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Simulation Models of Human Decision-Making Processes

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Abstract. *The main purpose of the paper is the presentation of the new concept of human decision-making process modelling using an analogy with the Automatic Control Theory. From the authors' point of view this concept allows to develop and improve the theory of decision-making in terms of the study and the classification of specificity of the human intellectual processes in different conditions. Literature shows that the main distinguishing feature between the Heuristic / Intuitive and Rational Decision-Making Models is the presence of so-called phenomenon of "enrichment" of the input information with human propensity, hobbies, tendencies, expectations, axioms and judgments, presumptions or bias and their justification. In order to obtain additional knowledge about the basic intellectual processes, as well as the possibility of modelling the decision results in various parameters characterizing the decision-maker, a complex of simulation models was developed. These models are based on the assumptions that: basic intellectual processes of the Rational Decision-Making Model can be adequately simulated and identified by the transient processes of the proportional-integral-derivative controller; basic intellectual processes of the Bounded Rationality and Intuitive Models can be adequately simulated and identified by the transient processes of the nonlinear elements. The taxonomy of the most typical automatic control theory elements and their compliance with certain decision-making models with a point of view of decision-making process specificity and decision-maker behavior during a certain time of professional activity was obtained.*

Keywords: *human decision-making process, automatic control theory, proportional-integral-derivative controller, nonlinear elements.*

Introduction

The importance of correct and effective human decision-making process (DMP) is very easy to understand, but in the same time it is difficult to be achieved, because it depends on many different and difficult elements – both on the problem statement side, and considering the personal making-decision style and experience.

The term "decision-making" in different sources was defined as a process in following editions: *"the procedure of reducing the gap between the existing situation and the desired situation through solving problems and making use of opportunities"* (Saroj, 2009); *"the transformation of knowledge and information into managerial action"* (Weick, 1979; March, 1991).

Human decision-making process has been the subject of active research from several perspectives:

- from a *psychological* perspective, it is necessary to examine individual DMP in the context of a set of needs, principles and preferences they are driven by;
- from a *cognitive* perspective, the DMP must be regarded as a continuous process integrated in the interaction with the environment and forming the recognize patterns as a yield of their professional activity;
- from a *normative* perspective, the analysis of individual DMP is concerned with the logic (rational) foundation of decision making (Kahneman & Tversky, 1974).

From the *managerial* perspective for effective decision-making process, a person must be able to forecast the outcome of each option of decision-making task (DMT), and taking into account all these items, determine the best option for that particular situation (Reason, 1990). At the same time, dynamic environment, rapid technological change and great uncertainty in most companies' environments create increasingly challenging working conditions for decision-makers. Decisions must often be made under substantial time limitation (Simon, 1997), in highly complex and fuzzy circumstances (Weick, 2001), with a lack or an excess of information and uncertainty or risk. Professional decision-makers must respond instantly and satisfactorily in the base of available knowledge and time interval (Wagner, 1986), use the reliable information or only experience and feeling (Hammond, 1996).

Therefore, the specificity of the human DMP strongly depends on the conditions of environment and, to be more precise, on particular DMT characteristics, which determine the so called individual's "decision-making styles" and could be conceptualized by the author as: the *set of intellectual activity* *techniques in order to transform the input of the given particular decision task into the right course of action.*

In this paper authors offers a new concept of human DMP *modelling* using the analogy with automatic control theory, which should help to find answers to the following research questions:

1. How does specificity of the decision task influence an aptitude of decision-makers using the particular decision-making model?
2. What basic intellectual processes underlie the distinguishing characteristic of the different decision-making models?

For this purpose the following hypotheses was proposed:

1. *The basic intellectual processes of the Rational Decision-Making Model can be adequately simulated and identified by the transient processes of the proportional-integral-derivative (PID) controller.*
2. *The basic intellectual processes of the Bounded Rationality and Intuitive Models can be adequately simulated and identified by the transient processes of the nonlinear elements.*

Fundamental decision-making models

Presently the most widely-spread scientific approach is the one that marks out three main decision-making models (MDM): Rational Decision-Making Model, Bounded Rationality Model and Intuitive Model (Allard, 2003). The following researches are dedicated to these models' brief analysis and structuring.

The rational model

People generally use a *rational* decision-making model when (Towler, 2010): *they are not under heavy time pressure; conditions are relatively stable and goals are clear*; *they do not have a great deal of relevant experience*; *the problem is computationally complex*.

According to the rational model, under the systematic DMP (Simon's model) could be merged into 4 more significant steps (author's edition see on Figure 1).

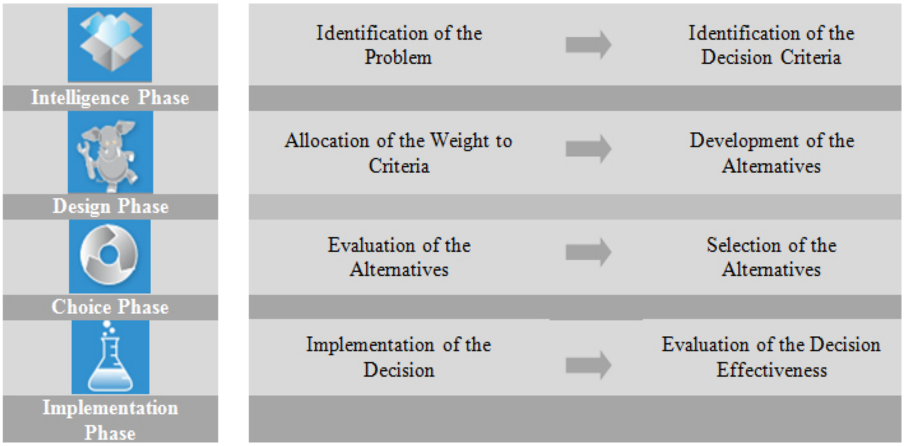


Figure 1. Decision Making Process of Rational Model

The bounded rationality (heuristic) model

The term *Bounded rationality* was invented by Herbert Simon (1997, 2009) to describe the decision maker who would like to make the best decisions but normally settles for less than the optimal (Lunenburg, 2010).

Proponents of bounded rationality (Luck, 2009) very often correlate it with “adaptive toolbox” – as the tried and tested strategy set which people use to solve DMT and to meet the demands of MD environments. These strategies are commonly named *heuristics* – simple MD patterns which are used as simplification rules for stopping the options search.

In contrast to complete rationality in decision-making, *bounded rationality model* implies the following steps (Simon, 2009), which in author’s version are presented in the figure 2.

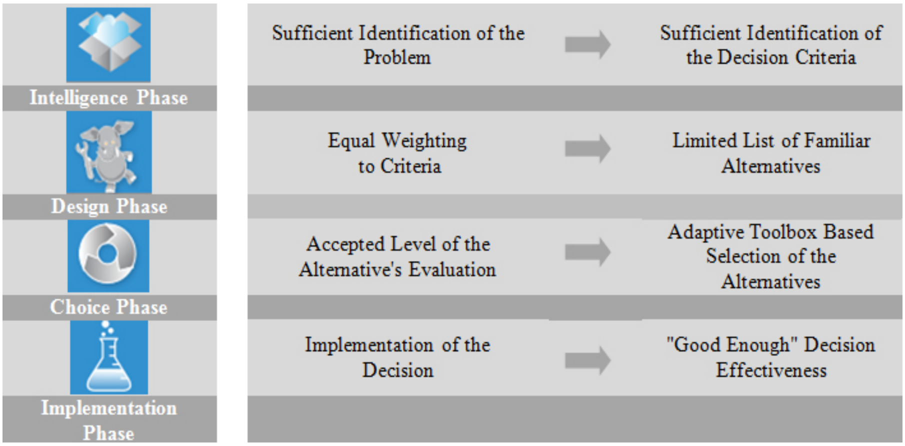


Figure 2. Decision Making Process of Bounded Rationality Model

The main ideas of *Bounded Rationality Model* implementation steps are the following:

1. Decisions are based on an incomplete and inadequate comprehension of the essence of the problem being faced. Usually it causes responses in the forms of: reducing the problem to a level at which it can be really understood and *satisfaction* type of seek solutions (Nielsen, 2011; Lunenburg, 2010).
2. Decision makers *never succeed* in generating *all* possible *alternative* solutions for consideration. They construct simplified models that extract the essential features from problems without capturing all of their complexity.
3. Alternatives are always *evaluated incompletely*. Following along familiar paths, the decision maker proceeds to review alternatives only until s/he identifies an option that is "*good enough*" – one that meets an acceptable level of performance.
4. The final solution represents a *satisfying* choice rather than an *optimal* one.

Informed intuition model

People generally rely on their intuition when (Lamb & Lachow, 2006): *they are facing a time-urgent situation*; *conditions are dynamic or goals are ambiguous*; *they have a great deal of relevant experience*; *the problem can be modelled in mental simulations*.

Intuition represents: "a quick apprehension of a decision situation based on past experiences and the reinforcement associated with these experiences, which is devoid of conscious thought" (Lunenburg, 2010; Luck, 2009); "a cognitive conclusion based on a decision maker's previous experiences and emotional inputs" (Pratt, 2007); "a tacit form of knowledge that orients decision making in a promising direction" (Policastro, 1999).

The root of the intuitive DM already exists in cognitive processes of information collection; knowledge structure; emotional awareness of decision makers (Ju et al., 2007). But exactly the *experience* is considered as a result of the decision-makers' *cognitive* processes. In a certain real situation the decision maker will pick up cues and indicators that gives him/her so-called scenarios – *recognize patterns* as a yield of their professional activity.

In regard to the *knowledge* structure – classically knowledge of the decision-makers can be divided into *explicit* knowledge and *tacit* knowledge. Mostly *explicit* knowledge ("*knows-what*" or *systematic* knowledge) is technical or academic data / information described in formal language, like manuals, mathematical expressions, copyright and patents (Smith, 2001). *Tacit* knowledge is practical, action-oriented knowledge or "*know-how*" based on practice, acquired by personal experience, seldom expressed openly, often resembles intuition and made up of mental models, values, beliefs, perceptions, insights and assumptions (Smith, 2001).

Emotional memory refers to the experience of decision-makers leaving the signs in the decision makers' spirit space (Ju et al., 2007), which determine the quality of decision-making and grows from mistakes.

In applying this model, we have to take into account the following statement: we need to "recognize that our initial, automatic response may be incorrect" (Hastie & Dawes, 2001). That's why it is important that we make decisions using informed intuition. Author's version of informed intuitive model steps is presented in the figure 3.

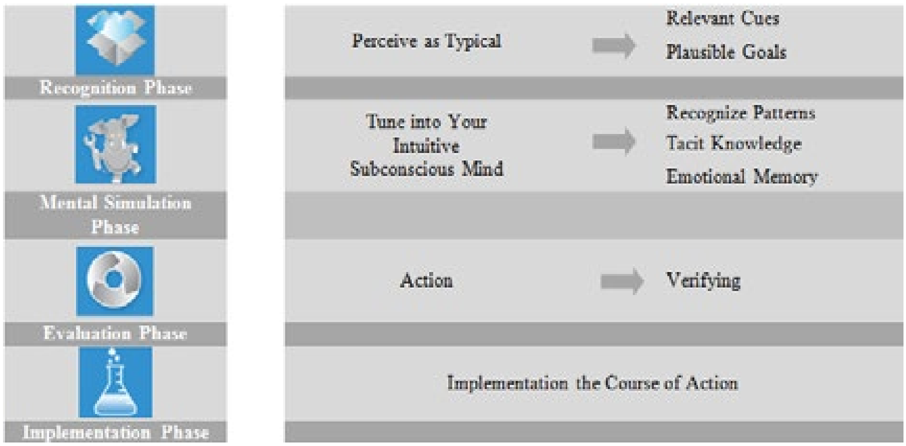


Figure 3. Decision-Making Process of Informed Intuitive Model

Decision-making process simulation model

Taxonomy of decision-making models

Taking into account the considered and structured Decision-Making Models (DMM) and for answering the following question "How does specificity of the decision task influence an aptitude of decision-makers using the particular decision making model?", the author has suggested the taxonomy of DMM based on the following groups of measurement (Luck, 2009; Beach & Mitchell, 1978):

- existing situation (*Capacities*), which describes the specificity of the DMT;
- *techniques* of knowledge and information transformation for DM, defined by the existing capacities of the DMT;
- right course of the DM action (*Choice*) as the consequence of using the particular techniques (Table 1).

Table 1. Taxonomy of the decision-making models

Indicators	Decision-Making Models		
	Rational	Bounded Rationality	Intuitive
Capacities			
Information	Complete	Incomplete	Arguable
Structure	Structured	Semi-Structural	Non-structural

Speed	Deliberate	Rapid	Instant
Goal	Clear	Fuzzy	Competing
Indeterminacy	Certainty	Risk	Uncertainty
Techniques			
Problem Processing	Problem Solving	Problem Resolution	Problem Finding
Accuracy	High	Enough	Low
Tools	Value	Heuristic	Judgment
Options Difference	Weighted	Acceptable	Indistinguishable
Situational Awareness	Details	Patterns, Clusters	Big Picture
Accountability	Statistics, Analytical Tools	Pre-Formulated Rules	Perception, Mental simulations, Feelings
Experience	Not necessarily	Embedded in Direct Habit	Embedded in Direct Experience
Emotional Level	Emotion Free	Legitimate Role for Emotions	Emotionally Associative
Effort	Requires Cognitive Effort	Requires Developed a Range of Successful Adaptive Strategies	Appears Effortless
Choice			
Metrics	Numerative	Good enough	Failure or Success
Time Horizon	Present	The Near Future	Future
Level of Detail	Detailed	Grouped	Aggregate
Decisions Formulation	Prescriptive	Suggested	Descriptive
Nature	Objective	Subjective	"Gut Feeling" Based
Conscious Level	Conscious	Traditional	Unconscious
Creativity	Creativity Free	Creativity Free	Creative
Decisions	Optimal	Satisfied	More Relevant

Simulation models of the decision-making processes

The decision-making model taxonomy and the authors' concept of analogy between DMT and automatic control theory allow answering to the following question: *What basic intellectual processes underlie the distinguishing characteristic of the different decision-making models?*

Simulation model of the rational decision-making processes

On the one hand, as have been noted earlier, a Rational Decision-Making Model is characterized by progressive logical approaching to a given optimal solution in terms of certainty and relative unlimited time. On the other hand, the automatic control theory known, that the *PID-controller* is a link in the contour of the control with feedback loop, used for maintaining the set point values of the measured parameter *PV*. Mathematical form of the PID algorithm is:

$$u(t) = K_P \cdot \left(e(t) + \frac{1}{K_I} \cdot \int_o^t e(t)dt + K_d \frac{de(t)}{dt} \right) \quad (1)$$

The authors suggest the concept of interpretation of *human intellectual processes* (HIP) *within the making-decision as a process of correspondence (maintenance) to the adjusted (required) set point level of the set problem solving (optimal, sufficient solution)* (Rizun, 2013).

In this view the authors proposed the hypothesis that: *the basic* HIP *of the Rational Decision-Making Model could be adequately simulated and identified by the transient processes of the proportional-integral-derivative (PID) controller*.

On the first step the following interpretation of the terms of the mathematical expression of the PID-controller as of the simulation model of HIP during the test task solving was developed:

Terms characterizing the DMP *quantitatively*:
$e(t)$ – *error (mismatch)*: the measure of difference between the current variant of task solution (process variable) at the moment *t* and optimal (sufficient, acceptable) solution (desired set point). For the specified DMT *j* is suggested to be considered as the difference between the received $S_f(t)$ and maximum S_{max} number of points for the task:

$$e(t) = S_{max} - S_f(t) \quad (2)$$

K_I – *integral gain*: the measure of degree of problem domain awareness (PDA). For the specified DMT *j* is suggested to be considered as the indicator of correspondence of the accumulated in the process of professional activity *explicit* knowledge EK_f^j for required for the level EK_r^j:

$$K_I = EK_f^j \big/ EK_r^j \quad (3)$$

K_d – *derivative gain*: the pace of making logical operations for processing the information. For the specified DMT *j* is suggested to be considered as the indicator of relative speed of DM – ratio of *actual* time (t_f^j) time of carrying out the DMP to the *optimal* (reference) time (t_r^j). It depends on human physiological abilities as well as on the practical experience of DM.

$$K_d = t_f^j \Big/ t_r^j \qquad (4)$$

Term, that characterize the DMP *qualitatively*:

K_p – *proportional gain*: according to the theory of automatic control depends on the current error $e(t)$ and compensates the current error proportionally to its value. For the specified DMT *j* the *proportional gain* is suggested to be considered as the difference between of the currently used individual's personal features IPF_f^j to achieve a given measure of DMT solution and required IPF_r^j one:

$$K_p^j = \left| IPF_f^j - IPF_r^j, \right| \qquad (5)$$

In the second stage, in order to analyze the possibility of using the PID-controller to interpret the features of intellectual processes of DM, the authors developed a simulation model, allowing to receive the transient response of the transfer function of an individual. For this purposes the authors have suggested that: *the simulation of Rational Decision-Making Model as a process of performing a certain number of stages of logical analysis of the problem by decomposing the original problem into simpler components and gradual approximation to the desired solution could be accomplished by using harmonic exponentially damped cosine signal* $x(t) = A \cdot e^{-\gamma \cdot t} \cdot cos(\lambda \cdot t)$.

For this purposes the authors have suggested that: the simulation of *Rational Decision-Making Model* as a process of performing a certain number of stages of logical analysis of the problem by decomposing the original problem into simpler components and gradual approximation to the desired solution could be accomplished by using harmonic exponentially damped cosine signal.

In order to extend the possibilities of study, the authors considered the variants, when the values of *derivative* or *integral* gains are equal to zero, that in the Automatic Control Theory is meet to the PI- and PD- controller. The results of a DMP simulation using the analogies with transient processes of PI-, PD- and PID-controllers are shown in Fig. 4

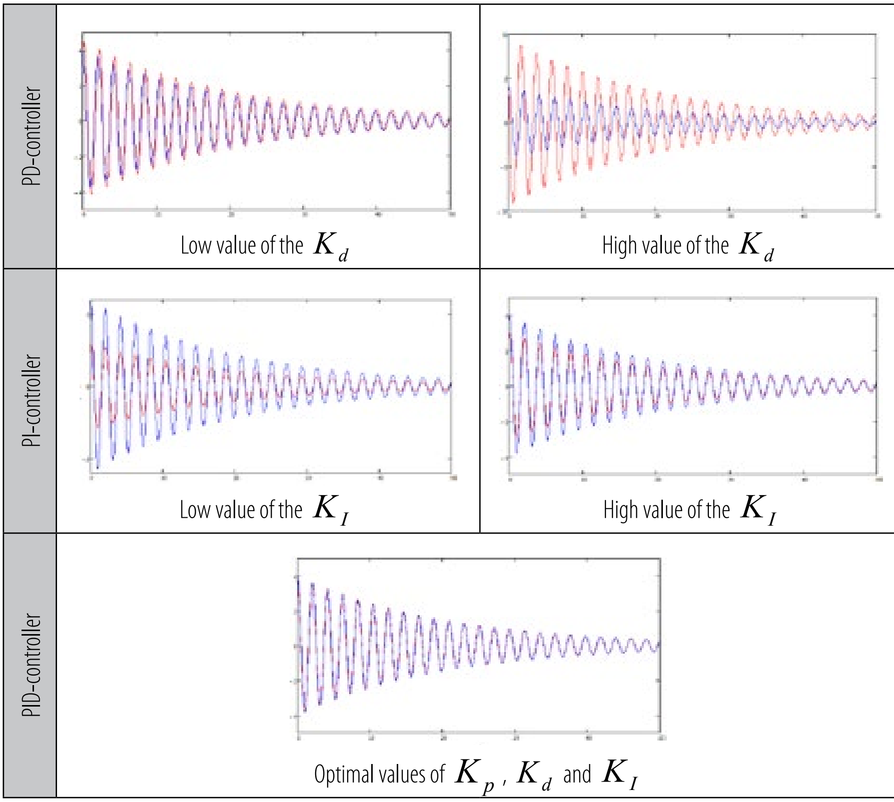


Figure 4. The results of a DMP simulation using the analogies with transient processes of PI-, PD- and PID-controllers

On the third step analysis of the transient response was carried out, which determined the following conclusions:

1. A common feature of transient characteristics of the PI-, PD- and PID-controllers as a simulation model of DMP is to attempt to repeat the signal corresponding to the Rational Decision-Making Model with varying degrees of accuracy and implementation speed of a given amount of logical steps of data processing relatively to a specific DMT.
2. The repetition of the input signal accuracy is determined by the values of the following configuration parameters PI-, PD- and PID-controllers: degree of problem domain awareness, pace of making logical operations and individual's personal features.
3. The input signal distortions (the amplitude or phase changing) are the result of the actual level of a person's readiness to solving this problem,

but not a consequence of the creative (subjective) approach to the task solving.

Thus, the authors propose to *accept* the following hypothesis: *the basic HIP of the Rational Decision-Making Model could be adequately simulated and identified by the transient processes of the PID-controller.*

Then, the classification of the DM strategies using the analogy with the PI-, PD- and PID- controllers can be the following (Table 2):

- *PD-controller* – the minimum cost strategy. Due to the major component of this controller is derivative gain, as the main cost criterion could be adopted the value of the DM time $K_d = t_f^j / t_r^j \rightarrow min$. Absence of the integral gain component indicates that this strategy characterizes the style of quick receiving the solutions of the simple routine problems;

- *PI-controller* – the maximum benefit strategy. Due to the major component of this controller is integral gain, as the main benefit criterion could be adopted the value degree of problem domain awareness (quality of solution) $K_I = EK_f^j / EK_r^j \rightarrow max$. Absence of the derivative gain component indicates that this strategy characterizes style of measured receiving the full solutions of the deep problems;

- *PID-controller* – the maximum utility strategy. As the main criterion could be adopted the value of the benefit cost-benefit ratio – maximum probability of corresponds of the individual combination of speed and level of assimilation problem area in conjunction with the individual's personal features to the required parameters of a DMT $e(t) \rightarrow max$. This strategy characterizes the style of receiving the optimal solutions of the certain problems.

Simulation model of the heuristic and intuitive decision-making processes

However, it is well-known that in the uncertainty and risk conditions characterized by the lack of complete information, inaccuracy of goals setting and limited time resources, to replace the *Rational* logical thinking, which is more suitable for performing standard algorithms and routine DMT, comes the need for subjective creative approach to solving problems based on personal experience and "gut feeling" (Table 1).

Continuing the analogy between HIP and the Automatic Control Theory, the authors proposed the following required analysis and verification the preconditions and hypothesis:

Precondition:

On the one hand, form the Automatic Control Theory it is well-known that the signal passing through the nonlinear elements, "enriched" by additional harmonic components defined by the parameters of this elements. On the other hand, a person, using for making-decision in unprogrammed, precarious and often stressful situation, his/her own experience and intuition (subjective vision, feeling of the current and future situation) alters input information, "enriched" by new subjectively formed components (decision) on the basis of their own knowledge, professional experience (skills) of the decisions adoption and implementation and the current state of psycho-physical activity.

Then, the phenomena of DMP that are classified as *Heuristic (Bounded Rationality) and Intuitive Decision-Making Models* were conceptualized by the authors as: *the set of HIP techniques in order to transform the input with missing, untrustworthy, inconsistent, "noisy" or not capable of interpretation information of the given particular decision task into the right course of action, "burdened by individual heritage" or "enriched" in the form of own propensity, hobby, tendency, expectation, axioms and judgment, presumption or bias and their justification.*

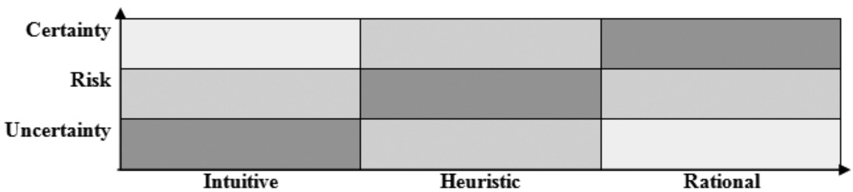
In this regard, the authors nominated the following *hypothesis*:

The basic intellectual processes of the Heuristic (Bounded Rationality) and Intuitive Decision-Making Models can be adequately simulated and identified by the transient processes of the nonlinear elements.

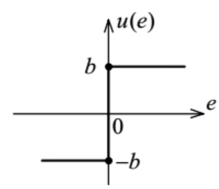
In order to analyze the possibility of using *nonlinear elements* (NE) for the interpretation of the features of intellectual processes of decision-making, the authors have developed a *simulation model* in which:

- as a template of input signal $X(t)$ was used the *harmonic exponentially damped sinusoidal signal*;
- the input signal distortions were analyzed in order to reveal the fact of "*enrichment*", interpreted as the use of "authors", subjective, professionally formed DM strategies that differ from the well-defined logical rational algorithms;

– for considering the structural scheme of NE was using the following rules: *X-axis* is taken as the scale of measuring the degree of decision rationality, the axis Y-*axis* – a scale of measuring the degree of problem's uncertainty:



Heuristic (bounded rationality) decision-making models



"*Arbitrary*". The results (Fig. 5) of a DMP simulation as the transient characteristics of the NE – "two-position relay" – were interpreted by authors as follows:

1. The decision, have made using this style, is invariant with respect to the different circumstances of time and place.
2. Nonlinear element "two-position relay" is proposed to define by term "*Arbitrary*", thus emphasizing the style's features, which are the result of *automatism* of perception, thinking, behavior, and which determine the reproducing the one unique familiar solution in the situation, which was identified as a typical.
3. Degree level of the uncertainty exception in the output signal *Y(t)* is determined by value of the parameter $|b|$.

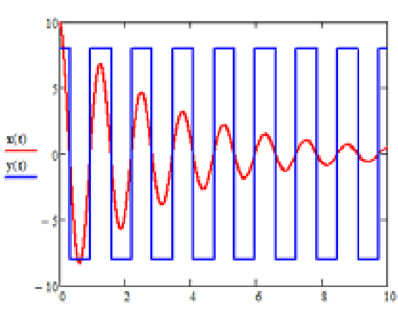
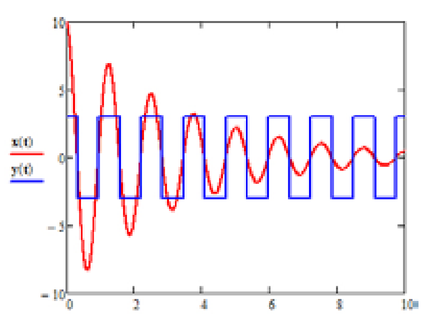


Figure 5, a



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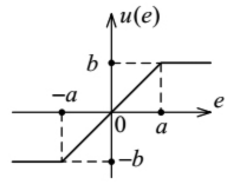
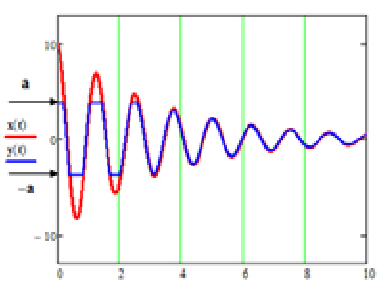


"*Principles*". The results (Fig. 6) of a DMP simulation as the transient characteristics of the NE – "saturation" – were interpreted by authors as follows:

1. On the DMP, on the phases and levels, which were identified by individual as non-compliance with the rational DMM, the "*heuristics*" are used as a "framework" for limiting the depth of analysis of the problem.
2. Nonlinear element "*saturation*" is proposed to define by term "*Principles*", thus emphasizing the style's features, which are the result of presence the individual's science-based theories and principles (heuristics) of DM in the conditions of incomplete information, semi-structural task statement and fuzzy goal.
3. As identification of the fact of the reducing the DMT uncertainties, this style provides the justified use of Rational DMM.
4. Degree level of the uncertainty exception in the output signal *Y(t)* is determined by value of the parameter $|b|$, the borders of possibility of using a Rational DMM – by value of the parameter $|a|$.
5. DMP has a tendency and retains elements of discretion (rationality).



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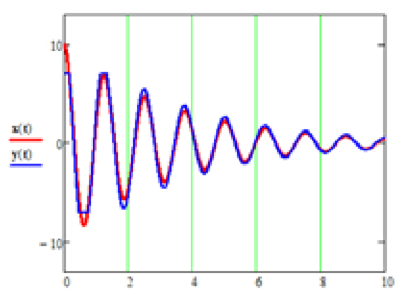

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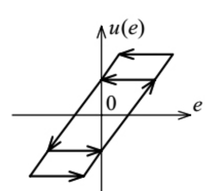
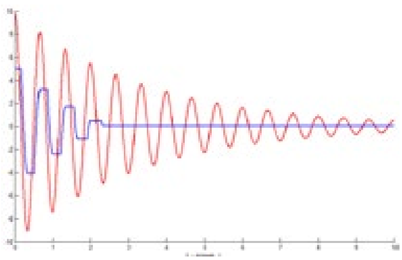


"*Anchoring*". The results (Fig. 7) of a DMP simulation as the transient characteristics of the NE – "*backlash*" – were interpreted by authors as follows:

1. Nonlinear element "***backlash***" is proposed to define by term "***Anchoring***", thus emphasizing the presence of professionally reinforced preferences (justified bias), that consistently violates the rules of rational choice и allow you to re-

duce the depth of analysis of the problem in order to make decisions in the conditions of incomplete information, semi-structural task, fuzzy goal and rapid time.

2. If it is necessary (and possible) individual can provide the maximum compliance with Rational DMM.
3. Degree of depth analysis of the problem in the output signal $Y(t)$ is determined by the parameter $|a|$.
4. Provided making the acceptable decision under time constraint.



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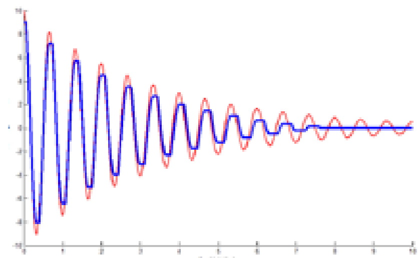


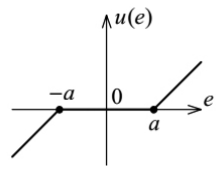
Figure 7, b

Thus, the proposed as identifiers of the DMM the NE "two-position relay", "saturation" and "backlash" can correspond to the three types of strategies:

- *Arbitrary – Automatic making-decision style*, in the implementation of which the phenomenon of "enrichment" of the input signal by unique invariant familiar solution (heuristics) is observed, confirmed by repeated successful use in the course of professional activities. Applicable for solving the problems, on the one hand, cannot be solved using a logical algorithm, on the other hand – do not require creative and flexible approach when taking into account the peculiarities of the problem;
- *Principles – Bounded Rational making-decision style*, in the implementation of which the phenomenon of "enrichment" of the input signal was observed, which is the ability to identify the degree of uncertainty of the problem, determines the need (appropriateness) at a certain stage use the science - and evidence -based theories and principles (heuristics) of solving the problems, enabling DMP closer to the Rational. Applicable for solving the problems that have a low degree of uncertainty;
- *Anchoring – Experimentally Bounded Rational making-decision style*, in the implementation of which observed the phenomenon of "enrichment" of the input signal, which is the ability to identify the complex of characteristics of the original problem – the degree task uncertainty

and the level of the time constraints, that predetermines the need for flexible use of proven presumptions of decision-making. Applicable for solving the problems in situations which characterized by a low degree of uncertainty and time constraints

Intuitive decision-making models



"*Common senses*". The results (Fig. 8) of the DMP simulation as the transient characteristics of the NE – "*deadband*" – were interpreted by authors as follows:

1. Nonlinear element "*deadband*" is proposed to define by term "*Common senses*", thus emphasizing the presence of own axioms and judgments, enabling DM under uncertainty and risk, as well as a limited time, and based on common sense, recognize the key aspects that need analysis, intuitively perceiving the other as a "big picture".
2. Latitude of the intuitive perception of the situation by "big picture" in the output signal *Y(t)* is determined by parameters of the nonlinear element – by so-called deadband $|a|$.
3. Provided making the acceptable (brings the success) decision under time constraint.
4. DMP retains the elements of discretion (rationality).-

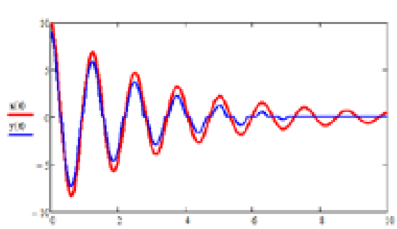


Figure 8, a

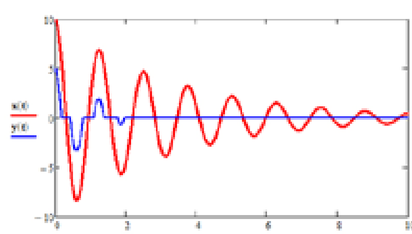
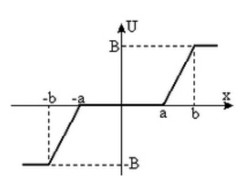


Figure 8, b



"*Empirical*". The results (Fig. 9) of the DMP simulation as the transient characteristics of the NE – "*deadband with saturation*" – allowed offering a variant of their interpretation as a consequence of the high level of professionalism, allows using the combined type of strategy, namely:

1. On the phases and levels, in which were identified the high uncertainty of problem is realized the "*Arbitrary*" strategy by adopting a unique solution.
2. Moving to the "*Common senses*" strategy by using based on own empirical experience axioms and judgments, which make the possibility on stages, characterized by an average degree of uncertainty, to evaluate the situation, using the theory of "big picture".
3. Nonlinear element *"deadband with saturation"* is proposed to define by term "*Empirical*", thus emphasizing the presence of individual strategies of behavior as an impact of accumulated empirical tacit knowledge, emotional memory and "behavioral prejudice".
4. Latitude of the intuitive perception of the situation by "big picture" in the output signal $Y(t)$ is determined by parameters of the NE – the so-called deadband $|a|$, the degree of development of "behavioral bias", which eliminate the rationality fact – by parameter $|b|$.
5. DMP retains the elements of the simplified discretionary (rationality), acceptable in the decision within the limited time.

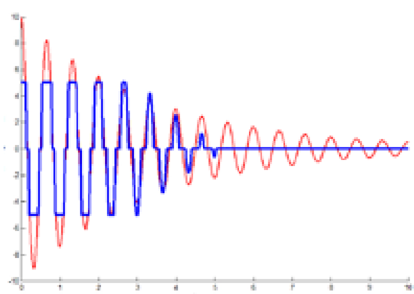


Figure 9, a

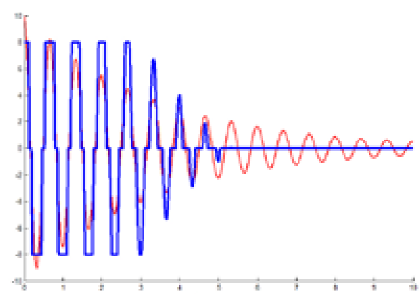
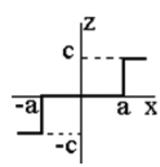


Figure 9, b

"Preference". The results (Fig. 10) of a DMP simulation as the transient characteristics of the NE – "*three-position relay without deadband*" – were interpreted by authors as follows:



1. Nonlinear element *"three-position relay without deadband"* is proposed to define by term "*Preference*", thus emphasizing the presence of adaptive intuitive automatism characterized by the possibility of thinking by "too big picture" and use a set of unambiguous preferred solutions for DM under conditions of high uncertainty and strict time limit.

Volume 2 (2014) no. 2, pp. 241-264; www.managementdynamics.ro

2. Latitude of the intuitive perception of the situation by "too big picture" in the output signal *Y(t)* is determined by parameters of the NE – the so-called deadband $|a|$, the degree of development of "preferences", which eliminate the rationality fact – by parameter $|b|$.
3. In the DMP absent the elements of the discretionary (rationality).

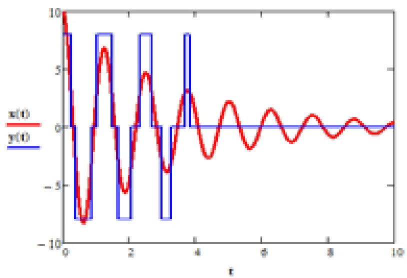


Figure 10, a

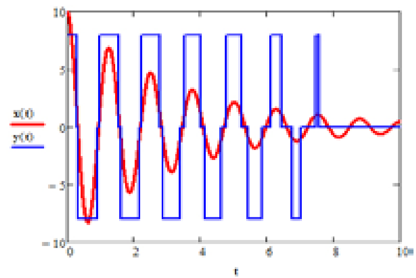
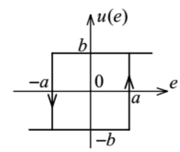


Figure 10, b

"Trial and Error". The results (Fig. 11) of the DMP simulation as the transient characteristics of the NE – "*two-position relay with deadband*" – were interpreted by authors as follows:



1. Nonlinear element *"two-position relay with deadband"* is proposed to define by term "*Trial and Error*", thus emphasizing the presence of style's features, based on the "Gut Feeling" and results of emotional memory, and which realizes by two solutions – Failure or Success.
2. Latitude of the intuitive perception of the situation by "big picture" in the output signal *Y(t)* is determined by parameters of the nonlinear element – the so-called deadband $|a|$, the degree of development of " exhaustive trial ", which eliminate the rationality fact – by parameter $|b|$.
3. In the DMP absent the elements of the discretionary (rationality). Acceptable for making emergency decisions.

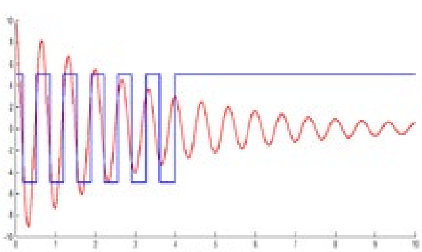


Figure 11, a

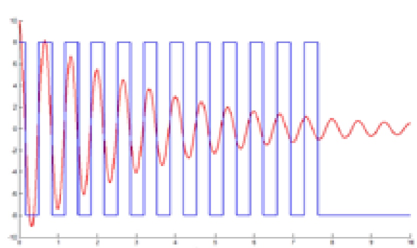


Figure 11, b

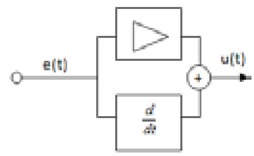
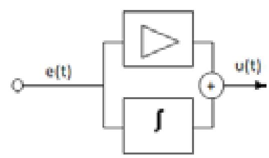
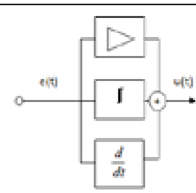
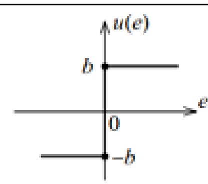
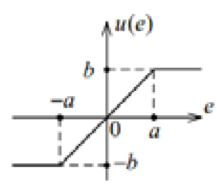
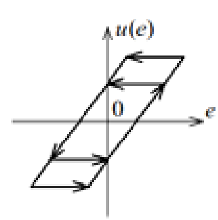
Thus, the proposed identifiers of the DMM nonlinear elements "*deadband*", "*three-position relay without deadband*" and "*two-position relay with deadband*" can correspond to the three types of strategies:

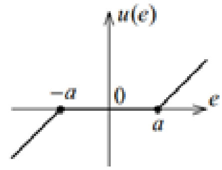
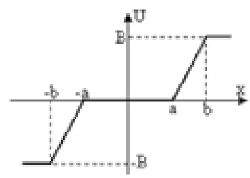
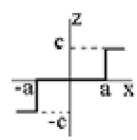
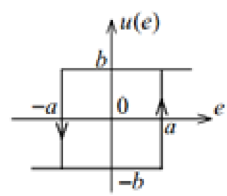
- *Common sense* – intuitive strategy in the bases of the *Own Judgment*, in the implementation of which the phenomenon of "enrichment" of the input signal by accumulated in the course of professional activities axioms and judgments was observed, allows to think in terms of "big picture" and to perform the modelling of possible outcomes, using the strategy of mental simulations. Applicable for solving problems characterized by an average degree of uncertainty and time constraints;
- *Empirical* – intuitive strategy in the bases of the *Own Experience*, in the implementation of which the phenomenon of "enrichment" of the input signal by using the "author" behavior strategies was observed, which has the flexible response to the specifics of the situation as a whole and its individual stages of the decomposition analysis. These "author" behavior strategies are the result of the presence of great deal of relevant experience – complex of the tacit knowledge, emotional memory and "behavioral prejudice". Applicable for solving the complex nonstructural problems characterized by dynamic conditions and ambiguous goals, as well as having an average degree of uncertainty and time constraints;
- *Preference* – *Semi-Automatic* making decision style, in the implementation of which the phenomenon of "enrichment" of the input signal by possibility of adaptive application of their own propensity, hobby, tendency, expectation. Applicable for solving the problems in situations characterized by increased uncertainty and tight time limit;
- *Trial and Error* – intuitive strategy in the bases of the "*Gut Feeling*", in the implementation of which the phenomenon of "enrichment" of the input signal by usage of the personal "know-how" based on signs in the decision makers' spirit space was observed. It is applicable for solving the problems in situations characterized by extreme conditions of complete uncertainty and the need for immediate decision-making.

Thus, the authors propose to *accept* the following hypothesis: *the basic intellectual processes of the Heuristic (Bounded Rationality) and Intuitive Decision-Making Models can be adequately simulated and identified by the transient processes of the non-linear elements.* The results of Simulation Modelling of the Rational, Heuristic and Intuitive Decision-Making Models are presented in the Table 3.

Volume 2 (2014) no. 2, pp. 241-264; www.managementdynamics.ro

Table 3. The Taxonomy of the automatic control theory elements depending on the decision-making models

Decision-Making Models	Strategy	Criterion	Analogy with Automatic Control Theory	Algorithm
Rational	Minimum cost	Based on minimizing time		Logical making decision style for quick receiving the solutions of the simple routine problems
	Maximum benefit	Based on maximizing gain of quality		Logical style for measured receiving the full solutions of the deep problems
	Maximum utility	Based on cost-benefit ratio		Logical making decision style for receiving the optimal solutions of the certain problems
Heuristic	Arbitrary	Based on the most easy or familiar choice		The result of forming the Automatic making decision style. Elimination of uncertainty and risk using certain familiar solutions
	Principles	Based on scientific theories		The result of forming the Bounded Rational making decision style. Elimination of uncertainty and risk in using scientific principles of simplification with sufficient degree of accuracy
	Anchoring	Based on presumption or bias and their justification		The result of forming the Experimentally Bounded Rational making decision style in the conditions of the time limit, using justified bias, limiting depth analysis of the problem, and early making of the most appropriate solution

Intuitive	Common sense	Based on axioms and judgment		The result of forming the intuitive strategy in the bases of the Own Judgment. Characterized by the ability to highlight key points of the problem situation and think by "big picture"
	Empirical	Based on existing knowledge		The result of forming the intuitive strategy in the bases of the Own Experience. Characterized by the ability to think by "big picture", but, if it is supported by his own experience, using empirical principles of simplification
	Preference	Based on propensity, hobby, tendency, and expectation		The result of forming the Semi-Automatic making decision style via certain preferred solutions due to thinking by "too big picture"
	Trial and Error	Based on exhaustive trial		The result of forming the intuitive strategy in the bases of the "Gut Feeling". Characterized by the ability to think based in the results of emotional memory, which realizes two solutions – Failure or Success

Concluding remarks

The conclusions of the experiments allow developing and improving the theory of decision-making in terms of the study and classification of specificity of the HIP in different conditions. Thus, it was found that the main distinguishing feature between the Heuristic / Intuitive from Rational Decision-Making Models is the presence so-called phenomenon of "enrichment" of the input signal by the own experience of decision-maker, as well as internal sensations (sometimes in the absence of logic) of certain decision steps correctness.

In this regard, in order to obtain additional knowledge about the mechanism of "enrichment" phenomenon as well as the possibility of modelling the decision results in various parameters characterizing the decision-maker, the authors propose a complex of simulation models of decision-making techniques using analogies with the Automatic Control Theory.

As a result of the experiments taxonomy of the most typical Automatic Control Theory elements and their compliance with certain decision-making models with a point of view of DMP specificity and on decision-maker behavior during a certain time of professional activity was obtained.

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