Decision-Making of Agent with Selectable Structure of Preferences

Vinogradov G.P., Vinogradova N.G., Bogatikov V.N.
Tver State Technical University Tver, Russia
Email: wgp272ng@mail.ru, n-nataly08@mail.ru,vnbgtk@mail.ru

***Abstract*—The article considers a model of decision-making by the agent capable of forming an internal goal and using subjective ideas of the choice situation. The approach is based on the ideas of subjectively rational choice.**

Keywords—reflexive control; decision making, choice model; compromise.

I. INTRODUCTION

Reflexive control is the information influence the purpose of which is to persuade a subject to make a decision that will be beneficial to a controlling party [1]. Its realization has become possible when there appeared decision models of a subject with internal images of himself and the party influencing him.These models take into account his subjective understanding of the choice situation properties.Their use permits to make performance evaluation of information influence before it is introduced. Note, that the decision-making process is thought of as an uncontrollable factor in the normative decision theory. The development of subjectively rational choice concept has opened up the opportunity: a) to explain decision-making of a subject in specific situations, b) to predict possible reactions of another subject by decision-maker in different situations, c) to make active forecast when a controlling party brings the party being influenced to take a desired image of the future. Subjectively rational choice suggests that the choice motivation is determined by both external and internal factors. The internal factors reflect subject's interests prompted by his needs and the ethical system he adheres to. The assessments of current purposeful state situation satisfaction made by a subject, as shown in [2], may lead to changes in the structure of subject's interests, and he can choose it. Since subject's preferences in the choice situation reflect his interests, we can determine the set of alternatives G in a preference structure. According to [3], we shall call them structural alternatives.

II. ASSUMPTIONS

1) The choice made by a subject is based on the ideas of purposeful state situation.
2) Idea components reflect different aspects of the subject's understanding of purposeful state situation and produce the information structure of his ideas. The set of possible idea options shall be designated as X.
3) For the set of environment states S, a set of observable environment states satisfies the condition $S \cap X \neq \varnothing$, that is, the subject's ideas can contain both objective and phantom components.
4) The subject selects structural alternatives depending on the assessments of satisfaction with purposeful state situation property values.
5) Ideas are formed driven by procedures of perception, awareness and analysis, in accordance with the cognitive abilities of a subject.

In accordance with the assumptions introduced, a subject uses three sets of alternatives in decision-making: controlling alternatives C (modes of action), structural alternatives G and identification alternatives X. Hence, we can assume the existence of three virtual parties involved in the choice of appropriate alternatives. Rules for the choice of these alternatives, depending on the subject's understanding of the environment and the structure of his interests, shall be designated as strategies.

Suppose that a decision-making is performed in several cyclic stages, and modes of action are selected at every stage n = 1, 2, ... of set C in accordance with the environment state idea $\in X$. This is due to the fact that the joint superconscious (intuitive) and conscious (formal) analysis of the environment state allow taking first vaguely aware and then more and more clearly formulated and sound decision in multiple iterations. At the same time, there are restrictions $C_x \subseteq C$ on the admissibility of alternative choice, depending on the idea of environment state $x \in X$. Dynamics of the processes in the environment of a subject are not available to direct perception, so the idea of them is formed by the identification procedures. They reduce to the choice of options presented depending on the observed state. At the same time, there are known restrictions on the admissibility of views $Xs \subseteq X$, which are taken as alternatives to identification depending on the observed states $s \in S$.

Based on these assumptions and following [3], we introduce the definition of strategies.

Single-valued transformation $\lambda : X \rightarrow C$ is such that $\lambda(x) = C_x, \ \in X$, is called choice or control function; we refer an ordered set $(\lambda_1, ..., \lambda_n) \equiv \lambda_1^n$ to strategy selection on the horizon of length n<∞; $lim\lambda_1^n = \lambda_1^{n\infty}$ with n$\rightarrow \infty$, is called the strategy aimed at achieving the local ideal that determines a reason for the subject's existence.

Monotone single-valued transformation $\xi : S \rightarrow X$ is such that $\xi(s) \in X_s, s \in S$, is called an identification function; ordered set $(\xi_1, ..., \xi_n) \equiv \xi_1^n$ is identification strategy on the horizon of length n<∞; we refer sequence $\{\xi_1^n, n = 1, 2, ...\}$ to identification strategy on the limited horizon. Since a subject strains after useful ideas, there exists lim$\{\xi_1^n\} = \xi^\alpha$ with n $\rightarrow \infty$.

Since sets S and X satisfy the condition $|S| > |X|$, then single-valued transformation ξ :S$\rightarrow X$ generates a partitioning of set S into subsets

$\xi^{-1}(x) = \cup\{s \in S : \xi(s) = x\} \subset S, x \in X$

The subsets $\xi^{-1}(x) \subset S, x \in X$ are connected sets, that is, any element s $\in \xi^{-1}(x)$, uniquely determines the corresponding ideas $\in X$. Consequently, we can say that subsets $\xi^{-1} \subset S, x \in X$ form classes of equivalent representations. For the purpose of formalization of subject's ideas, this allows using the methods of a fuzzy-set theory, for example, as described in [4].

Structured alternative $\gamma_n \in G$ selected at moment n is a structural choice at the n - th decision-making stage; ordered set $(\gamma_n, ..., \gamma_1) \equiv \gamma_1^n$ is meant to be structural choice strategy on the decision-making length horizon $n < \infty$; sequence $\gamma_1^n, n = 1, 2, ...$ appears as structural choice strategy γ_1^n on the limited horizon. As much as a subject wants the structure of his interests to meet the requirements of the adopted by him ethical system, there is $lim\{\gamma_1^n\} = \gamma^\infty$ with $n \to \infty$.

III. Model of Decision-Making with Selectable Preference Structure

According to [2], the criterion of control strategy choice means the expected specific value of a purposeful state based on the result. Its formalization is written as the ut$S \times C$ to Sility function $E\phi^g(C \times S \times X)$ which depends on structural alternative $g \in G$ viewed as a parameter. Since the control process begins with a certain situation $x \in X$, criterion $E\phi_n(\gamma_1^n \mid \gamma_1^n)$ also depends on situation $x \in X$ viewed as an initial condition. So far as many situations X are finite, criterion $E\phi_n(\gamma_1^n \mid \gamma_1^n)$ comes down to vector in space R^X of dimension $|X|$. Its components can be written as $E\phi_n(\gamma_1^n \mid \gamma_1^n)(x), x \in X$. According to the result of choice, a subject is having an emotional experience, so the quality of structural choice strategy is to be described as the criterion having a sense of 'satisfaction with the choice result'. Consequently, the strategy quality γ_1^n can be described as convolution of the expected utility vector $E\phi_n(\lambda_n \mid \gamma_1^n) \in R^X$ to a certain composed function. Hence, the criterion of strategy quality can be written as

$$\mu_n(\lambda_1^n \mid \gamma_1^n) = \mu(E\phi_n(\lambda_1^n \mid \gamma_1^n)) \in R^1.$$

A subject associates the quality of his ideas with the assessments of possibility to achieve the desired states, providing $c \in C$, as well as possibility to expand set $\uparrow$ by means of introducing effective alternatives. The terms of linguistic variable "utility" which are based on values $E\phi_n(\lambda_n \mid \gamma_1^n)$ were used in [5] as an idea assessment criterion. In this connection the utility assessments depend on the control strategies λ_1^n and structural choice viewed as given conditions. Let us write down the criterion "utility" as $\psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n)$. Since the identification process begins with a certain state $s \in S$, this criterion will depend on state $s \in S$ specified as an initial condition. As much as this set of states is finite, the identification criterion is represented by vector $\psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n)$ in space R^S of dimension $|S|$.

In the situation of purposeful state, the quality of control strategies and structural choice is determined by criteria $E\phi_n(\lambda_1^n \mid \gamma_1^n) \in R^X$ and $\mu_n(\lambda_1^n \mid \gamma_1^n) \in R^1$ having a sense of specific value based on the results and satisfaction with the choice. The quality of identification strategy is determined by criterion $\psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n) \in R^S$ that makes sense of utility of ideas for the purpose of achieving the desired states. The criteria applied require adequate information structures and models to be used in order to make the corresponding choice. Let us assume that there is the information structure of ideas I reflecting subject's knowledge and experience of: modes of actions (control), their interests and preferences, and dynamics of environment transition into different states. In that case we may suppose this structure to be structurally transformed into the information structure that can provide an opportunity to construct the criterion of a specific value $E\phi_n(\lambda_1^n \mid \gamma_1^n)$ and a subject domain model. The transformation will be referred to as specific value transformation, the structure induced will be referred to as information structure of specific value for the purposeful state based on the result and denoted $U = U(I)$. Similarly, with a structure I being transformed into an information structure to establish an identification criterion $\psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n)$ and identification procedure models, the transformation will be referred to as identification transformation and denoted R, and the information structure induced will be designated as identification information structure and denoted $R = R(I)$.

The subject's ideas of purposeful state situation are subjective, qualitative, and based on observations and analysis of the environment transition under control $c \in C$ into different states $s \in S$. Let the transition rule be $q^g(S \mid S \times C)$ from $S \times C$ to S. Actually, to assess the value of possible results a subject uses model $Q^g(X \mid X \times C)$ from $X \times C$ to X based on identification strategy results ξ_1^n. When constructing a model, we consider control strategies λ_1^n and structural choice γ_1^n, or it is specified by such strategies. This means the transformation of actual function $q^g(S \mid S \times C)$ into the function of the subject's understanding of environment processes $Q^g(X \mid X \times Y)$ is only possible a posteriori and depends on the strategies used $(\lambda_1^n, \gamma_1^n, \xi_1^n)$.

Transforming and constructing the measure of expected specific value $E\phi_n(\lambda \mid \gamma_1^n)$ is possible when the 'utility' of information structures is formed sequentially depending on the strategies applied. This condition may be written as $U_n = U(\lambda_1^n, \gamma_1^n, \xi_1^n)(I), n = 1, 2, ...$ Since the condition is a prerequisite for a criterion of expected utility and a model of subject domain, it is to be identified every time it is used. Note that the criterion $E\phi_n(\lambda \mid \gamma_1^n)$ is implicitly dependent on a diagnostic strategy ξ_1^n owing to the structure U_n induced in a choice model. As mentioned above, the criterion of structural choice quality $\mu_n(\gamma_1^n \mid \lambda_1^n) \in R^1$ is determined by convolution of criterion $E\phi_n(\lambda_1^n \mid \tau_1^n) \in R^X$ The generality of their construction information structures leads to

$$\begin{cases} E\phi_n(\lambda_1^n \mid \xi_1^n) \\ mu_n(E\phi_n(\xi_1^n \mid \lambda_1^n)) \\ U_n = U(\lambda_1^n, \gamma_1^n, \xi_1^n)(I) \end{cases}$$

The construction of an identification criterion requires some 'utility' function. The construction of an identification criterion requires some 'utility' function. So it is necessary to construct some verbal estimates with the utility function values $E\phi_g(S \times X \times Y)$. The transformation required exists and may be done a priori (i. e. before the decision choice).

The transformation is determined by a subject with regard to a fuzzy measure that can be constructed if function $q_g(S \mid S \times C)$ is identified from to $(S \times C)$ to S.

Since its analog of subject's consciousness is of the form $Q_g(X \mid X \times C)$ and may be uniquely identified in the information structure I, no additional transformations are required. The construction of the 'idea utility' function exhausts the required structural transformation which is referred to as the structural transformation of 'identification' and denoted R, with the information structure induced being called the information structure of 'idea utility' and denoted $R = R(I)$.

Accordingly, the identification criterion is finalized as

$$\begin{cases} \psi_n(\xi_1^n \mid \lambda_1^n, \gamma_1^n) \\ R = R(I) \end{cases}$$

The definitions and constructions introduced show that the quality criteria of strategies are different and interdependent. Hence, the choice problem is of a game character and reduces to searching for a persistent compromise between the aspiration for maximizing the expected specific value of purposeful state based on the result and that of minimizing potential losses from wrong ideas. The compromise is referred to as equilibrium.

Note that since the information structure of 'specific utility' $U_n = U(\lambda_1^n, \gamma_1^n, \psi_1^n)(I)$, under which the criterion $\mu_n(E\phi_n(\gamma_1^n \mid \lambda_1^n)$ is determined, is to be constructed sequentially and depends on the strategies applied, the desired equilibria are not only interdependent at each stage $n = 1, 2, ...$ of decision- making but are dependent on the decisions chosen at the previous steps. Accordingly, the equilibria are naturally referred to as dynamical equilibria.

The triple of strategies

$\{o_{\lambda^\infty}, \overset{o}{\gamma^\infty}, \overset{o}{\xi^\infty}\}$

obeying

$$\begin{cases} \begin{cases} E\phi_n(\overset{o}{\lambda^n} \mid \overset{o}{\gamma^n}) \geq E\phi_n(\lambda^n \mid \overset{o}{\gamma^n})\forall\lambda_1^n, \\ \mu_n(\overset{o}{\gamma^n} \mid \overset{o}{\lambda^n}) \geq \mu_n(\gamma^n \mid \overset{o}{\lambda^n})\forall\gamma_1^n, \\ U_n = U(\overset{o}{\lambda^n}, \overset{o}{\gamma^n}, \overset{o}{\xi^n})(I) \end{cases} \\ \begin{cases} \psi_n(\overset{o}{\xi_1^n} \mid \overset{o}{\gamma_1^n}), \overset{o}{\lambda_1^n}) \geq \psi_n(\xi_1^n \mid \overset{o}{\gamma_1^n}), \overset{o}{\lambda_1^n})\forall\xi_1^n, \\ R = R(I), n = 1, 2, ... \end{cases} \end{cases}$$

are referred to as dynamical equilibriums.

The number of decision cycles is not assumed to be limited. Hence, dynamical equilibria must make sense, even if $n \to \infty$.

The following additional conditions are naturally to be fulfilled:

1) If $n \to \infty$ the strategy quality criteria must converge to some limits.
2) Such limits must not depend on initial conditions.

Since the criteria are not given explicitly, the fulfillment of the conditions is not obvious. This requires the necessary conditions. Then the explicit type criteria which meet these conditions are to be given.

According to the assumptions made, the quality criteria of stationary strategies $lambda^n, gamma^n, xi^n$, when $n \to \infty$ have some limits and then the triple of stationary strategies $(\overset{o}{\lambda_1^n}, \overset{o}{\gamma_1^n}, \overset{o}{\xi_1^n})$ are referred to as stationary equilibria if they have limits meeting the conditions:

$$\begin{cases} \begin{cases} E\phi_n(\overset{o}{\lambda^\infty} \mid \overset{o}{\gamma^\infty}) \geq E\phi_n(\lambda^\infty \mid \overset{o}{\gamma^\infty})\forall\lambda_1^\infty, \\ \mu_n(\overset{o}{\gamma^\infty} \mid \overset{o}{\lambda^\infty}) \geq \mu_n(\gamma^\infty \mid \overset{o}{\lambda^\infty}) \ \forall\gamma_1^\infty, \\ U_n = U(\overset{o}{\lambda^\infty}, \overset{o}{\gamma^\infty}, \overset{o}{\xi^\infty})(\mathrm{I}) \end{cases} \\ \begin{cases} \psi_n(\overset{o}{\xi_1^\infty} \mid \overset{o}{\gamma_1^\infty}), \overset{o}{\lambda_1^\infty}) \geq \psi_n(\xi_1^\infty \mid \overset{o}{\gamma_1^\infty}), \overset{o}{\lambda_1^\infty})\forall\xi_1^\infty, \\ R = R(I), n = 1, 2, ... \end{cases} \end{cases}$$

Thus, the problem of choice modeling consists in searching for a compromise between the aspiration for maximizing the expected specific value of purposeful state based on the result and that of minimizing potential losses from wrong ideas, with their interdependence being taken into account. According to the principle of equilibrium decisions, choice modeling must be 'not improved' for all the components of interest simultaneously. When compromising, it is fair to say that the subject's interests are realized with 'the best result'. Provided dynamical equilibria meet the requirements of asymptotic stationarity, we can also argue that the subject's interests are implemented with 'the best results' on the whole endless horizon, including n[U+F0AE][U+F0B5]. Hence, dynamic equilibria specify the sense and the way of interest realization with 'the best result'. In this regard dynamic equilibria naturally specify the internal aim of decision-making.

The above assumptions allow finally defining the concept of decision-making in the adopted axiomatic environment by means of the following basic ideas.

1) Observation and detection of the state is a necessary but not sufficient condition for the control choice feasibility.
2) A sufficient condition for the control choice feasibility is determined by specifying the subject's relation to the state defined by a qualitative index called a purposeful state situation.
3) Due to the fact that the cause-effect relations defining the environment behavior are inaccessible to the direct observation, it is necessary to perform the environment state identification procedures. The goal of these procedures is to select the observable state situation model.
4) The control rule selection is performed on the basis of the expected utility criterion.
5) The identification rule selection is performed on the basis of risk criterion.
6) The problem of selecting the control and identification rules has a game character; the "best" solution of it is to reach the invariable compromise called "equilibrium."
7) The development and usage of equilibrium rules for control and identification procedures is an internal control objective.

The formulated ideas define the concept of "purposeful control of active systems with internally generated goals". The

assumptions introduced formalize the existence of two aspects of subject's interests. One of them is determined by the interest in the evolution of object, and the other – by selecting the scope of interests. The concept of purposeful control brings forth the third aspect of interests associated with the necessity to identify the situation depending on the observable state. According to these three aspects, the information structure of ideas assumes to designate sets of controlling, structural and identification alternatives. It is expected as well to introduce the utility function and the function of transition from the initial purposeful state situation to the desired one. This allows designating the control choice quality criterion with the meaning of expected utility, and the identification rule quality criterion with the meaning of risk. To select structural alternatives, we can introduce the quality criterion reflecting, for example, the degree of satisfying the interests.

Thus, when making a decision on the mode of action, a subject uses three sets of alternatives to comply with his interests. Selection of the alternative from a corresponding set is made according to the individual quality criterion, so it is natural to associate this selection with a certain virtual operating party that can keep options open within the scope of its competence. Subject's interests are dominant for the selected parties, and he acts as their control center. Since the interests of all players are interdependent, this game can be subsumed under the category of corporate interests. Its solution is based on a set of agreed compromise derivatives. It will be stable if it cannot be improved without deterioration of at least one of the criteria. This choice modeling is possible if the structure of ideas will be provided with a set of data media in order to construct the required criteria. In this case each selected party is sure to solve the task of standalone "best" alternative selection according to the relevant criteria. Then we can expect that the joint task of finding a compromise to satisfy the corporate sustainability requirements will also be solved.

In line with the concepts introduced, we can determine the information media corresponding to objects of interests as a set of the following formal objects: S – a set of states; $\beta(S)$ – priori distribution on a set of states; X – a set of situations; $X_S \subset X$ – restrictions to validity of situations as identification alternatives depending on state $s \in S$; C – a set of control alternatives; $C_x \subseteq C$ – restrictions to validity of control alternatives depending on situations $x \in X$; G – a set of structural alternatives; a transition function from $S \times C$ to S; utility function representing priori preferences based on alternatives $c \in C$ depending on conditions $s \in S$, situations $x \in X$ and structural alternatives $x \in X$. The information structure feature I is that the choice of control actions depends on the choice situation ideas that are based on identification procedures. Under these conditions, the regularity of situation dynamics cannot be set a priori. Therefore, an agent uses subjective assessments of the state dynamics regularity determined by transition function from $S \times C$ to S. If a subject is sceptical about his ideas of information structure elements, he uses the additional information to formulate some plausible approximation. For example, if an explicit form of transition function is not known a priori, it is always possible to formulate a set of hypotheses on it.

IV. Conclusion

The paper examined the model of making-decisions by an agent being capable to specify an internal aim and applying subjective ideas of the choice situation. The authors showed that the choice aimed at maximizing the specific utility of choice situation based on the result. The choice result was shown to be determined by the agent's ideas of the choice situation and his own interests. When making decisions, he uses three sets: control alternatives C (actions), structural alternatives G, and identification alternatives X. Therefore, three virtual parties choosing appropriate alternatives being equilibrium strategies are assumed to exist. The research was financially supported by Russian Foundation for Basic Research as part of project 14-01-003284.

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ПРИНЯТИЕ РЕШЕНИЙ АГЕНТОМ С ВЫБИРАЕМОЙ СТРУКТУРОЙ ПРЕДПОЧТЕНИЙ

Виноградов Г.П., Виноградова Н.Г., Богатиков В.Н.

Рассмотрена модель принятия решений агентом, способным формировать внутреннюю цель выбора. В основу подхода положены идеи субъективно рационального выбора. Развиваемые идеи субъективно рационального выбора позволяют: 1) объяснить принятие решений субъектом в конкретных ситуациях; 2) предсказать принимающим решение возможные реакции другого субъекта в различных ситуациях; 3) решать задачу активного прогноза, когда управляющая сторона создает у управляемой стороны нужный образ будущего. Основное принимаемое предположение состоит в том, что мотивация выбора определяется как внешними, так и внутренними факторами. Внутренние факторы отражают интересы субъекта, индуцируемые его потребностями и этической системой, которой он придерживается. Оценки удовлетворенности текущей ситуацией целеустремленного состояния субъектом могут приводить к изменению структуры интересов субъекта, и он ее может выбирать. Предполагается, что выбор осуществляется на основе субъективных представлений о свойствах ситуации выбора. Компоненты представления отражают различные аспекты понимания субъектом ситуации целеустремленного состояния и образуют информационную структуру представления. Конкретный вариант представления также является результатом выбора.