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COGNITIVE MODEL OF INTUITION IN SOLVING INVESTMENT PROBLEMS

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ABSTRACT

The problem of rational investment and allocation of funds for an agent with individual goals and experiences is presented in this paper. Simon Herbert's model of decision making, the EPAM model of intuition as a decision tree with the accompanying Soar software which is a modern cognitive architecture for modeling intelligent agents are considered. The state space and selection of decision rules for determining the optimal solution are presented, emphasizing the role of intuition. A decision-making scheme is presented, leading to the acquisition of distinct experiences resulting in an increase in the procedural knowledge stored in the long-term memory. The next stage is to visualize the decision-making process in the working memory in order to satisfactorily allocate funds into three categories. The results obtained indicate the intuitively correct decision according to an assumed quality factor which is the level of overall agent satisfaction. Reference is also made to the possible application of GAN neural networks, showing their potential in supporting intuitive decision making in the stock market. The considerations confirm the validity of an intuitive approach to business solutions and also enable a closer look at multidimensional aspects of intuition. The considerations confirm the validity of the intuitive approach to business solutions, as well as presenting an insight into multidimensional aspects of intuition itself.

Keywords: intuition, EPAM model, decision making
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1. Introduction

Every human uses his or her resources in some way, this may be while driving a car and burning fuel, walking and burning calories or spending money on products that are supposed to benefit him or her in the present or future time. The former type of spending resources is called consumption, which serves to fulfill the temporal life needs, and the latter is called investment, which is supposed to improve the overall quality of somebody's life on a long term basis, but which also requires compromises to sacrifice some easier and pleasurable benefits.

A confirmation of the usefulness of assuming a long-term benefit and refraining from immediate consumption is the famous Stanford Marshmallow experiment [1] which involved giving children the option of eating a sweet marshmallow immediately or waiting an extra 15 minutes without eating it, so that they could receive a second piece as a reward. The observation of the experiment was that most children succumbed to the temptation and when they saw the candy, they ate it immediately. After about 12-14 years, the people who had been tested in the experiment were found and questioned again, and it was observed that those who were able to abstain from eating the candy were more successful in their studies, more aware of their development and long-term benefits and showed more self-control. The observed effect was called the delayed gratification ability. It explains that refraining from the immediate reward and focusing on long-term gains leads to success in life.

People who had had a chance to apply a given solution had a greater chance to apply the same behavior in later experiences which increased the desired effects. This is the basic scheme of the human's mind architecture, which explains that successive experiences shape a person's view of the world, views, emotions towards certain stimuli, and then the behavior and decisions [3]. Investing in the future is subject to a high degree of uncertainty, it is never known for sure how a situation will develop and what variables will affect it. There are a very large number of factors that may affect the development of the situation, possibly even immeasurable, which is the reason why such decisions are significantly difficult to model and which forces us to consider the most important factors only. A specific human skill called intuition is immeasurable exactly to the same extent. It performs the function of instant pattern recognition in the observed situation and indicates the action that will lead the decision-maker to satisfaction. This is one of the basic laws derived by Simon Herbert, saying that the goal of making decisions is to achieve a specified level of satisfaction [8]. Intuition can be used in a variety of ways, and different models have been developed to explain its meaning and origins [31]. It comes from the person's emotional state, from an individual subconscious way of processing information, from ethical principles understood in a given environment and culture, and from individual life experience and knowledge [6]. This work focuses in particular on the experience and knowledge-based approach described as a cognitive model, modeled mainly on Simon's Herbert discoveries.

As described in articles [4,5] intuition plays an important role in business management, where decisions made are almost always limited by a high degree of uncertainty as it is impossible to possess all the available knowledge. Key decisions are usually made by people with the greatest experience and well-developed cognitive abilities. Valuable results for the development of science in the cited works include enrichment of knowledge about human mental processes used in cognitive science. Over time, this field of science more and more thoroughly justifies the essence of internal mental processes, reaches information about the functions of individual parts of the brain, interprets the reasons that result from our mental states, such as satisfaction with life or work efficiency. For example, the knowledge of what motivates a person to behave in a certain way can be used in the processes of evaluating consumers and matching manufactured products by a company to customer preferences. A person who has made a significant contribution to the development of this field of science in Poland is Włodzisław Duch [2,3]. In his works, he explains the essence of cognitive science, its value in our everyday life and the fact that it actually gives us the possibility to understand ourselves. It is a very broad field, and its essence is to understand the process of perceiving the outside world, processing information about it and delivering the resulting reactions in the mind. Intuition is closely related to these processes and manifests itself through recognizing a pattern in a situation, having a feeling about what might happen in the future or signaling what actions are right. It is based on the integration of many factors, without focusing on a strict deterministic analysis.

Herbert Simon's work in the field of the decision-making research [8,11] helped broaden the general knowledge in economic decision management and gain a better understanding of the psychological substrates of certain decisions, for which he received the 1978 Nobel Prize in Economics [9]. His work has had a great impact on econometrics and identification of economic parameters in organizational procedures. What is more, he proposed block models to optimize complex managerial decisions [11], which was highly influential for the future work taken up by other researchers [13]. The effect of applying such theories was to make potentially economically best decisions with an understanding of the reasons behind them [31]. He has also contributed to a better understanding of psychological processes. He would describe the Gestalt psychology as the ability to see patterns which resulted in maintaining balance in life, having the ability to find the golden mean in life, the ability to understand and intuition [6]. In his works, he describes the processes of shaping mental information and the way of using it, which was used in building expert systems described below. A large part of his research concerned the rationalization of decisions [8,9,10,12] and translating psychological processes, philosophical and logical theories into mathematical properties, flowcharts and computer programs [41].

Herbert Simon was also highly influential in the early development of arti- ficial intelligence [7,25]. He participated in the development of the first intelligent decision models such as the ”Logic Theory Machine”, ”General Problem Solver” and ”Elementary Perceiver and Memorizer”, which were the prototypes of systems with the ability to reason, plan, perceive stimuli and execute decisions. Later, more advanced systems called cognitive architectures were developed [2,28,29,33,34]. In the early stages of the development of artificial intelligence, it was mainly rule-ba- sed, which changed with developing numerous machine learning methods like SVM and neural networks. The recent important years for artificial intelligence were 2006-2010, when computer hardware allowed efficient neural networks training. At that time, there was special growth in this field and one of the very valuable discoveries were the generative adversarial networks (GAN) invented in 2014. They exhibit creative properties, and their effects often show the most impressive results of artificial intelligence [36,37,38,39,40].

The problem analyzed in this paper is the way of making decisions about investing money. The work tries to present possible ways of interpreting this process in terms of modeling the intuition. It focuses on presenting the application of Soar's cognitive architecture in the process of selecting the decision-making rules and distributing funds. The decision-making process takes place mainly through the ability to recognize the current state and determine the optimal course of action. This requires knowledge of possible solutions to problems and the ability to observe and draw conclusions. The selection of an action and its consequent utility depends on the agent's current state and his preferences. This paper addresses the problem of distributing money based on the agent's current knowledge. It also explicitly presents the pattern recognition capabilities of generative neural networks in predicting future indications of market values based on dynamically changing data which can help the potential investor make the right choices.

The second chapter describes a cognitive model of intuition developed on the basis of the available sources in cognitive science, psychology and Simon Herbert's concept. The EPAM decision tree model is presented which fulfils the assumptions of intuition, including the ability to immediately draw conclusions without knowing the reasons behind them and the ability to gain the quality of action with the acquired knowledge [25]. The model improves through knowledge acquisition with each stimulus received. It recognizes whether each stimulus is already in the knowledge base or not. When it is not in the knowledge base, the tree consistently grows and enhances its capabilities. The Soar cognitive architecture which is used to model agents that have the ability to make intelligent decisions resulting from a combination of perceptual functions, semantics of symbolic meanings and procedural inference is also described.

The third chapter describes the concept of applying intuition in the process of investing money. The main concepts are investing in oneself and one's emotions, in employees [14], in stocks and alternative cash investments [16,17,19], which should be ecological to other people and the environment [18]. The approach of investing can be determined on the behavioral properties of a person, determining, for example, whether he or she is cautious, how much risk he or she takes, how much he or she has learned from his or her own and other people's experiences [23]. Developing a good intuition for investing money requires a lot of theoretical and practical knowledge acquired along with experience, which has been described with details in the papers [20,21,22]. It is often impossible to make a decision completely rationally due to having too little time and knowledge, which results in making decisions in an intuitive way [24].

The fourth chapter describes the model of making rational choices [10], which is a mathematical description of making right decisions by an agent with limited computational capabilities. It is based on the knowledge of possible actions, reached states and their numerically defined effects. The defined effect has to be based on the gained experience to assess which of the possible choices would bring the best results. Historically, the model was most useful in business activities, where it helped to make the right choices based on the acquired knowledge, and it was used in a similar way in this work. For this purpose, a specific space of states and rules was created that determined the possible course of decision-making, leading to the acquisition of various experiences. The acquired knowledge determined the rules drawn and the way of making decisions in the following processes.

The fifth chapter describes a generative GAN used for the purpose of predic- ting stock market indications. The similarity of this neural network architecture to intuition is compared and the legitimacy of the approach for investing in stocks is described. The architecture consists of a generator which is a network performing the estimation of stock market indications and a determinator assessing whether the checked data is generated or real. The resulting effect of the network opera- tion is able to properly approximate the distribution of real data in the generated data.

2. The cognitive model of intuition

Intuition is a result of intelligence and experience from which the subject is able to draw more effective conclusions and take better actions, and can therefore be equated with the choice of optimal decisions. Intuition differs from rationality in that that it does not require estimating the optimal choice through analysis of each possible choice effects, but acts almost immediately. It can be described as subconscious pattern recognition without the need for reasoning [25]. This concept was born in the context of economics and is used in a similar way in this thesis.

Decision making can be understood as the optimization of the goal function, aiming for maximum good outcome depending on what profits a person is able to achieve by making the right choices. Herbert Simon's assumption is that the human being usually seeks to maximize the effects of multiple goals. He or she also does not have complete information about all possible solutions, often limiting himself or herself to the best tested ones. Another limitation is his or her low computing power and the low prediction ability compared to computers, what does not allow him or her to make appropriate comparisons between specific alternatives. Due to these limitations, the rational entity is not guided by the principle of optimization, but by the principle of bounded-rationality [8]. This can be understood as making a choice that satisfies a person in terms of many different requirements. Intuition can be compared to a rational analysis performed by humans, and in both cases the limitations are human computational capabilities and the lack of knowledge of all the alternatives. According to Herbert, there are no logical differences between intuition and rational decision making as they both lead to a certain goal. Herbert Simon tried to investigate how computer language was able to create symbols and operate on them like a human's mind. These experience-based programs work in a similar way to the cognitive model of behavior in psychology [13]. For humans, this means that they have learned certain ways of behavior in the past, from which their current behavior is derived. On the other hand, it is assumed for a computer program that the model responds to the input data depending on what data has been fed into it at an earlier time. This leads to the description of certain laws within the analyzed field of knowledge, which can be both physics, chemistry or cognitive psychology. The context in which the human mental complexity was born comes from the issue of formulating and transmitting information through speech. Thanks to this function, human beings have managed to evolve the ability to create symbols and meanings between them and, as a further result, the ability to draw conclusions and process them complexly. Based on the coded information, he or she has been able to improve his or her behavior in order to maximize his or her chances of survival. Artificial intelligence mimics the human's mechanism of processing information in artificial neural networks. It allows recognition of a specific pattern in the data and works by minimizing errors or maximizing reward functions (for reinforcement learning). It is able to model natural language processing in the form of architectures such as RNN, LSTM, BERT. Other methods of artificial intelligence are expert systems the origins of which date back to the 1960s [25,26]. They were considered to be the artificial intelligence of those times because they were able to come to conclusions resulting from given conditions, they had learning functions and were providing expert assistance in specific fields of knowledge. An example of an expert system architecture is EPAM (Elementary Perceiver and Memorizer) described later in this paper. Simon believed that intuition could be modeled by creating programs capable of finding patterns and deducing the cause and effect. Programs that existed in his time that met this requirements were EPAM [25,26,27] working in conjunction with the then version of Soar [28,30], a cognitive architecture that associates multiple problem areas and learns by chunking. Cognitive architectures can be successfully used to create agents that can make decisions intuitively based on their ability to learn and interact with the environment [29,35]. Other models of that time meeting the requirements of intuition were developed by Bacon [25,41], Glauber, Stahl, Black [7]. The operation of these systems was based on principles analogous to thought processes.

On the basis of the conclusions written above, it can be concluded that neural networks themselves represent intuition, but in their case, it works within a very narrow range of the learned features. They are not able to create links between separate issues and do not have the ability to find similarities between them as fast as the human. A modern solution that could properly represent intuition with meaningful symbols would be a complex model of neural networks drawing inferences from knowledge graphs or other machine learning models. The input data for such models could be the parameters of measured emotional features (e.g. the level of happiness at a given moment, the number of close relationships, the quality and intensity of these relationships), indicators of a person's knowledge, experience, as well as his or her cognitive skills and cultural influences. In order to correctly estimate such factors, designers must carefully analyze the experience itself, the processes and the architecture of the processing conclusions. The criteria that the human intuition fulfils are immediate decision making after getting a problem and the inability to determine how many steps the subject needs to take to achieve a solution [26]. Knowing these laws, it is possible to start the implementation of intuitive decision-making in a computer program, which should proceed analogously to the human mind. In this case, The Soar software notation was used.

2.0.1. EPAM computer model

A program that operates on the principle described above is EPAM, which was first launched in 1960 [25,26,27]. It was intended to recognize the process of verbal learning by heart by humans, and its side effect was the correct modeling of intuition. This program is based on a decision tree the branches of which grow as stimuli are received. It learns to recognize symbols from experience and has a short-term memory. It gains experience by learning to correctly recognize the meanings of stimuli, thanks to the 'true' or 'false' feedback from the environment. EPAM networks have been taught to recognize almost 105 possible types of stimuli. An example of the use of this system could also be identification of a patient's symptoms in order to determine the disease. The system is able to quickly reach a diagnosis, but is unable to justify the reason for its choice. What is more, it is not able to determine which one of the many inputs is actually used to reach a given conclusion or what weights each individual inputs had in the diagnosis process. For a better diagnosis in more complex cases, Herbert Simon suggests using a combination of EPAM and Soar. This improves the ability to recognize symptoms and their causes, and also makes it possible to determine which additional tests are worth performing. There have been more effective programs in the field of decision support, but the special feature of this solution is that it models the cognitive intuition properly. The result comes quickly and it is not clear on what the actual decision is based. The features of the prediction performed by EPAM are both the lack of recognition without prior knowledge and the lack of intuition without prior recognition. According to this conclusion, experts in their fields should report what their intuition tells them, and they would be right in most cases, whereas beginners using intuition would have a much lower quality of prediction. As an imitation of the human cognitive process, EPAM consists of a recognition component, processing, short-term memory storage and access to symbol semantics. This provides a combination of perceptual functions capable of capturing object features (front-end) and long-term memory for semantic data processing and inference (back-end). In the case of this program, feature extraction is performed by adding the observed elements to a tree. The leaves of the decision tree contain indexes to the semantic database. The role of the short-term memory is to perform the learning process. The strength of the model is to minimize the number of tests performed to a minimum and achieve fast performance. Herbert Simon calls the created decision tree as a discrimination net. The leaves of the decision tree are called "images", i.e. the information remembered by the model, and act as long-term memory. All other nodes are T-tests, which check a condition and determine if a stimulus is recognized or not. Each test node is an n-element array of "switch" functions. One branch of the n-branches from one node is labeled as n.e.c. ("not else-where classified at this node"). It means that the perceived stimulus is different from the other learned in this node. During the learning phase, it is often recognized that an object is new, there is no way for a node to recognize it and there is no branch pointing to this object. It is then classified into the n.e.c. branch. The learning process occurs through the growth of the discriminative network, which tends to grow in breadth more than in depth. Information about the observed features is found in the I cells along with the C causes, which are indicators in the knowledge base for the features. The program operation steps can be defined as follows:

1. Recognition of external stimuli, some features of the stimuli are already in the tree;
2. Adding a new stimulus to the memory by building a new test to distinguish between the stimuli previously learned; 3. The possibility of associating an object with a sub-object;
4. Responding to external stimuli with a response previously learned by retrieving a sub-object pointer to an object and then retrieving the response.

Herbert Simon used the Soar cognitive architecture to recognize external stimuli and EPAM to perform a decision-making process. In later years Soar continued to be developed and did not need additional components to model cognitive processes. The architecture seeks to create a strong artificial intelligence, an independent computer model capable of behaving intelligently and learning from its own experience. Cognitive architectures are mostly developed to model human behavior in situations with multiple tasks to be fulfilled simultaneously [2]. The model of a cognitive system should provide adaptive, dynamic and flexible behavior.

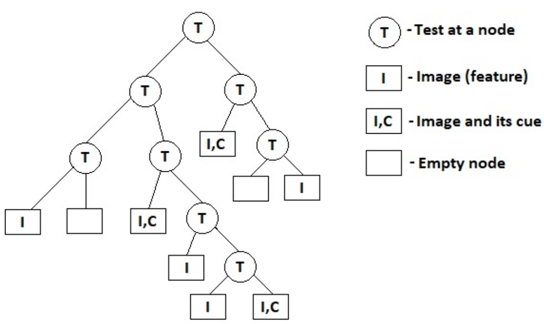

Figure 1. EPAM tree structure and component designations

2.0.2. Soar cognitive architecture

Soar is an architecture that has been regularly developed since the 1980s and it has now reached its 9th version [28,29,30]. Its name Soar is derived from the words "State, Operator and Result", but this name is no longer understood as an acronym but as its own name proper. It is mainly used to perform various types of scientific research, having less importance in commercial applications. It allows creating models in areas such as learning and memory, problem solving and decision making, natural language understanding, perception and cognitive development. It meets the requirements previously set and in its current version allows achieving far better modeling intuition than earlier models from Simon's time. It is a classical cognitive architecture based on expert rules. Soar stores its knowledge in the form of production rules, determined by operators that operate within a given problem, described by sets of states occurring in the task. The learning mechanism in Soar is called chunking. It is an automatic process of learning the correct rules. This architecture also includes an optional reinforcement learning mechanism, deriving its functionality from learning from statistical data. It is used to learn which actions have given success in the past and calculate which operator should be selected in the inference stage [42]. The knowledge contained in the program is built from 3 types of knowledge - episodic knowledge (about specific past experiences), semantic knowledge (to describe abstract concepts) and proce- dural knowledge to determine the behavior performed. Additional enhancements to the program include the ability to visualize images, model emotions, mood and feelings what improves the quality of reinforcement learning process and direct deduction [2]. The Soar architecture is described as an implementation of psy- chological knowledge rather than a programming language. It involves analyzing the available knowledge about a given task and, through written rules, leads to expressing this knowledge and causing certain behavior. The decision-making pro- cess is similar to EPAM, i.e. consecutive checking of specific nodes and making selections one by one leads to a possibly satisfactory solution. In theory, cognitive behavior is defined by the following characteristics [28]:

1. It is goal-oriented. As human beings we perform actions linked to our desires and intentions, e.g. if we do not have a job and money, we submit our CVs to companies where we would be willing to work and be satisfied with the environment. This requires acquiring the appropriate knowledge and increasing various competences, such as the skill to present oneself well, demonstrate technical knowledge, and become familiar with the interview practices.

2. Dependence on the external environment, which is very complex. The individual's perspectives of perceiving and performing actions in the world are limited. He or she does not perceive all possible solutions in a world composed of a large number of objects and their effective impact on utility factors. These are the key factors leading to the understanding how to achieve a goal.

3. It requires a large amount of knowledge to implement possible procedures for action, i.e. behavior in particular situations and specific rules for using this knowledge.

4. It requires symbols and abstractions. Behavior is not only derived from perception, a part of the information is integrated internally in the mind forming symbols that point to specific meanings relevant to cognitive processes. Also important is the individual drawing of conclusions, the so-called abstract thinking, which allows one to start the learning process with no prior knowledge.

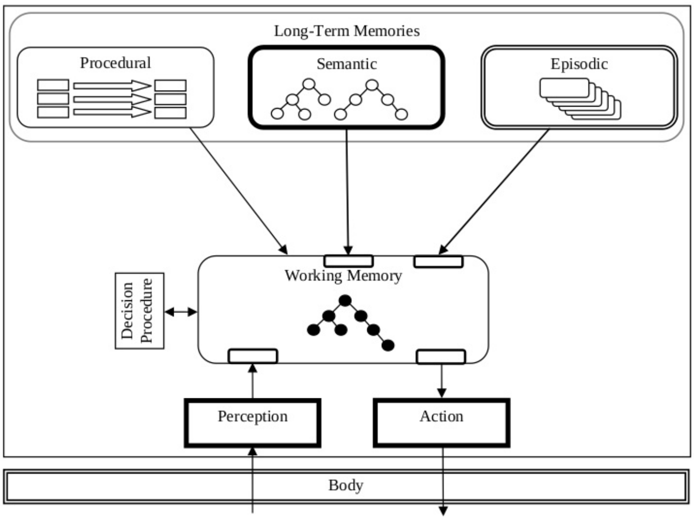

Figure 2. Memory architecture in the Soar system [28]

5. Flexibility and dependence on the environment. If a major life event occurs in a given moment, such as an accident of a loved one, there is a significant change in the approach to the current tasks and priorities.

6. Learning from environment and experience. We are not born with all the re- quired knowledge for life, such as solving mathematical tasks, knowing how to write a scientific article or making a dinner. However, with experience, we become better at the performed activities.

The central mechanism of the Soar architecture is the cyclically occurring decision procedure, which is an interaction between the procedural and working memory. The procedural memory defines the knowledge of the functioning processes and the working memory represents the current temporary situation. The information in the working memory is represented by a symbolic graph structure identified with the state of the object. The procedural knowledge, on the other hand, is represented by if-then rules that define the conditions and actions to be performed. They are checked on a regular basis during the program's operation cycle and compared to the operational memory. The architecture reacts to new data received by the perception functions, interprets it, compares the available solution alternatives and selects one. The selected action changes the state of the short-term memory and leads to the next processing cycle. Long-term knowledge is stored in the semantic memory, which can be used by the working memory during rule checking. The episodic memory is the knowledge about the effects of previous experiences and can optionally be used by the agent to predict the consequences of the actions taken. The behavior manifested by the model is the result of the architecture built and its content, which continuously improves in the course of learning.

3. Investment characteristics

Financing is an area primarily aimed at achieving the highest possible profit with the lowest possible risk. In this process, it is important to investigate which activities will bring a significant overall improvement of the investor's situation and obtain profits in the shortest possible time. Factors affecting the moral quality of an investment include the ecology of financing [17,18], i.e. doing it in a way that is not harmful to other people and environment and should also focus on helping other people. An example of an experience that may have taken place in the past that gave relatively best benefits is, for example, reading a good book, including time spent reading and analyzing it. The book could have been about optimizing the daily responsibilities, improving the existing habits, work competences, developing hobbies or improving relationships with other people. Another investment could be a tool to help with one's daily activities, such as computer equipment or a car. Physical training and consultations with specialists are also important aspects of life, investments in this field can concern consultations with a personal trainer, psychotherapist or a doctor. A person should also broaden the horizons of his or her view of the world, cultivate relaxation and well-being, e.g. through travel to other countries, massages in spas, beauty treatments.

In order to determine what is really important for a person and what leads to the desired result, it is necessary to know his or her own values, the goal to which he or she aspires and what gives him or her the greatest satisfaction. On this basis, he or she should define his or her criteria and regulate his or her actions. On the subconscious level the human intuition knows and uses these criteria to evaluate the solution related to the experienced emotions and the acquired knowledge. The acquired skills and knowledge help to better assess the situations encountered, predict the likely course of events, and also allow protecting oneself from potential harm or discover a new valuable solution.

3.0.1. Tangible investment

An investment in terms of wealth is the placement of financial or other non-financial resources in various types of assets that are expected to generate a profit for the investor in the future [18,21]. They are distinguished from consumption in that that the investor does not expect immediate benefits but obtains them over a longer period of time. They usually require extensive knowledge of the wise investment principles [20] and orientation in the current market trends. Acquiring financial knowledge requires a lot of patience, discipline, and an inner desire to learn. It also requires controlling emotions, as excessive excitement about gains can bring large losses. Investments can be purely financial and based on operating in the economic market [21]. They can be divided into:

1. Dynamic deposits which require relatively little work, are secure, but offer low returns [21];
2. Purchasing market investments, such as buying stocks, bonds. The returns on stocks and bonds have been opposite at different times. For example, in 1972, the profit on high-interest bonds was 7.19% and on industrial compa- nies 2.76% (in 1949, these values were 2.66% and 6.82%, respectively) [20];
3. Life insurance policies with an investment fund. They allow safeguarding health and also generate potential interest on the sum paid in if certain requirements are met;
4. Alternative investments, such as in works of art, antiques, real estate, bullion, wine [16]. They can have varying degrees of return.

All investments placed on the stock market or other monetary operations involve many different fluctuations that can take place over time. It is never possible to one hundred percent predict the course of local events, global events and actions of competing companies. Intuition in market investing is used to predict which commodity, service or stock will soon gain in demand and market value. In this process one must also take into account the inflation [15] reducing the actual monetary value over a longer period of time and use the ability to predict what will have a long-term upward trend in the current times. Examples of economic sectors fulfilling this property were the aerospace or computer sectors at the end of the last century, and nowadays there are companies working with widely defined artificial intelligence or Big Data analysis.

We can invest in things over which we have no direct influence and our task is to skillfully follow the events of the outside world, analyze the economic market and current trends. We can also focus on what we have direct impact and shape it with much greater control, adjusting it to the directions of development with potentially higher profits. In this regard, investing in ourselves and being independent of countless external factors is an incomparably better option. In the context of money, this refers to investments in one’s own business, but it can also be simple intangible investments in personal development and in supporting the loved ones. Intangible investments for entrepreneurs can be licenses, marketing activities or registering patents.

3.0.2. Investing in people

The monetary input allocated to human development is called human capital investment [14]. The human capital is a resource of knowledge, skills and executive energy that a given person has and is able to use for functions related to the performed role. It increases the revenue of the organization and the individual. Potential investments include training, practical exercises or education. The acquired skills translate into a better ability to assimilate modern technologies, operate them more efficiently and correctly. The gained experience often translates into improved human performance. An example of a universal personal investment nowadays is improving the communication skills with other people, learning foreign languages or gaining knowledge about other cultures. A private individual can invest in things that are not quantitatively measurable, such as:

- Knowledge and the ability to use it, professional skills;
- Self-realization, emotional sphere. This improves the well-being, living comfort and subsequently increased productivity;
- Helping others, which in the context of establishing a community between people can bring positive results for the individual in the future.

A wise suggestion, dating back as early as to 220 BC, is to divide one's investments into three equal parts, one in land, one in business conducted, and one in savings, quoting ”One should always divide his wealth into three parts: a third in land, a third in merchandise, and a third ready to hand” [32]. It can be understood that the first part from the income, which does not include consumption, is related to investing in real estate and values unchanged throughout the history of mankind, and the next is individual business activities while the last one is bank savings.

3.0.3 The role of intuition in investment decisions

Intuition requires calmness and a clear understanding of the situation. Emotional issues are not considered in the cognitive model, but they must be taken into account, when describing the actual human behavior. Intuition can be distracted by disruptive factors and for an investor observing the market situation, it can be rumors from his or her friends, news in the press or rapid price changes in the market. The investor may then succumb to his or her mood and extreme feelings such as fear or greed to make money [23]. By acting on impulse, the heuristic view of the situation is diminished and the risk of failure increases. Another human limitation is that investors always have a limited amount of information, they must then display insight and imagine possible courses of events.

An individual investor does not determine his or her decisions strictly by specific rational premises. He or she does so with a certain degree of approximation depending on his or her objective, his or her knowledge and his or her possibilities. In doing so, he or she uses his or her intuition. The decision-maker determines the effects that satisfy him or her, he or she needs to make the decision in a short period of time and rely on his or her experience.

An important element for the cognitive intuition is the ability to rely on one's own individual knowledge. It allows shaping and optimizing the personal situation, becoming resistant to the opinions and influences of the environment. Valuable behavior is to follow solutions of more experienced people because thanks to them one can see some ready-made paths, protecting oneself from making mistakes. Thanks to skilful observations, a person is able to reproduce the learned behavior on his or her own example and make more progress in less time.

It is necessary to answer how much money should be spent on consumption, how much on savings, and how much should be invested, as well as to skillfully manage the risk. The considered risk may manifest itself in various ways: by avoiding it, a neutral attitude to it or a conscious preference for it. An proper appropriate analysis of the market rules should be carried out to make skilful investment decisions in the market. In this context, the important things are the market information on the situation and events occurring in the market. It is valuable to known whether the market strategies, tendencies or prices change in a specific direction. The important aspects are also the limits of recurring regular market trends and duration of these tendencies, which may last from several weeks to even several years.

In the process of inference, the investor should be careful about the mistakes of a schematic approach and excessive generalization, estimating a small fragment of the whole as a representative picture of the observed phenomena. Other mistakes that may be committed include entrepreneurs ignoring the external factors and overconfidence that the trend will change. People tend to trust more what they have learnt in the past, closing their minds to new future solutions that may bring higher profits. Additional psychological factors that influence the human behavior when facing the risk of loss are overestimation of small probabilities and underestimation of medium and large probabilities of given events, as well as regretting a loss more than enjoying a gain. Investors mostly perceive the attractiveness of an offer in light of its price and the risk associated with such investments is low at the moment of buying cheap stocks. The case gets riskier as stock get more expensive. A smart investor is afraid of a bull market (a long-term upward trend in stock market prices) because stocks cost more and more and during a bear market (long-term downward trend) one should have money in cash and wait for stocks to sell off [20]. A very important criterion in the perspective of making investments is the comparison of the outlays made with the effects that resulted from them [17]. A rational manager will strive to minimize the outlays in relation to achieving the desired effects and to maximize the effects with the contributed specific outlays. Since the human being improves his or her decisions as part of gaining experience, as a beginner, he or she should start with relatively low-risk ventures to limit the maximum possible losses and then gradually gain a better idea of the possible decisions and their consequences. Four investment principles have been proposed to safely gain experience and wisely prepare the novice investor [20]:

1. Saving is the key to healthy investing, allowing the investor to be mentally and materially secure.
2. Defining one's own investment system and not being influenced by the behavior of other people.
3. Diversification of investments, i.e. investing in different assets.
4. Patience and a limited number of transactions at any one time.

Moreover, investments can also be divided into different time duration periods after which satisfactory results are expected which can be:

- In the case of tangible assets these may be investments in long-term securities, investments in the development of a company, purchase of real estate, long-term loans, marketing activities, creating a good reputation among customers. In the case of intangible investments, most of them have a long-term effect, because it is never known when the knowledge that we have will be useful in life and its benefits can be obtained throughout life.
- Short-term with a time to maturity of less than one year, such as holdings shares or securities for several months.

4. Intuition in decision-making

4.0.1. Using the Soar architecture

The most important principle of the Soar architecture in connection with intuition is to work through recognition, similarly to the EPAM model. This means that Soar refines a tree of possible events depending on the perceived stimuli and the knowledge possessed. Recognition occurs whenever Soar receives a stimulus, and when it is unable to recognize it, it has to create a subcomponent to allow subsequent identification. In order to do so, the program should behave recursively to avoid getting into an impasse. A new component is created through a process of deduction and learning. A ”chunk” is then created, which is the basic element of the memory structure. The most important terms in the decision-making process are the following:

- Goal - to achieve the desired state;
- State - a representation of the situation as the problem is being solved;
- Problem space - the set of states and operators for a given task;
- Operator - transforms the state through the performed action.

Problem solving takes place by selecting and applying operators for a given state to achieve a given goal. For example, in the state of initiation, the agent has too little value in the area of professional competence, then he has a choice of many actions to perform from which some will give him a better effect, and others a worse one. If he considers professional development to be the most important criterion, he should give up other activities and focus on performing actions that would increase the desired state parameters, such as knowledge or self-confidence, and then the overall level of the achieved satisfaction. Figure 3 presents a state space with one decisive state parameter, which is the level of satisfaction. Several possible decisions and experiences that could change the state in different aspects are presented, and a software implementation in the Soar language is shown.

The creation of the program required the definition of the decision problem, during which the current and desired state recognition takes place. This information is contained in the agent’s working memory, which tells about the agent’s existing internal parameters and the values of these parameters. When creating an agent to solve a problem, attributes and values must be given to categorize the different states. In an investment problem, a state must indicated by how much the utility criterion of a given choice has increased, in other words, what profits the agent is able to obtain after making a certain decision. In each successive state the values of the attributes change depending on the actions performed. Attributes are prefixed with ”^”, and next words are values defined for them. Attribute values change after performing actions, but attributes remain the same. The num- ber of possible attributes can increase as the model learns, i.e. when operations containing previously unknown attributes take place. Initially, the initial state must be initialized, which in the above example would look as follows:

```
(state <s>
        ^Education Studying
        ^Goal GreatCareer
        ^Energy Tired
        ^Money LotsOfMoney
        ^Employed PartTime
        ^Support LackOfSupport
        ^Satisfaction 65%)
```

After appropriate initialization of the state, appropriate operators, i.e. production rules modifying the state parameters should be added. There may be many operators for each state and they are executed when the conditions are met. They should first be implemented together with their corresponding rules and during the program execution they should be checked recursively. An example operator relating to the first branch:

```
 ## Set production rule
sp {propose*business-course
        (state <s>
        ## conditions for attribute’s value
                ^Goal GreatCareer
                ^Money LotsOfMoney)
        --> ## apply operator
                (<s> ^operator <o>+)
                (<o>                    ^name
GoOnBusinessCourse)}
```

Conditionally, the operation will be written as follows:

If Michal is in the “propose*business-course” problem space, AND in the current state Michal has LotsOfMoney and the GreatCareer goal, THEN propose an operator to apply to the current state and call this operator “GoOnBusinessCourse”.

In addition to the procedural rules, rules are also implemented for recognizing the desired state that defines the end of program execution. In this case, it is primarily the value of the criterion of the required overall satisfaction. In order to further improve the program, search control rules can also be implemented, whereby the agent is able to determine a preference between two operators. Their purpose is either to avoid useless operators or to direct the search to the desired state. Theoretically, it would be possible to write enough rules so that the correct operator is always chosen for each state. However, it is first necessary to understand the problem entirely to know all the possible rules and the goal of the program is that it will be able to solve the problem on its own by using the knowledge that it has. The final condition of the program: If the task is to have satisfaction equal or greater than 80 % and GreatCareer has been completed, then write that the problem has been solved and halt. In Soar, the condition would look as follows:

```
sp {satisfaction*detect*goal*achieved
        (state ^Goal GreatCareerCompleted
        ^Satisfaction 80%) -->
        write (crlf) The problem has been solved)
        (halt-)}
```

4.0.2. Rationalizing decision-making process

Both, the human and the agent created by the computer program exhibit a strategic approach to fulfilling their goals. For this reason, making the right decision requires the ability to determine whether a given choice is satisfactory and leads to the goal fulfillment. Possible solutions to this problem are varied and may include weighted benefits and costs, creating connectionist models, gathering knowledge and creating production rules, or maximizing the utility functions [31]. The Model of rational decision making [10] was aimed at reaching the set aspiration level in the process of analyzing which actions would give better results and have greater probability to the proper state set. The level of satisfaction is the value of the goal variable, which must be achieved or exceeded as a result of making satisfactory choices (in the case of investing, the goal variable may be income).

The human aspiration levels are not fixed, but adapt dynamically to the existing situation. They rise when it is easy to find good enough alternatives and fall when it is difficult to do so. The proposed model is based on the consideration of 4 psychological factors influencing the quality of intuition functioning and 3 main assumptions for constructing such a model.

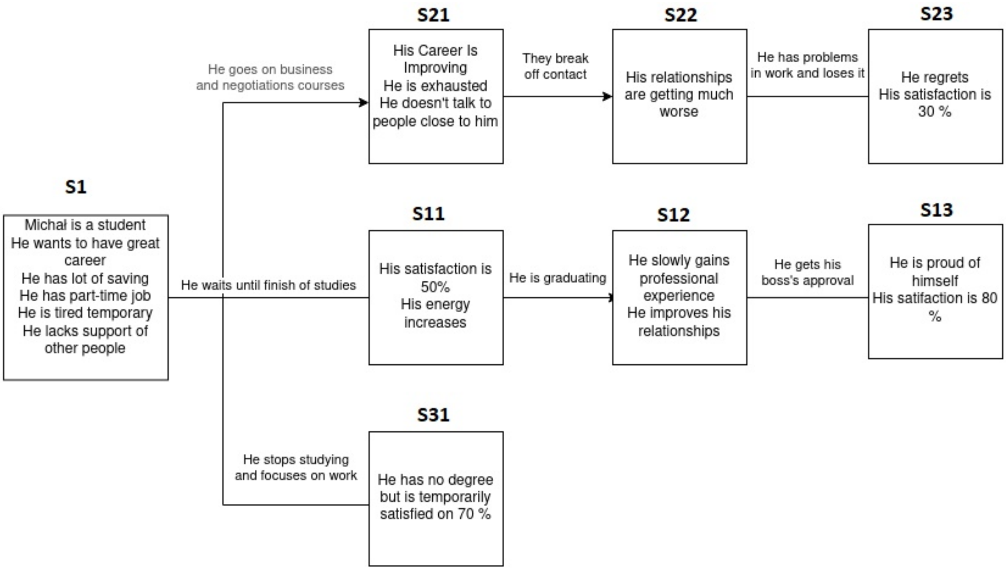

Figure 3. Example of a decision flow leading to changes in states and attribute values

Psychological factors [25]:

- Perception, which determined a person's abilities to perceive his or her environment;
- Memory, i.e. the capacity to store knowledge and the speed of processing it;
- Imagination;
- The way of thinking.

Model assumptions:

- Decisions are not perfectly rational because they are made by individuals with limited rationality;
- The quality of the decision is proportional to

the knowledge of the decision maker;

- It is important to study what steps led to a particular decision to understand the decision-making process.

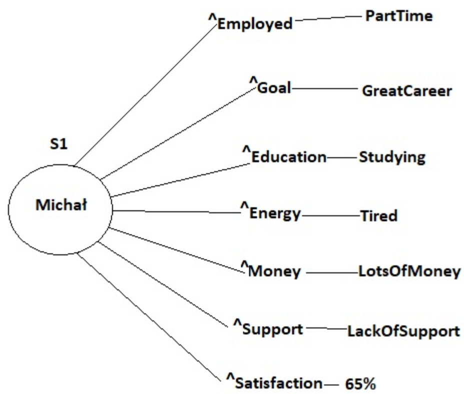

Figure 4. Operational memory indicating the S1 state of an agent, its attributes and values

The acquired experience allows people to solve given problems in a shorter time, take fewer steps find a solution, spend less time implementing a given step, pay less attention to previously unknown facts and increase the certainty of their decisions. Associations between actions and their consequences evolve as decisions are made and are based on the success or failure experienced in the past. According to Simon Herbert, intuition is a sophisticated form of inference developed through years of experience, and its executive functions include creativity, integrating facts and coming up with new valuable conclusions and information. An example of this approach is when a team manager must make dynamic choices and consider both the responsibility and the risk.

Herbert Simon describes how decisions are made from a rationalization perspective, which he describes with a mathematical model composed of six component variables [10]. These allow describing possible situations and their potential outcomes. Satisfaction with the choices made is denoted by U(s). Satisfaction is fulfilled when it exceeds an assumed threshold k for the utility function V(s) which is the final utility result obtained in a state s. Description of the variables:

1. *A* - a set of possible actions to be performed by an individual in a given situation;
2. *A'* - a subset of set *A*, i.e. the actions that the individual perceives and processes;
3. *S* - a set of possible future situations *s*;
4. Utility function V(s), defined for all *s* belonging to *S*. In the process of making a decision, it is only the relationship between the utility of the states *s* that is relevant. The state *s* that leads to the best available state is selected;
5. Information about the content of the situation *s* to which the event *a* will lead, whereby there may be more than one probable state s after the occurrence of event *a*;
6. Probability $P_a(s)$ that a particular state s will occur after event a.
7. Variable *U(s)* may take the value 1 or -1 depending on whether *V(s)* exceeds an assumed value of *k*

According to the above, the model consists of three variables that will condition the possible courses of the process, these will be the chosen action *a*, the achieved state s and its utility outcome *V(s)*. The variable *U(s)* refers to the fulfillment of expectations, which the subject should define himself or herself according to his or her own requirements. These may be satisfactory or unsatisfactory, which depends on the value of variable *V(s)*. The three rational approach principles can be applied to find a solution and the utility value:

a. The max-min rule which ensures that the number of states and actions needed to achieve the maximum outcome *V(s)* is minimized:

$$\hat{V}(\hat{a}) = \mathrm{Min}_{s \in Sa} V(s) = \mathrm{Max}_{a \in A} \mathrm{Min}_{s \in Sa} V(s) \quad (1)$$

b. The probability principle, which aims to select actions that maximize the probability of achieving a satisfactory outcome *V(s)*:

$$\hat{V}(\hat{a}) = \sum_{s \in Sa} V(s) P_{\hat{a}}(s) = \mathrm{Max}_{a \in A} \sum_{s \in Sa} V(s) P_{\hat{a}}(s) \quad (2)$$

c. The principle of certainty is based on the choice of actions having certainty of certain outcomes:

$$\hat{V}(\hat{a}) = V(S_{\hat{a}}) = \mathrm{Max}_{a \in A} V(S_a) \quad (3)$$

d. The condition for the value of satisfaction function *U(s)*:

$$\text{If } (V(s) \geq k) \text{ then } U(s) = 1. \text{ Otherwise: } U(s) = -1 \quad (4)$$

Assuming the following:

V(s) - utility of being in state;
U(s) - satisfaction of being in state;
$P_{\hat{a}}(s)$- probability of occurrence of state s after the selected action â;
V(â) - optimum utility of choosing a particular action ;
â - selected optimal action;
A - set of all possible actions;
a - single action;
S - set of states;
s - single state;
$S_{\hat{a}}$ - set of possible states for the selected action;
S_a - set of possible states for the selected action;
k - threshold of the utility function that meets the satisfaction requirements.

4.0.3. Allocation of funds

The decision-making process analyzed in subsection 4.1 was intended to present the process of making decisions and gaining different experiences that shape the agent in various ways. The next stage would be to determine his financing preferences based on past events that shape his current priorities, values and lead to creation of the decision rules he uses in the financing process. Figure 5 shows a process of chunking, i.e. writing production rules that result from selecting the appropriate actions in the working memory processes, which leads to satisfaction. The wealth management process is described in the Soar architecture notation. This process allocates funds to three categories: savings, investment and consumption. In the initialization state the funds are distributed equally to each category. The agent’s needs are then initialized on a scale of 1-10 and a target is set to meet the aspiration levels for each attribute. The goal of the actions taken is to bring the current state to at least the specified level of needs and to observe how the distribution of funds will change.

<u>Summary of S1 status:</u>

```
^money
    ^money-for-consumption 0.33
    ^money-for-investing 0.33
    ^money-for-savings 0.33
^aspiration
    ^entertainment
        ^present 2
        ^wanted 9
    ^improving-relationships
        ^present 4
        ^wanted 8
    ^investing-in-passion
        ^present 6
        ^wanted 8
    ^professional-development
        ^present 5
        ^wanted 6
```

The operators execute actions to regulate the distribution of funds depending on the difference between the values of the needs in the initiation state and the desired state.

3. If the difference between the indications of the need to improve the relationship is 4 or 5 then add 0.04 to consumption at the cost of 0.02 in savings and 0.02 in investment

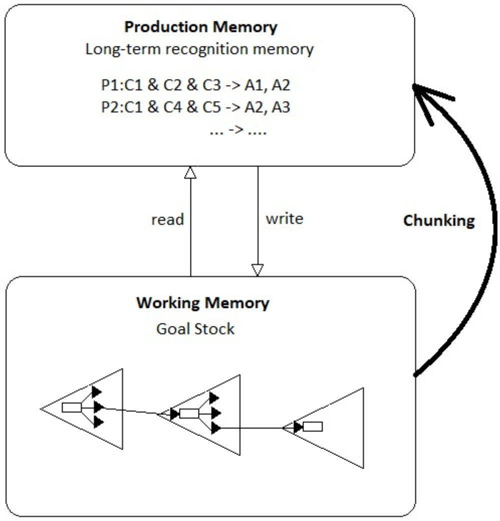

Figure 5. Working memory, production memory and chunking processes

Examples of operators:

1. If the difference in entertainment needs is 4 or 5, add 0.06 to consumption at a cost of 0.03 investment and 0.03 savings
2. If the difference in passion needs is 2 or 3 then add 0.04 to investment at a cost of 0.02 in savings and 0.02 in consumption

4. If the difference between the professional development indicators is 0 or 1 then do not change anything

A functional program adapted to each possible case would require the selection of a much larger number of rules to regulate the distribution of funds. Each special case would

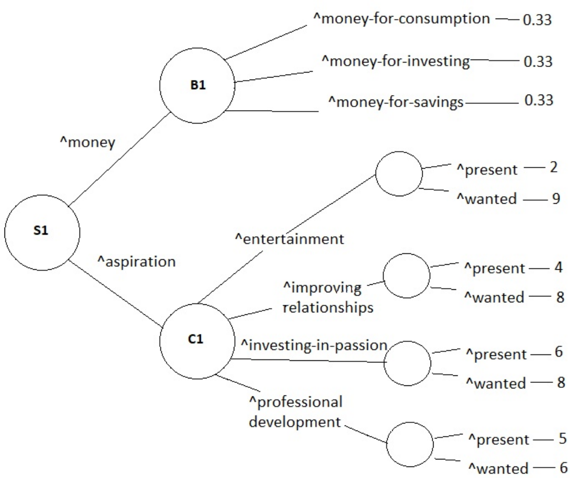

Figure 6. Agent state tree showing the distribution of money and aspirations, i.e. the production activities of the model

require editing the parameters for the current state and a separate call. As a result of applying the rules for the current case (Figure 6), the end result is as follows: consumption - 0.42, investment - 0.32, saving - 0.26.

5. Neural networks for supporting intuition

The Soar system example was mainly based on the representation of a binary way of identifying optimal decisions. As intuition itself is indefinable and immeasurable, the mechanism of special neural network architectures with pattern recognition capabilities GANs, was indicated as its representation. GANs are successfully used to generate new objects with excellent similarities to the real cases on which the network has been learned. The most common examples of using this algorithm are generating new images of human faces, new protein structures to create drugs or many other objects seen in images. These networks can be used to increase the resolution of computer images or transfer styles between images by being able to generate new data by finding patterns in the algorithm. The principle is based on feeding a random set of data to a generator neural network that tries to produce a new image from this set. This is then classified by a discriminator neural network, which assesses whether it is generated or original data. When the discriminator is unable to distinguish between generated and original data, the learning process is successful.

The similarities that these networks have with the mental model of intuition include focusing on finding patterns in the data and constantly improving through experience. For humans, experience is a complex process where they analyze a wide variety of factors correlated with the action taken and the various outcomes that follow, whereas a neural network focuses only on a cost function index measuring the quality of the learning process based on the similarity of the generated data to the real data. The cost function determines how close the learned model is to the maximum satisfactory outcome. The discriminator estimates whether a specific sample comes from the original set or from the generated set, which can be compared to the analysis whether the modeled decision-making abilities lead to the right outcomes. A symbolic example of a problem for which GANs have been used to interpret intuition is prediction of stock price indications. Neural networks have been successfully applied in the field of financial data processing, and the use of GANs is one of many possible approaches to such issues. They make it possible to recognize upward or downward trends in stock market indications and to determine predictions of their values. It is a more modern approach than econometric models from Simon's time, it is more sensitive to changes, requires less human input into the functioning of the model and is characterized by the ability to find patterns without the need to implement prior knowledge. In this model, the input values are data from current SP 500 stock index quotes, representing indications for the 500 largest US companies. The model was trained on data over the last 10 years. Each company is analyzed separately for a given calculation model with columns labeled "High Price", "Low Price", "Open Price", "Close Price" "Volume", "Adjusted Closed". They denote successively the highest, lowest, initial and final price of a share on a given day, the total cash flow and the adjusted final value of a share on a given day. These quantities make up a vector of six variables that are indicators of the cash flow and the stock market value. They are analyzed by a neural network that produces a new vector for each predicted moment in time and finally returns it in the form of a time series indicating the predicted change in the value of the stock market shares. The vector is determined for each analyzed moment of time t (which in this case means the next day), producing a series that can be continuously updated with new actual measurements of stock market indications:

probability that the sample comes from the learning data rather than from the generator [39]. The generator models the distribution of the data initially from random noise over a specified range of values, and then a training procedure is performed that leads to maximizing the similarity between the distribution of false and

$$\begin{gathered}\left[x_{k,i}\right]_{i=1}^{6} = \left[x_{k,High}, x_{k,Low}, x_{k,Open}, x_{k,Close}, x_{k,Volume}, x_{k,adj\_close}\right], \\ X_{\text{fake}} = x_1, x_2, \ldots, x_t, \hat{x}_{t+1}, \\ X_{\text{real}} = x_1, x_2, \ldots, x_t, x_{t+1},\end{gathered} \tag{5}$$

where:

$x_{k,i}$ - a single vector of stock parameters;

X_{fake}- generated series of indications;

X_{real}- real series of indications;

k - index of a single vector;

t - number of used time samples;

i - indicator columns High, Low, Open Close, Volume, adj_close

In engineering terms (see Figure 8), a GAN is an architecture consisting of a generator model G that manages the distribution of input data, which it tries to make as similar as possible to

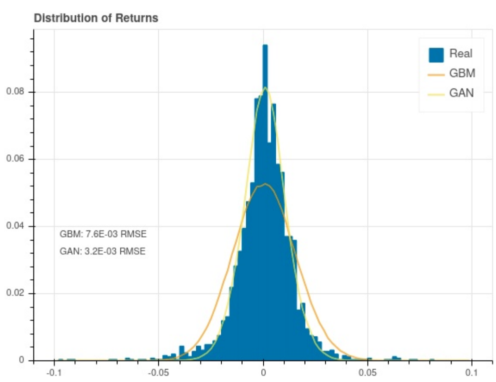

Figure 7. Fragment of stock market values [38]

a training set. The training set is the real stock market indications. The second part of the model is a discriminator *D* that estimates the

true data and the discriminator's recognition ability. In this case, the generator can be an LSTM network [40] or a multilayer perceptron [38] to perform temporal prediction of stock value indications, while the Discriminator is based on convolutional networks [40] or a multilayer perceptron for the classification task. Both parts are learned parallel, which is written by a summary cost function *V(G,D)*. It indicates the resulting performance of the network and seeks to find a global optimum when the discriminator is unable to distinguish whether the financial data is generated or true. The sign *E* means looking for this optimum. Once the network knows the patterns present in the data distribution it is able to reproduce them for future time samples indicating reliable outputs. The cost function equation is as follows [39]:

$$minmaxV(G,D)=E[log(D(X_{real}))]+E[log(1-D(G(X_{fake})))] \tag{6}$$

Figure 9 shows the effective distribution of investment returns based on the model results for intuitive stock market predictions on the example of an [38] enterprise. In contrast to the schemes described for the Soar software, this solution targets directly measurable information, estimates the probability and potential level of profit or loss. This model works automatically and is adjusted to the desired time horizon. It is completely separate from human considerations

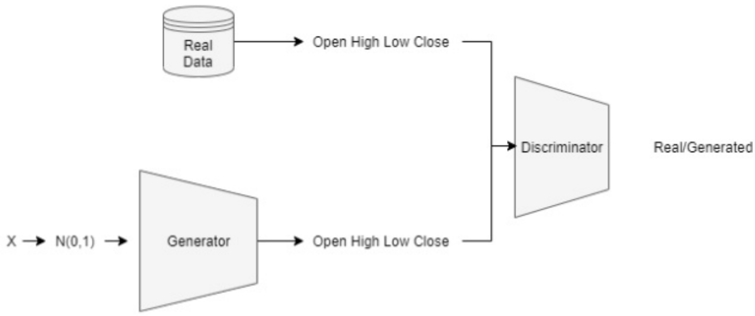

Figure 8. Schematic diagram of GAN neural network architecture [36]

and therefore simplifies the decision-making and does not require construction of an excessive number of rules that probably would not be able to fit into this example. This solution extends the range of possible intuitive decision-making by constructing a model based directly on the database and returning results that are relevant to the history of the stock market value indications. It suggests probable values of stock exchange shares, which is a valuable hint for persons investing their money in such a way.

high double Decimal	low double Decimal	open double Decimal	close double Decimal	volume double Decimal	adj_... double Decimal	date date Date
25.159...	24.540...	24.8700...	24.739...	8302700.0	20.271...	2010-07-06T00:00:00.000Z
26.350...	25.5	25.75	26.319...	1.55042E7	21.565...	2010-07-07T00:00:00.000Z
26.569...	25.659...	26.5200...	25.959...	9691000.0	21.270...	2010-07-08T00:00:00.000Z
26.239...	25.75	25.9699...	26.229...	5400600.0	21.491...	2010-07-09T00:00:00.000Z
26.389...	26.030...	26.1000...	26.270...	4736900.0	21.524...	2010-07-12T00:00:00.000Z
26.950...	26.459...	26.4799...	26.850...	1.07188E7	21.999...	2010-07-13T00:00:00.000Z
26.809...	26.420...	26.6299...	26.610...	7324900.0	21.803...	2010-07-14T00:00:00.000Z

Figure 9. Return on investment distribution for the GAN model and another model - GBM

6. Final conclusions

The considerations were aimed at analyzing the modeling of intuition according to Simon Herbert's cognitive model. Herbert presented the cognitive software Soar as an element perceiving data from the environment in combination with the EPAM decision tree acting as a data recognition and decision-making system working similarly to the human mind. The main principle of intuition was also explained, as being a particularly sensitive human ability to recognize patterns in a large set of information within a short moment. The decision-making process was presented in order to roughly model this ability. The decision made by the agent depended on his current state and decisions taken, which was constantly shaping the agent in many possible ways. The experience gained determined the further behavior in the management of the funds held. In the context of a personal situation, possible experiences can be modeled only in an approximate way, because internal mental states cannot be fully described. A limitation of the human capabilities should be assumed in the modeling process, the focus should be on achieving a sufficient level of satisfaction and not necessarily aiming at the maximum possible profit. Experiments on the intuition model should be carried out under certain conditions to verify the correctness of the results. In this process it would be necessary to verify false positives, know from what they resulted and establish the criteria that would indicate whether a chosen decision is right or wrong. The process of stock market investing was presented as an example of a real problem solution to present the processes and possibilities of pattern recognition. The method of predicting stock market values with a GAN neural network architecture and analogies to the essence of intuition were presented. The result generated by the network provided important information for a potential investor.

To sum up, intuition is the result of the pattern recognition ability based on previous experience stored in the long-term memory to which the subject has access in real time. The ability to find novelty, i.e. creativity, plays an important role in the process of intuition actually used. Its basic mechanism is generating and testing whether objects meet the set criteria. An example of a system from the last century that has this property is the BACON system [41] which is also based on decision trees, It works by processing numerical input data and returning rules that match such data. Nowadays, the best examples of a creative algorithm are the GAN and autoencoders capable of generating new data with the same features as the data that on which these networks have been learning. Using them in a complex decision support system could increase the quality of its functions. However, building such a system is extremely difficult, as it requires integration of many different functionalities such as perception, natural language processing, integration with the knowledge base with various subcategories, an advanced learning system that operates also on symbols and demonstrates creative activity. So far, the best way to meet these requirements have been cognitive architectures such as the Soar system. Its connection with the generative capabilities of a GAN neural network opens up new possibilities for the study of intuition.

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Conflicts of interests

The author(s) declare(s) that there is no conflict of interest.

Milan Ziuziakowski finished Bachelor's Degree in Control Engineering by developing a system to detect objects in traffic road with using deep neural network architecture. Currently I'm writing my Master's thesis about detection of Autism Spectrum Disorders and ADHD based on fMRI scans along with an assessment of various machine learning algorithms accuracies.