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Multi-agent systems for modelling of self-organization and cooperation processes

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1 Introduction

The progress of any company nowadays requires a high level of self-organisation and co-operation of working processes.

One of the most important aspects of modern industry is co-operation, embracing all sorts of activities of the humankind: science and manufacturing, trade and business, maintenance and services, etc. The problems of co-operation are closely connected with those of inner organisation of such activities. The more versatile the activity of a company is and the more complex the products are, the more important the co-operation is and the more sophisticated organisation is required. And as a rule this high level of organisation assumes a sufficient autonomy within the company departments. Thus the rigid hierarchical management of the working processes is substituted with co-operation and self-organisation.

At the same time both inner and outside co-operation, providing the paying company is always risky. Should one of the co-operation partners fails to fulfil the responsibilities taken then the whole co-operation chain is broken. To survive in such environment the company should have the utmost flexibility, mobility and intellectuality. These features might provide the capacity for adjustment and evolutional adaptation for the new market requirements on the one hand and the ability for revolutionary expansion to increase competitiveness on the other hand. The latter is possible only provided that the organisation of the company is being constantly developed and has the ability for self-organisation.

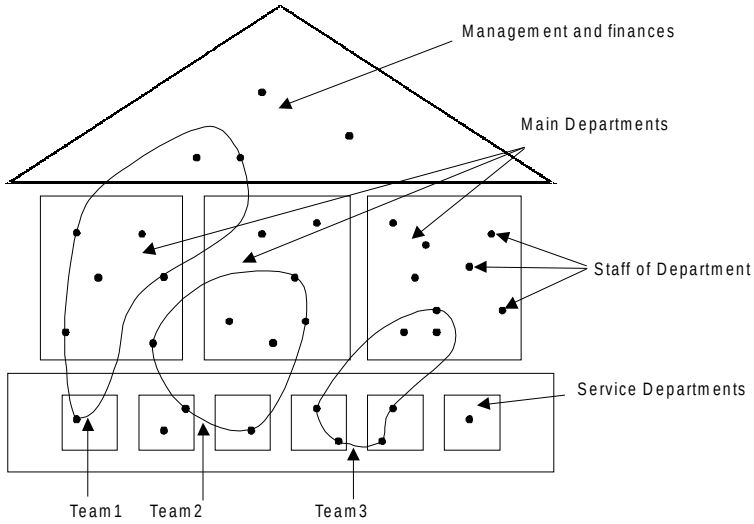


Fig. 1. Structure of company and multidisciplinary teams

A disregard or underestimation of the self-organisation significance can be far-reaching. The lack of this ability of self-organisation can ruin the company and the outward stability and prosperity of big and mighty companies can be fatally illusive without it. A latent process of accumulating the inner problems and being non-diagnosed and unsolved at their due time starts to corrode the company basis and once, all of a sudden, the company goes flop though the apparent cause seems insignificant: some overdue credit or at last, a dismissal of one of the specialists.

The development of the systems for modelling of self-organisation and co-operation processes could be a way to solve the problem. The aim of such systems is not only facilitating of the necessary co-ordinated decision making, but also encouraging the company self-organisation processes at all levels of its activity. As it is demonstrated below, the main feature of the said systems is their ability to detect and solve any potential conflicts of interests both of the inner and outside co-operative activity of the company.

This approach to developing the systems of this kind is presented in the paper.

2 Company Development Problems

For the successful development the company should have the changing structure, though the simultaneous management of a variety of diverse branches is sophisticated. In the typical structure (Fig. 1) there exist subdivisions en-

suring the united management and financial planning, major directions of activities of branches and a certain technological processing that is common for all activities. The figure represents also the multi-discipline teams that are formed to solve the problems. The teams can initiate the new directions of activity or form some new departments or branches.

It is assumed that the problems related to one of the spheres of the company activities can always be quenched by other projects. In real life it often happens and normalises the situation, but as often this process results in damaging other trends of activities. The development of projects slows down and thus hampering the co-operation and leading to the conflict between the branches (and sometimes – to the conflict or even to the breaking-off of the company constitutors' relations). As a result a successful branch of the disintegrated company becomes independent owing to its self-arrangement. Time and competition might cause fall of the profitableness of this new self-organised subdivision, new branches are detached from it forming a new co-operation and the process is iterated. But the company reverse reorganisation is not always possible, and even the promising project is regressing and vanishing, with only one thing left – the losses.

The ideal model of management for such kind of companies is to create the inner competition within the company and to sustain the self-organisation process of various trends ensuring the integrity of the company. The main problems of the company activities are strategic planning and co-ordination of co-operative work in the frames of joint projects and between different projects. These problems are connected not only with the optimum scheduling of works and resources allocation, but primarily with the need for continuous re-scheduling and re-co-ordination of the plans of the parties involved in the co-operation as well as the relevant re-organising of their activities. However, if the changes in the approved plans of one party baffle the plans of another one then a conflict is inevitable. It does not matter how and where it happens – at the level of branches themselves or between particular employees. And these changes not always caused by blunders, errors or other negative factors. Sometimes they are initiated by customers' reasonable requirements, or by the company desire to solve a certain problem in a more effective way, or by objective confinements for the other co-operating partners.

Is there a way for a company to achieve a highest level of its organisation, being the guarantee of its intense and perpetual progress? According to the traditional views, the company managers are fully responsible for company organisation though as a rule they are professionals, not experts. Their ambition to administrate along with a disregard for nuances of the business usually leads to an excessive bureaucratisation of intellectual and produc-

tion ever-changing relations within the company and finally to its collapse. The growing amount of new regulations, restricting and prohibitive orders (not to be confused with the technological or labour discipline) are indicative of the disability to control the company.

Some negative examples are known then, on the contrary, the leading experts in the role of managers could ruin the already formed (sometimes spontaneously) organisation of work and the company collapse in spite of all its modern bald and revolutionary ideas.

The self-organisation as much more complex process affects the guidelines of the company activity resulting in the changes of the activity trends, the company inner structure or constitutor staff, in up-dating of technology and equipment and management rotation. These novations are both important and morbid for any company. It is vitally important to introduce these novations at their due time and this requires the highest level of substantiation and, therefore, concurrency of decisions, made by all the participants of the process.

Anyhow, the adjusting of a concurrent and co-ordinated activity on all the levels of the company is the starting point and it usually takes decades to achieve this under normal conditions.

3 Self-organisation and Co-operative Work

A company foundation and progress are always connected with the forming of a collective body of persons who join their efforts and resources to achieve the common aims. Usually a co-operation of creative workers or formation of working groups (in big companies they include both managers and specialists) is the beginning of the process. As soon as some progress become noticeable the "loose group" transforms into a small company or becomes a department of large company. A further transformation may lead to a conglomerate of companies, multiple establishment, consortium etc. Whatever is the form of the organisation, the decisions on every level are made by a collective of individuals who can plan and co-ordinate their activity while solving the common problems.

The simplest and generally accepted form of such organisation is the stuff meeting at the "round table". In the contrast to other meetings the aim of this meeting is to detect and solve the common problems and contradictions arising during co-operative activities. Here knowledge and experience are more important then hierarchy and ambitions. The more thoroughly the contradictions are discussed, the more explicit they are and the better are the concurrent solutions. (Note that such practice requires common rules of game and certain limitation, accepted by all participants). It can be stated that every meeting of that kind forms a temporary creative group of experts, so to

say a new virtual subdivision of the company structure. As a result, these very collectives starts to control the company and through it – the business itself, perhaps in a latent form. And the formal administrators of any level of the company take the role of arbiters. They can participate in the meetings and discussions as ordinary professionals, but they are responsible for "fair play" under existing constraints and limitations.

Self-organisation is the highest form of the collective work. Self-organisation is the basis of the intensive progress of the company and its ability to immediately respond to the environment changes by changing both the policy of the company and the code of inner structure and operation. In our specific case described in the paper the self-organisation reveals itself in the ability of specialists to form new teams for every kind of activity irrespective of their position at the scale of ranks. A lot of inventions and discoveries are made at the junctions of various spheres of activity provided that there are proper conditions for the specialists to communicate with each other, even if these contacts are in the smoking room. In some companies the working premises are specially located so that the workers of different subdivisions could often meet each other even by chance.

Thus, the current activity of the company (or group of companies) can be presented as a pattern of the temporary or permanent teams ("round tables"). The "snapshot" of the working group at this moment is presented in Fig. 1, where the rings show the operating "round tables".

The introduction of self-organisation principles to company must start not so much at the bottom levels of management as from the moment of the company foundation, first involving individual specialists, micro-groups, small departments and so on. (It is normally more convenient to grow a new company than to re-organise the old one.) Ultimately, the structure of the company is virtual. It exists in every moment but it is so changeable and elusive that in fact there is no structure. There is also no hierarchy of control anymore and the control effects can be initiated both at horizontal level and vertically. But soon new leaders appear owing to their knowledge and experience. They participate in each newly formed "round table". And every common executive is probably working independently in a lot of horizontal and vertical teams and probably making concurrent decisions within his scope. While doing this, the worker is constantly acquiring new knowledge and experience and as a result improving his professional skills. Any new idea (irrespective of the level it was originated) is picked up and evaluated by all other teams and can initiate the change of the work schedule or the company structure without breaking its commitments before the partners.

It is intuitively apparent that this high extent of the decision concurrency (i.e. company organisation) is highly paid. The payment is the exponential

increase of the overhead expenses made for the decision co-ordination process itself at all the horizontal and vertical levels of the company as far as it is theoretically feasible to set the "each-to-each" relations. In the routine work of companies this painstaking process is hardly possible. As a result, a widely known type of the "overloaded administrator" responsible for everything appears. The activity of the whole company completely depends on one person. However, the resources and time of this administrator are limited. It is impossible to accept new revolutionary ideas without comprehensive study and these ideas are a priory condemned to be unrealisable.

The approach discussed below is primarily addressed for such companies and their leaders. The potential power of a self-organising "think tank" exceeds the abilities of any leader, even of a man of genius. This fact urges to search for new ways to solve the problem of co-operation and self-organisation of companies on the base of computer implementation.

4 The system of activity

The view on the co-operative activity as a set of interacting "round tables" is too general and simplified. The main idea of the offered approach is that in order to model the process of specialists negotiation at the "round table" it is necessary to simulate the whole activity of each of these experts, including its three main hypostases: behaviour, thinking and communication.

What is the activity of an individual (or organisation)? It is already more then three centuries that the philosophers have been endeavoured to answer this question in the scope of general theory of activity. The germ of the theory can be found in the works of Aristotle. In the works by Johann Fichte, Friedrich Schelling and Georg Hegel the reasons are given to comprehend the activity as a cognition object of a distinct categorical type, for which neither the logic of "property-attribute", nor the logic of "process" is applicable.

Methodological grounds for the development of the theory of activity are disclosed in a number of philosophical trends, particularly, in the principles of pragmatism (Greek *pragmatikos* from *pragma* – act) by Charles Peirce. According to his viewpoints, "philosophy should not be a speculation about the cradle of being and cognition, but the general method to solve the problems, which emerge during different real life situations, in the course of people's practical work taking place in the ever-changing world" [1]. From the pragmatic point of view, the cogitation is considered as adaptation means of an organism to its environment for successful actions; the main responsibility of thought is "to overcome a doubt being the obstacle for action, in the course of choosing the means to achieve goals or to solve some problematic

situations". Thus the ideas, notions and theories are mere tools, instruments or action plans. According to the "Peirce principle", their meaning is reduced to possible practical consequences. If the essence of the theoretical mind interest (after Immanuel Kant) is the question *What may be known?* then the interest of the practical mind is expressed in the question *What must be done?*

At the same time hitherto the most important results in this field are related not so much to the specific object itself, as to the development of means and methods of the research of this object. One of the originators of this study is V. Bogdanov. In the beginning of the century he stated the basic principles of the organisation theory, called *tectonics* by him.

It is believed that the notion "activity" originates from the notion "behaviour", and hence activity is conceived as somewhat that is produced, created or carried out by an individual. Even nowadays the assumption that some activity can be impersonal seems absurd and irrational for most people. Then why is it so hard to explain how individual acts? How he uses the products made before as the tools for new activity and how the past, the present and the future are linked together in his actions, and, at last, what the knowledge about activity is?

The philosophical dictionary treats the question in the following way: "Activity is a specific human form of an active relationship with the outward things, and the content of it is its purposeful alteration. Any activity means the purpose, mean, result and the process of activity itself" [1]. Therefore, activity is something more substantial process proper. Activity is specified by the resources of its participant and assumes some initial and final substances, methods and techniques of a product creation, availability of knowledge etc. It seems intuitively clear that all the categories, describing the activity, are interconnected in a sophisticated way.

Apparently, the answer to the question asked above is more complicated than it seems to be. Parallel with conventional viewpoints, another, more profound perception of what is activity has been established. According to the latter, the human activity should be treated not as an attribute of individual, but as an initial universal integrity, which is more comprehensive than "individuals" themselves: "activity is not initiated and produced by the individuals; on the contrary, it *involves* them, and force them to *behave* in a certain manner" [2].

And indeed from his very birth every human being reveals some routine and formed activities all around. And his primary task is to master particular kinds of these activities in co-operation with other people. This process determines the main social aspect of activity. And it turns out that along with different objects or equipment the people belong to activity as mere components, materials or means.

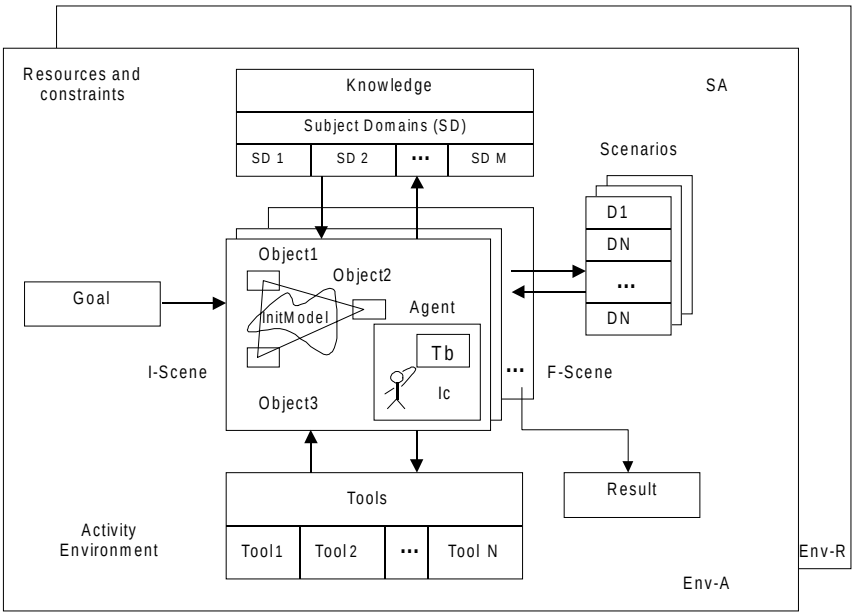


Fig. 2. System of activity (SA)

The development of up-to-date principles of the activity theory in the field of technical system design was carried out by a prominent philosopher G.P. Tshedrovitsky. The major idea stated in his works is that activity should be considered as a system of heterogeneous poly-structure formed by numerous constituents and relations [2]. Besides, according to him, human cognition is also an activity. Therefore, the existing formal logic is "inadmissible over-simplifying" of the cognition process [3].

The analysis of different approaches to the description of the activity structure leads to the necessity of using several categories. While developing of system of activity (Fig. 2) the following categories are distinguished: activity purposes (*Purpose*); activity environment, comprised of environment of actions (*Env-A*) and environment of reasoning (*Env-R*); individual subjects (*Agents*) and activity objects (*Objects*); initial substance (*Init-S*); means and instruments (*Means*); knowledge (*Knowledge*), which are set apart of other means and fixed in special token forms; initial and final scenes (*I-Scene & F-Scene*); result (*Result*); activity scenarios (*Scenarios*) and activity constraints.

The categories applied to the description of subject activity, are set apart in a special way. The designations *A1*, *A2* ..., *AN* located within the scenario are the actions applied to the object (substance) by an activity subject; *Tb* is sense tableau of an individual; *Ic* are inner facilities and abilities of the individual, needed to use all these means and to carry out actions.

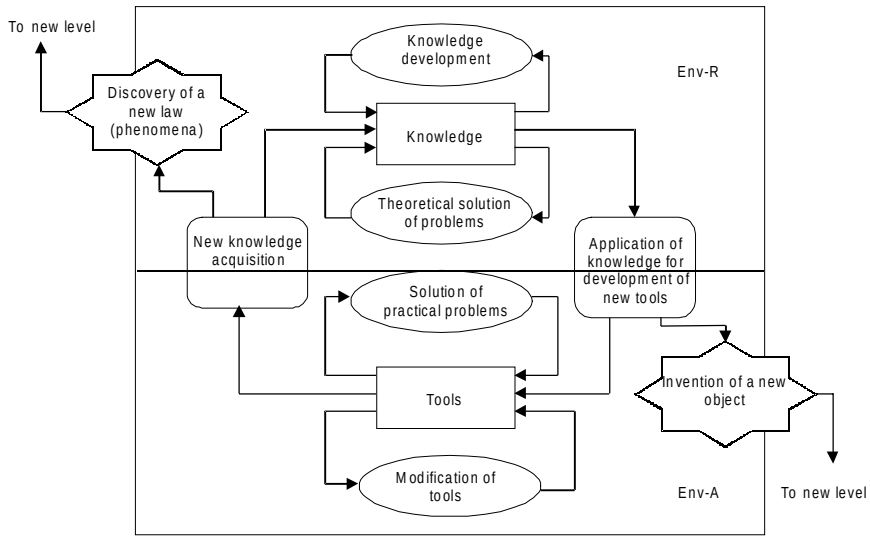


Fig. 3. Evolution of SA

The dialectics of knowledge and tools, knowledge and technology environments (natural and artificial) is most important in the evolution of any system of activity. More detailed analysis of the complete activity reproduction cycle for different domains allows to build a general diagram of the activity evolution. Its main stages can be singled out as: knowledge acquisition, knowledge improvement, knowledge application, tools (technologies) improvement (Fig. 3).

The purpose of the new knowledge acquisition is the revealing of new phenomena and object properties and their further description. The apex of this action is the discovery of new laws. The target of this activity is studying of these phenomena and new objects properties (discovering and description, revealing of regularities, etc.). Apparently, this process can be carried out both empirically and by pure reasoning (e.g. the prediction of Neptune location by Leverrier).

The knowledge improvement process is aimed at the systematisation and reorganisation of knowledge. Knowledge-based theoretical solving of problems is carried-out simultaneously. This process enhances the knowledge system itself. The apex of these actions is a new theory creation that widens the scope of automatically solvable problems. These actions evolve entirely in the field of reasoning, but their results are applied in all others processes of activity.

Another important class of creative tasks is solved in the process of knowledge applications for the synthesis of new tools (in engineering it cor-

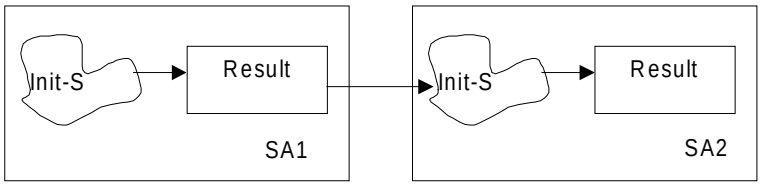
responds to experimental development). The purpose of this activity is to design and implement the new machines, tools and instruments (or advanced methods of their use). The culmination of these actions is the invention of objects of a new type. Similarly with the knowledge acquisition, these inventions can be made both on the "top" level (as a result of the theoretical researches) and on the "bottom" level (as a result of the practical work). However, knowledge is the input of this process, and the prototypes of products are its output.

In the process of handling with tools some practical tasks are solved and the tools themselves are updated. This activity is closed to the described above theoretical activity, but the former evolves in the framework of actions (and not in the realm of reasoning). In the progress of activity some advanced tools and instruments are mastered and commercial products are manufactured. The acme of this activity is the development of a new production of goods.

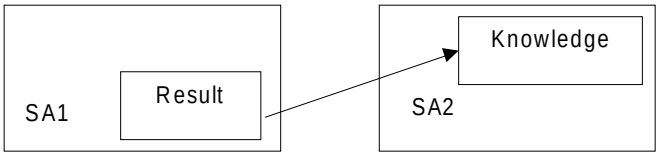
As it follows from the above discussion, the proposed scheme is universal and fits the development of companies working in different fields. E.g., for a trading company the stage of new knowledge acquisition is connected with the marketing, unveiling new kinds of goods, evaluation of their consumer qualities, specialising of buyer category etc. A business plan is prepared at the stage of the theoretical solution of problems. The stage of knowledge application means the development of the design for the shop building that is put into service later on.

The offered theoretical scheme of the activity representation allows describing a complete system of relations that appear concurrently with the co-operation (Fig. 4). Thus, a product of one activity system can be initial substance for the other (Fig. 4a); knowledge and tools delivered to other systems may also be products of system of activity (Fig. 4b & 4c); and, at last, an individual himself as a sum of skills and expertise (Fig. 4d) can be a product of some other system of activity (e.g. system of personnel retraining).

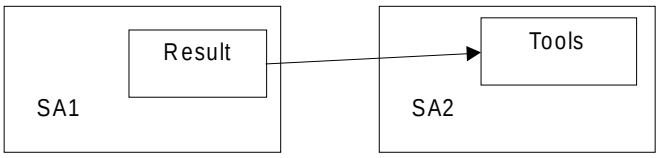
It should be noted that the presence of two environments (environment of actions and environment of reasoning) is essential even for modelling of a single person activity. The interrelations and contradictions of these environments are extricated by minor and major "innovations" and "novelties" (for example, original financial transactions or new kinds of profitable goods). This dependence of environments determine the genesis of the particular activity field: discovery of a phenomena and inventing of new theory will encourage the advent of advanced tools and instruments (and vice versa). During the problem solving the lack of knowledge may be compensated by the availability of tools (means) or vice versa.



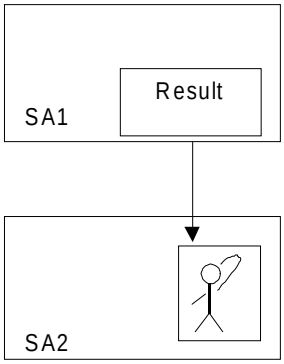
a) result of first system determines initial substance for the second system



b) result of first system supplies knowledge to the second system



c) result of first system supplies tools to the second system



d) result of first system is an individual for the second system

Fig. 4. Examples of cooperation schemes

Note that the activity cycle is also inherent to the commercial business, service trades and everyday life itself. The cycle doesn't depend on the intellectualisation level of labour and is applicable to the jobs of a scientist and engineer, businessman and banker, worker and craftsman. It seems that a hairdresser who invents new hairstyle and a barman who mixes some peculiar cocktails are also discoverers and innovators each in his own field. Essentially their actions are similar with the process in the field of the most advanced technologies.

Therefore, the described cycle is the essential "way of a master" of an expert in his field. The cycle expresses the unity and conflict between demands and abilities of the man. On assuming that the latest knowledge firstly forms new demands, we can state then that the advanced new tools make it possible to satisfy these demands. This is the essence of a human professional activity in any field. The process repeats again and again during learning and training; it influences the quality and efficiency of the knowledge acquisition by the apprentice [4-7].

This very scheme is used as a basis for development of the activity models of organisations and individuals in different domains.

5 An Agents/Worlds Approach

To solve the problem this paper proposes an approach based on the idea of the activity agents and worlds. For the first time the idea of the environment for learning in multi-discipline domains that comprises the actions and reasoning worlds and activity agents was expressed in [4].

In contrast with the conventional approaches, this approach is realised by composing of the aggregate world of the co-operating parties' activity and separate worlds of activity of each party. Therefore an integrated environment of managers and specialists activity is created ensuring reproduction of the essential constituents of the activity process for each enterprise and mutual understanding. The managers can model three corporate hypostases: behaviour, thinking and communication by using intelligent agents together with the worlds of actions and reasoning. Each participant can authorise its agent to solve the appearing problems concurrently. The possibility of a virtual "round table" realisation is discussed below. Such "round table" can provide the aggregate world of actions for all agents.

In the approach under consideration any world of actions is a knowledge-based model of the reality that is used for the modelling of the actions. Unlike conventional modelling systems this system contains a model of space and provides a direct access to the objects of the world, located in this space. The objects are used to carry out actions. The responses to these actions are

simulated in accordance with the rules of the world. Models of the physical reality allowing to simulate the effect of the activity subject presence are usually called virtual. Worlds of knowledge are constructed in a similar way, but they use the models of abstract objects (geometrical figures, formulae, etc.)

Let us consider the structure of the worlds in details. The principles of construction and performance of the worlds can be stated as:

- a world consists of the objects able to interact in accordance with the rules of the world. For the user these worlds are presented as scenes consisting of the specified objects with the determined interrelations between them that can be applicable in the scene.
- objects are specified by their properties ensuring their ability to interact as the objects. Their properties and relations define the object states. Potential object properties are determined by the world rules, applicable in the current scene.
- action scenarios specify the world rules. These scenarios are defined as rules of changing of the world objects state. Complex scenarios are made of simpler ones.
- relations between objects determine their dependencies. Typical are relations "the part — the whole", "membership", "measure", etc.
- the main concepts are expressed through the attributes of substance, space and time, energy and information.

These basic categories allow to construct worlds of actions for diverse domains. As it is shown in [5-7] the considered principles allow to compose worlds of reasoning as well (such as Mechanics, Optics, Algebra and Geometry, etc.). The same principles are feasible for composing Economics, Politics, Technology and Trade worlds, etc.

Actually, a multi-discipline knowledge base as a semantic network is formed for creating of the world of a particular market sector or the world of a separate enterprise. The knowledge base is then used in reasoning of agents. Its main difference from the conventional approaches is the orientation to the description of "actions" and use of correspondent action logic. This knowledge base combines both declarative and procedural knowledge.

Let us now consider the corresponding model of the agent thinking and memory designated above as "Sense Tableau" of an individual.

The following components of the architecture of agent memory (Fig.5) are marked out:

- Agent long-term memory containing complete semantic networks of domains of knowledge. In the course of the agent training this memory is supplemented by knowledge that is regularly transformed and systematised. The input facts are filtered through that knowledge.

- Medium-term memory (space) of sense containing the world objects images. This memory stores the scene description (also as a semantic network) for every world. The main reasoning actions with these objects representations are carried out here.
- Memory of facts and memory of scenarios are the most alterable memory structures (operating storage). The memory of facts contains initial and final facts obtained in the process of evaluation and reasoning. The memory of scenarios is also transformed. That is primarily caused by the generalization and instantiation of scenarios.
- Genetic knowledge memory is the set knowledge rigidly built-in into the system. It is the knowledge about the structure and performance of the worlds and agents.

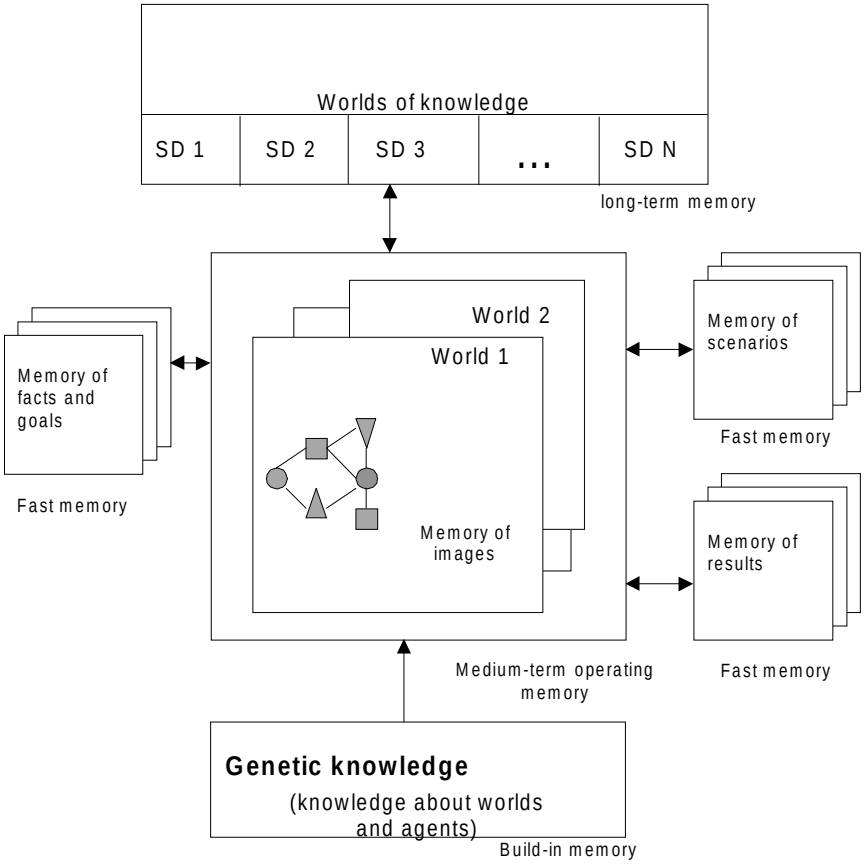


Fig. 5. Architecture of agent memory

The general principles of the agent reasoning are conventional enough and consist of three main stages (Fig. 6):

- *perception*, during which the composing of a scene model is carried out for current world;
- *cognition*, during which a scenario of subject actions aimed to achieve the stated purposes is formed;
- *execution*, during which the scenario is fulfilled, and the desired and observed results are regularly matched.

The realisation of these stages in the system is different from other existing systems. It is implemented through a couple of basic mechanisms: abstracting and instantiation that are tightly interconnected. In metaphorical language the agent thinking is the motion of engine pistons: first a move up through abstracting, then move down through instantiation and so on.

The reasoning actions take the most of time during "layer-to-layer" inferences. Such inferences are the actions with the object images (notions) resulting in the change of the state of a scene and, thus, confining the use of deductive inferences. The logic of the used actions also makes the proposed model different from conventional deductive systems.

Another peculiarity of the proposed model is its orientation to the detection of contradictions. For the above discussed system, typical are the contradictions between the knowledge and tools, the purposes and means of activity, the action scenarios of an individual and his inner abilities, etc.

The typology of these contradictions is initially stated within the system and is regularly enriched and modified further on.

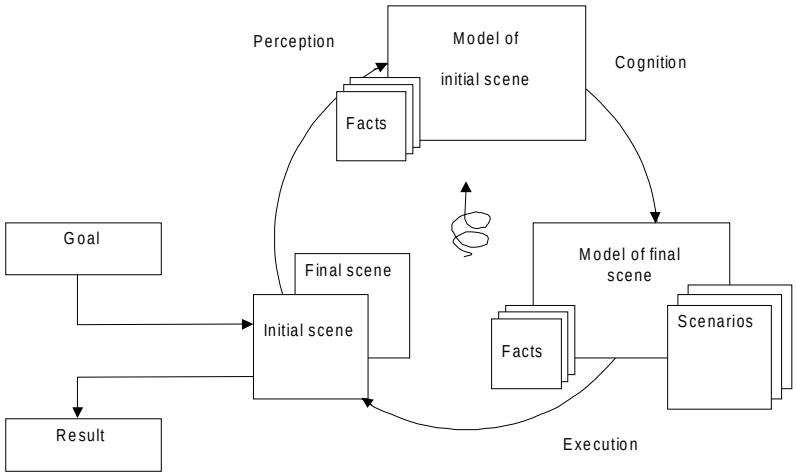


Fig. 6. Scheme of agent reasoning

6 Virtual "round table" for modelling of negotiations

The processes of the co-operation and self-organisation of the company are realised by the negotiations. The virtual "round table" is integrated in the system being developed in order to model the negotiations between the members of the formed teams or their agents. The virtual "round table" can be realised both through local or global network (Fig. 7).

The negotiation procedure is organised in the following way:

1. An initial scene of the aggregate world of actions (that is shared by all agents) is formed; goals, constrains and common resources are specified.
2. Each agent interprets the scene state and initiates the processes of perception, actions planning and execution of these actions. The necessary worlds of knowledge are initiated and restarted. A correspondent model of the initial scene is formed for each of these worlds. The first agent, which has completed its actions, makes first move thus offering first action of its scenario.
3. If this action satisfies all common constraints and doesn't contradicts with the plans of other agents then the action is preliminarily accepted. If some of common constraints are not met then the agent has to change its plans. If the constraints are met but still there are contradictions then it is necessary to solve the conflict. And the system decides whether the plans of the first agent or actuated plans of some agents are to be changed.

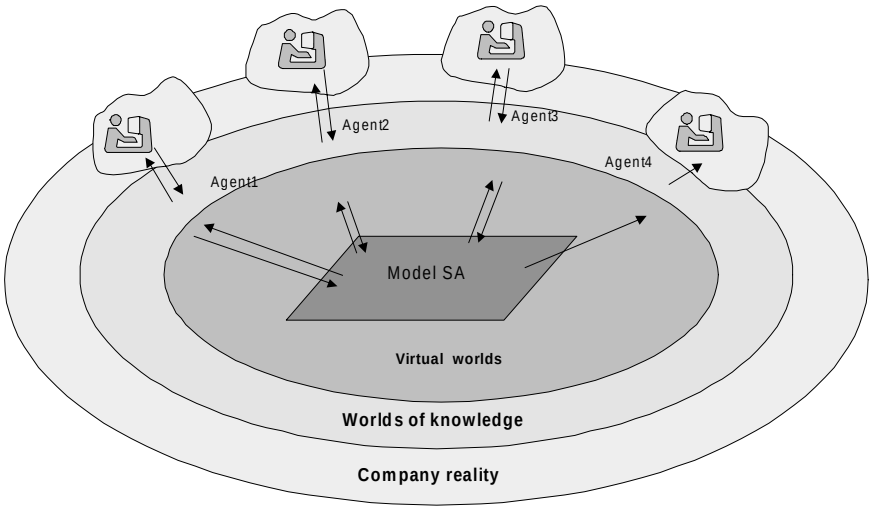


Fig. 7. Virtual "round table"

4. Later on other queued agents are engaged in this process by actuating the corresponding actions of their scenarios. If an agent has to reconsider its actions that were accomplished during one of the previous moves then the negotiation process backtracks to this point and starts again.
5. The negotiation process is completed when the stated goal is reached.

Evidently, this procedure is associated with a probable extensive search of the solution variants. Its convergence speed depends on the knowledge base depth and intellectual abilities of agents. The procedure is painstaking for human beings, but in our case one and the same agent of a manager or a specialist can simultaneously participate in several working meetings.

To entirely comprehend this problem, it is enough to imagine, for instance, the vast quantity of the coordinative work made for an oil well development. It is necessary to take into consideration the requirements of a geophysicist, digger, pipelayer, master-builder, economist, sociologist and specialist of environmental protection. And it could be dramatic indeed to discover after say half a year of joint work that one of the experts was wrong and the whole scenario must be changed. The project is then thrown back to the starting point and the process is re-iterated. The comparable amount of negotiations is made in the course of a large contract preparation when all the prospects are engaged.

In spite of many other difficulties caused by the convergence of process, the system under development is free form the mentioned main problem. Remote participants may communicate with each other in the scope of the system via Internet.

7 Architecture and interface of the system

The following architecture of the multi-agent systems for modelling of the co-operation and self-organisation is proposed (Fig. 8). It allows to model the activity and reasoning of managers or specialists for detecting their possible conflicts:

SA Knowledge base contains the descriptions of the activity environment, aims and tasks, knowledge and instruments, scenarios of actions and also the description of all other components of the above discussed structures of the activity systems;

Modelling sub-system allows to simulate the activity processes (the behaviour of the activity subjects);

Evaluation and inference sub-system allows to simulate reasoning processes;

Control sub-system realises the processes of the solution consistency support. The procedures of the virtual “round table” are the communication

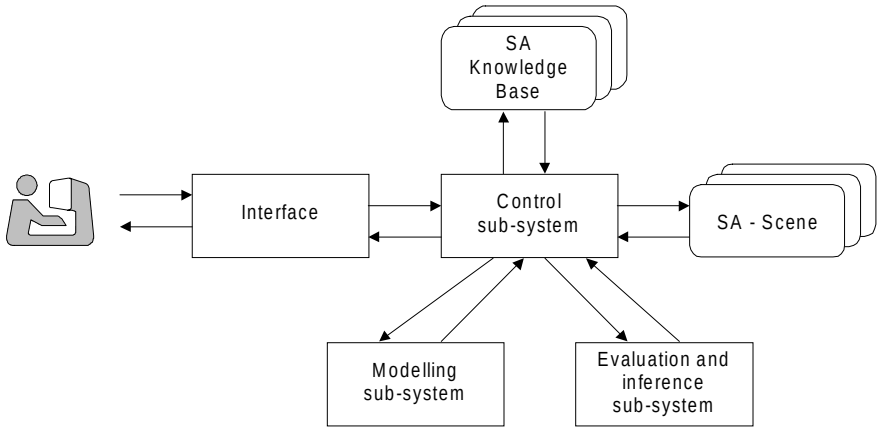


Fig. 8. Architecture of system

procedures of the activity subjects. Besides, this sub-system performs as a constructor of the worlds and the scenes of these worlds;

Interface sub-system provides the interaction with the user;

SA Scenes are the current representations of activity;

As it supervenes from this scheme, the main components of the system structure are connected with the central modelled components of activity: behaviour, thinking and communication.

The system interface also fits this architecture and comprises the following parts or window (Fig. 9):

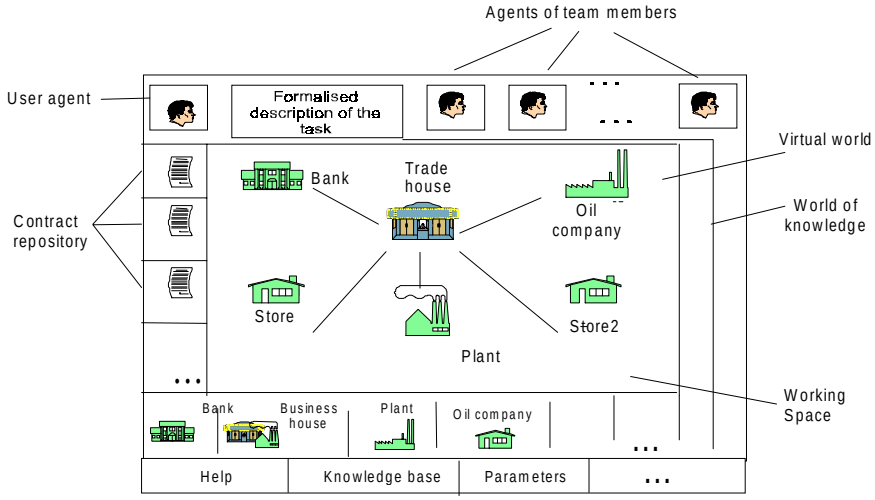


Fig. 9. System interface

Task window contains a formalised definition of the problem;

Working space is the working area for composing of the action scenarios where scenes of the aggregate world of actions and particular worlds of reasoning are formed and simulated. The presented interface is a subsystem part for simulating of activity the a business enterprise occupied with the agricultural production;

Agent window displays the current team agents, which can be either activated by user or triggered by some actions or inferences;

Object repository is the list of all potential co-operation parties (or company departments). These objects can be placed to the Action window;

Contract repository is the list of all possible relations between companies (promoter contracts, delivery contracts, sales contracts, etc.)

In the presented system the user can initially load, for example, models of bank, poultry farm, business house and store, which are symbolised as pictograms. To compose the initial scene for simulation the user should specify those objects interrelations that are important for him. For example, the business house can get a credit from the bank, buy some goods of the poultry farm at the wholesale price and then transport them to the store for sale. If another wholesale buyer for the goods of the poultry farm appears, the correspondent model is added to the system. The possibility of a new successful contract is simulated for the changed situation.

All actions are performed by activation of the appropriate pictograms. Thus the individual action box is opened to each object. Here in the manual mode the user can take credit, start shipment of goods, or purchase shares of an enterprise.

The system commands of the menu contain correspondent short cuts of access to the knowledge base (for viewing and re-training modes), setting of simulation parameters, on-line help, etc.

8 Application examples

At present several projects of development of the system for modelling of the co-operation and self-organisation processes are carried out. The following companies are involved into these projects:

- The firm that develops and produces multimedia-CDs along with their documentation and video-courses.
- The big company occupied with the export and import of diverse foodstuff and is also an investor in agricultural production.
- The holding company that is the owner of chain store, restaurants and service-centre.

The structures of the companies are presented on Fig. 10-12. The

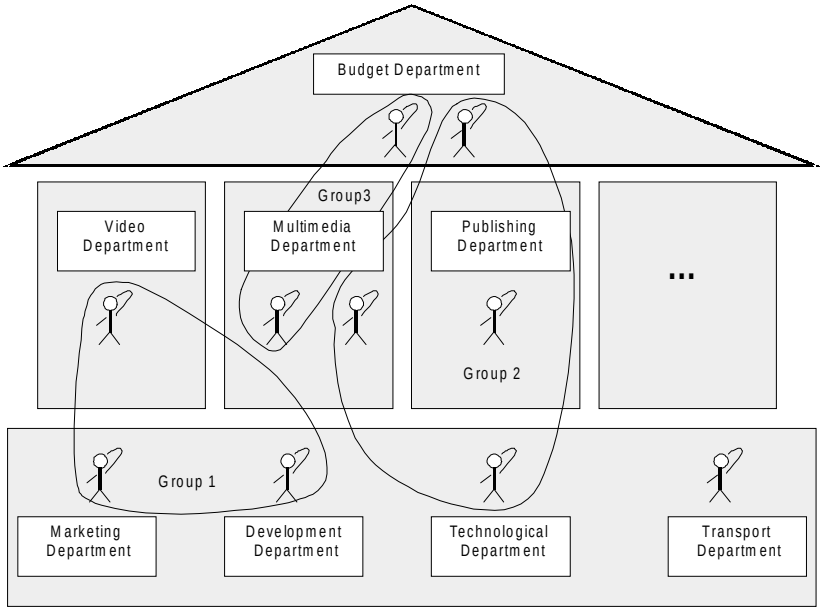


Fig. 10. Structure of multimedia-company

main task of the mentioned systems is the organisation of work of the "round tables" involving the specialists of different company departments and the support of their negotiation process. To do this the words of activity for every company and the initial models of specialists agents are being developed.

The examples of the interactions between the system developing for different companies and their personnel are given below.

Example 1

A marketing manager suddenly apprises that some other firm is ready to issue CD-ROM that is almost the same as the multimedia-disk being produced. The input of this information into the system activates the company departments involved into the estimation of the project profitability, project realisation, advertising of the product, etc.

The system supervises the list of departments participating in the reconciliation of this problem. In progress, the system revises the priorities of the current activity of employees according to the existing regulations and gives the highest priority to solution of new problem.

As a result of these negotiations the current project may be cancelled, or, on the contrary, completed by the expeditious schedule. In the latter case

additional specialists and resources can be involved if needed. It also affects activity of the company.

The teams that can be organised by the system is shown in Figure 10.

Example 2

Several managers are responsible for the wholesale and retail contracts on foodstuff. When they run the system the existing contracts in all details are displayed together with the current situation at the market and in the company. The purpose of the managers is the maximum profit (they have their buying commissions). However, the maximisation of the profit amount of one contract may cause losses to the company on the whole.

To avoid this situation each manager should simulate a step-by-step scenario of the corresponding deal in the scope of the company activity. The results of each simulation step demonstrate the deal consequences and allow to evaluate its fitness to the available credit resources, warehouse areas, capacity of refrigerators, transportation etc. If there are contradictions then the system arranges priorities of the corresponding deals. After that relevant managers analyse the deals and common resources to accept these deals and compose their schedule.

The teams ("round tables") that can be organised by the system for solution of the problem is shown in Figure 11.

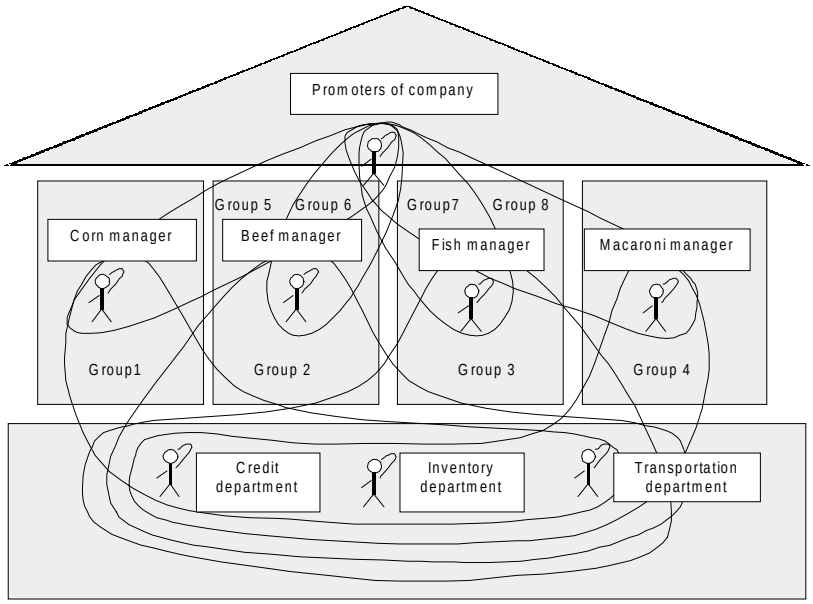


Fig. 11. Structure of wholesale and retail company

Example 3

A manager of the service-centre while preparing the monthly balance report on repaired equipment detects the imbalance between store-room requisition forms and the available spare parts in the inventory.

The manager runs the system and specifies the problem. On having analysed the situation the system concludes that the cause of the problem is either the program failure or wrong blank filling by the receiving personnel. In order to solve this problem the system activates new workgroup consisting of the manager, receiving employees and system operator. These people should check their actions once more. Note that everyone does it within own department only.

Suppose the error is found in the report-making program and is caused by the methodology of stock records. The methodology modification should be accepted by the bookkeeper of this service-centre (and, possibly, by its director). If these modifications relate to the methods of blank filling then the manager and receiving employees are to be retrained by the system operator. It causes the formation of temporary workgroups existing till the problem is solved completely.

This procedure can be carried out either with blocking of all actions in inventory or in the background mode.

The workgroups that can be organised by the system for solution of the problem is shown in Figure 12.

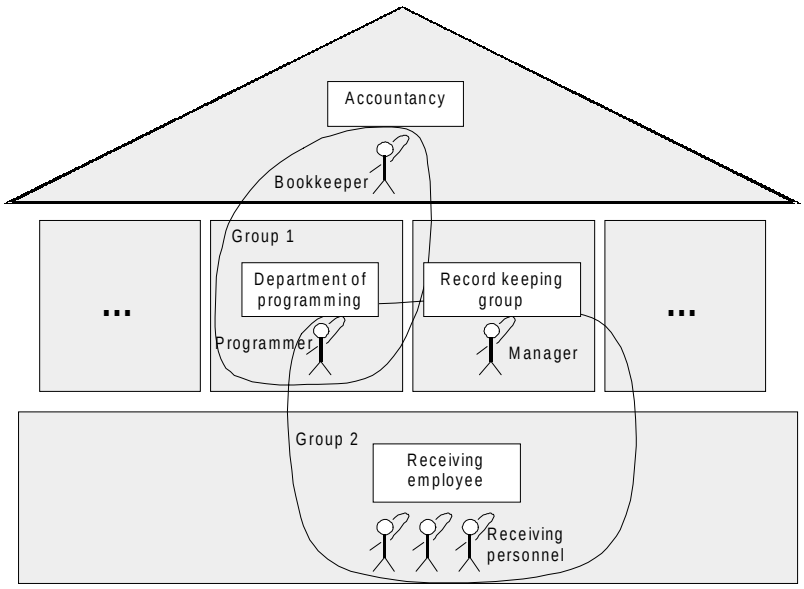


Fig. 12. Structure of service-centre

9 Conclusions

This paper presents the multi-agent approach to model the processes of the self-organisation and co-operation in the modern companies.

The peculiarities of the approach are connected with the construction of the virtual worlds of the specialists' activity and intelligent agents for the specialists. The "round tables" are used for organising of the agents interaction. The first stage of experimental prototyping gives hopes for successful realisation of the proposed approach for the solution of actual problems of the companies development.

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