positive emotions. However, not only expected emotions influence decision-making process. Also immediate emotions influence decisions by altering the decision maker's perceptions of probabilities or outcomes or by altering the quality and quantity of processing decision-relevant signs. [4 p.619-642]

The interrelationship between decision-making, immediate, and expected emotions is illustrated in the Figure 1.

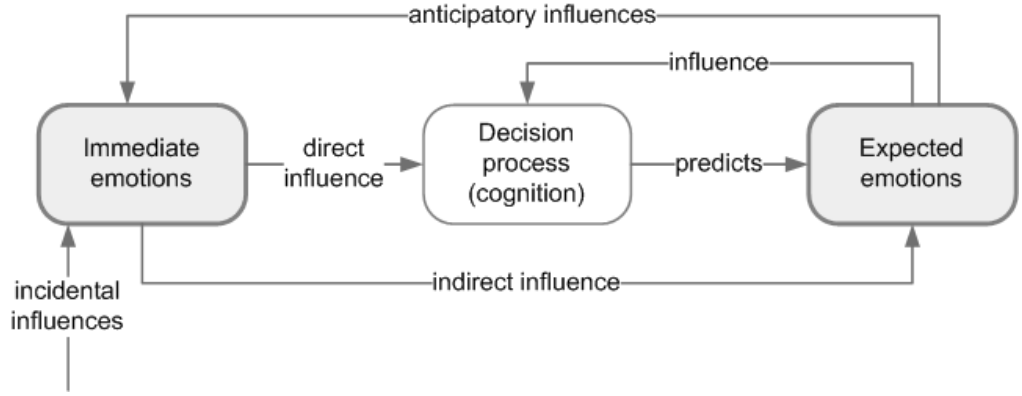

Figure 1. The interrelationship between decision-making, immediate, and expected emotions (Adapted from [4 p. 621])

The reasons why people are not purely rational in their decision-making process are at least twofold: they lack information to make strictly calculated (rational) decisions, or they simply don't do calculations, but relay on so called 'gut' feeling. Very often in our daily life and in our daily or business processes, we simply don't have enough information or knowledge to calculate the welfare values of all possible alternatives and utility values of possible choices. [11, 12, 13] addresses this problem in SE field in the context of method selection and Knowledge Management. Hammond, Keeney and Raiffa (1998) identify six fundamental flaws in the way managers think in business situations and indicate that very often crucial decisions are not based on rationality, but rather personal feelings. They suggest that these flaws are "well documented psychological traps that are particularly likely to undermine business decisions." [14].

The aspect of human being emotional is very important challenge a modeller will meet when developing human-like agents. The most challenging task will be to formalize aspects of emotion and its relation to agent's cognition and behaviour.

Among computer scientists, one of the most popular emotion appraisal models is OCC model. Many researchers in computer science have used OCC model to generate emotions in their embodied characters. For example, Clark Elliot used OCC model to build Affective Reasoner system. Tomoko Koda synthesized emotions using OCC model for developing poker-playing agents with facial expressions. Joseph Bates and Scott Neal Reilly working on "Oz project" used OCC model to implement emotion system in believable agents. [8, 9, 10]

OCC model was first introduced in 1988 by Andrew Ortony, Gerald L. Clore and Allan Collins in their book "The Cognitive Structure of Emotions". The name OCC came from the first letters of these three authors names. In OCC model emotions are grouped according to cognitive eliciting conditions. It is assumed that emotions arise from positive or negative reactions to situations. OCC model outlines specifications for 22 emotion types. [15]

3. Humans are personalities

Another challenge that is necessary to take in to account when modelling and simulating human behaviour is that each human has different personality that influences particular person's behaviour.

In simple systems (or agents) without memory, the output of the system at any point of time depends only on the value of the input at this time. In systems with memory or state variables, a given input may induce different outputs depending on the value of the state variable. [16, 17]

Humans are complex 'systems' with a huge set of inner state variables, such as, current mood (emotion) and desires (will). Therefore, when modelling and simulating human-like agents, one needs to model and develop each agent's personality. Agent's personality will influence agent's output (behaviour) on the given input. Therefore, the same input at different points of time may lead to different behaviours depending on the agent's personal state in the given time. Accordingly, different agents may react differently to the same input depending in their personal characteristics or their different personalities.

Development of the artificial human-like agent personality must be heavily based on the research in psychology. One of the personality models in psychology research is five-factor or OCEAN model [16, 17]. In this model, thirty personality facets are clustered in five groups or factors. The value of each factor is determined by the values of its six facets. The five factors are Openness, Conscientiousness, Extraversion, Agreeableness, and Negative emotionality [16, 17].

Oren et al. suggests using fuzzy logic for implementing OCEAN personality model in human-like artificial agents. [16, 17]

4. Humans are dynamic personalities

Another challenging aspect when considering to model human-like agents is that humans are not static systems with static personalities. Humans learn, adapt, develop and change over time. Therefore, it is not enough just to implement a static personality feature for an agent and simulate agent behaviour with this static personality. In such an agent a very important human characteristic would be lacking - the dynamics of personality.

Oren at al. states that when at least one of the thirty personality facets (from and OCEAN model) changes its value, the personality is affected and the whole model should be updated and personality should be re-evaluated. [16, 17]

5. Humans are social beings

The last challenge identified in this paper is that humans are social beings. It means that humans are influenced by other humans, as well, that humans are influencing other humans. Dynamic relationships are formed among different individuals and these relationships initiate changes in individual's inner states and personality facets.

There exists kind of 'invisible hand', which directs the actions of individual self-interested agents to serve a social function. [18]

Cognitive scientists tend to focus on the behaviour of single individuals thinking and perceiving on their own. However, people create group level behaviours that are beyond the ken of any single person. Individuals participate in collective organizations that they might not understand or even perceive, and these organizations affect and are affected by individual behaviour. [3] Therefore, when developing artificial human-like agents it is important to take into account that healthy human can't be isolated from society.

Ron Sun, Professor at Cognitive Science Department at Rensselaer Polytechnic Institute in New York, points that although a significant amount of work has been done in cognitive science for studying individual cognition, the sociocultural processes and their relation to cognition have never been a focus of cognitive science. [18]

Sun's belief that the interaction of these two fields (cognitive modelling and multi-agent systems) may be more significant than either alone is brought as one of the main ideas in this thesis.

Cognitive models may provide better grounding for understanding multi-agent interaction, by incorporating realistic constraints, capabilities, and tendencies of individual agents in their interaction with their environments (both physical and social). [18, 3]

If each individual is to be modelled as a conceptual network with interrelationships between different components of the mind, then a social group is to be modelled as a network of networks with interrelationships between different individuals (see, Figure 2 for illustration).

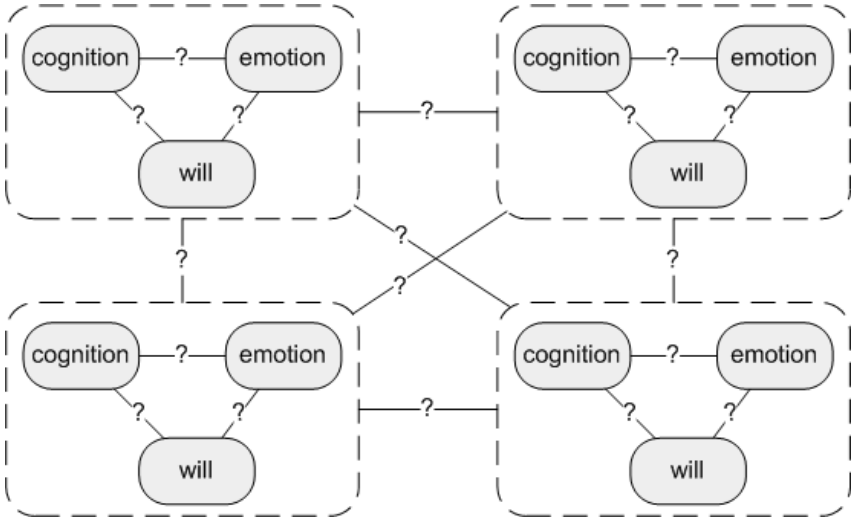

Figure 2. Abstraction of the network of human-like agent networks

A challenging task for human-like agent modeller is to define how these two levels of networks – individual and interpersonal – interact and affect each other. Communicating is not simply transmitting individual concepts. It is something more – it is aligning the conceptual systems of agents. One implication of this alignment process is that as concepts migrate across individuals, they will be systematically altered to fit their owner's conceptual network. [3]

6. Conclusion

Human mind is very complex system. Therefore, modelling and simulation of human-like agents, which incorporate at least basic features, and characteristics of the human mind, is a very challenging task.

In this paper, we have identified four challenges in modelling artificial human lie agents. The first challenge is that humans are emotional and not purely rational. Therefore, modeller's attention should be paid not only to logical cognitive processes of human mind, but also to seemingly irrational emotional processes. The second challenge is that human has a complex inner state consisting of many variables that form individual's personality. Personality facets influence how individual perceives the world and behaves. If any of personality forming variables changes, the whole individual's personality model should be updated. The third challenge is that individual's personality change over time – it is dynamic. As individual learns and adapts, its personality changes and develops. The fourth challenge is that individual human does not exist in isolation, but in society. Society has a great influence on individual, its beliefs, values, understandings, etc. As well as society is influenced by an individual who exists in the particular society. It means that modeller need to model not just the network of individual's mind functions and processes, but rather a network of networks which shows how individuals are forming relationships with other individuals, how they interact and behave in a group.

Deeper research on each of identified challenges and solutions is needed to develop comprehensive human-like agents' model. This model will be further implemented in a computer simulation where it will be tested.

Some of the benefits of building models for computer simulation are:

1) it helps to think systematically about the modelled phenomena and search for relevant data with which to test, explicate or elaborate created assumptions about the phenomena;
2) it makes the developer to set out the assumptions in a formal language, that can also often be represented in terms of graph diagrams and other figures setting out the subsystems and relationships involved;
3) enables developer to present results in detailed graphical form, graphs, charts etc., allowing a comparison of results for different times or conditions.

Therefore, the most important challenge for the further research will be to deal with the four identified challenges in a systematic and formal way to incorporate the solutions in a formal model that can be simulated with a computer program. The main aim is to study how different processes in a human mind affect each other, how individuals affect each other and how human societies emerge, and to define these interrelationships in a formal language.

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Apšvalka D. Mākslīgu cilvēkiem līdzīgu aģentu modelēšanas izaicinājumi

Cilvēka prāts ir sarežģīta sistēma. Tādēļ izstrādājot cilvēka prāta modeļus un implementējot tos datorsimulācijās, nākas sastapties ar vairākiem nopietniem izaicinājumiem. Šai rakstā tiek identificēti četri galvenie izaicinājumi. Pirmais izaicinājums ir, ka cilvēki ir emocionālas būtnes. Tādēļ modelētājam ir jāņem vērā un jāiestrādā savā modelī ne tikai loģiskie spriešanas procesi, kas noris cilvēka prātā, bet arī šķietami neracionālie emocionālie procesi. Otrs izaicinājums ir, ka cilvēkiem ir sarežģīti iekšējie stāvokļi, kas sastāv no dažādiem mainīgajiem un kopā veido indivīda personību. Indivīda personība ietekmē, kā indivīds uztver pasauli un darbojas. Un pasaulē neeksistē divi indivīdi ar pilnīgi vienādām personībām. Tādēļ arī mākslīgajā cilvēkiem līdzīgu aģentu pasaulē nebūs aģenti ar pilnīgi vienādām personības vērtībām. Trešais izaicinājums ir, ka indivīda personība mainās laika gaitā – tā ir dinamiska. Līdz ar indivīda pieredzi un adaptēšanos, arī viņa personība mainās un attīstās. Ceturtais izaicinājums, ar ko nākas sastapties modelētājam ir, ka cilvēki neeksistē izolēti viens no otra, bet gan sabiedrībā. Sabiedrībai ir liela ietekme uz indivīdu, viņa pārliecībai, vērtībām, izpratnei un tml. Un no otras puses, indivīds ietekmē konkrēto sabiedrību, kurā viņš eksistē. Tas nozīmē, ka modelētājam ir jāmodelē ne tikai viena indivīda prāta funkciju un procesu savstarpējo saišu tīkls, bet drīzāk tīklu tīkls, kas formālā veidā attēlo, kā indivīdi ir saistīti sabiedrības grupas ietvaros un kā tiek ietekmē viens otru un veido funkcionējošu sabiedrību.

Apshvalka D. Challenges in Modelling Artificial Human-Like Agents

Human mind is very complex system. Therefore, modelling and simulation of human-like agents, which incorporate at least basic features, and characteristics of the human mind, is a very challenging task. In this paper, we have identified four challenges in modelling artificial human lie agents. The first challenge is that humans are emotional and not purely rational. Therefore, modeller's attention should be paid not only to logical cognitive processes of human mind, but also to seemingly irrational emotional processes. The second challenge is that human has a complex inner state consisting of many variables that form individual's personality. Personality facets influence how individual perceives the world and behaves. If any of personality forming variables changes, the whole individual's personality model should be updated. The third challenge is that

individual's personality change over time – it is dynamic. As individual learns and adapts, its personality changes and develops. The fourth challenge is that individual human does not exist in isolation, but in society. Society has a great influence on individual, its beliefs, values, understandings, etc. As well as society is influenced by an individual who exists in the particular society. It means that modeller need to model not just the network of individual's mind functions and processes, but rather a network of networks which shows how individuals are forming relationships with other individuals, how they interact and behave in a group

Апшвалка Д. Вопросы моделирования искусственных человекоподобных агентов

Разум человека - это очень сложная система. Поэтому разрабатывая модели разума человека и выполняя их компьютерную имитацию, приходится сталкиваться со многими серьёзными проблемами. В этой статье идентифицированы четыре главные проблемы. Первая проблема связана с тем, что люди являются эмоциональными существами. Поэтому в процессе моделирования необходимо взять во внимание и встроить в модель не только процессы логических рассуждений, которые происходят в уме человека, но также и кажущиеся нерациональными эмоциональные процессы. Вторую проблему определяют сложные внутренние состояния человека, которые состоят из различных переменных и все вместе формируют личность человека. Личность человека влияет на то, как он воспринимает мир и ведёт себя в нём. В мире не существует двух людей с полностью идентичными личностями. Таким образом, также в искусственном мире человекоподобных агентов не может быть агентов с полностью идентичными личностями. Третьей проблемой является тот факт, что личность человека меняется с ходом времени, то есть, является динамичной. Поскольку человек приобретает опыт и приспосабливается, меняется и развивается его личность. Четвёртая проблема, с которой приходится сталкиваться, моделируя человекоподобных агентов, связана с тем, что люди не существуют в изоляции, а живут в обществе. Общество оказывает большое влияние на человека, его убеждения, ценности, понимание и т.п. С другой стороны, человек влияет на конкретное общество, в котором он существует. Это значит, что необходимо моделировать не только функции и сеть взаимосвязанных процессов разума отдельного человека, а скорее сеть сетей, которая формальным образом отображает, как связаны индивидуумы в рамках общественной группы и как они влияют друг на друга и создают функционирующее общество.