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ADAPTABLE AND INTELLIGENT LARGE SCALE DISTRIBUTED COMPUTING SYSTEMS IN COMPLEX ORGANIZATIONS FACING RAPIDLY CHANGING ENVIRONMENT

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CONTENTS

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INTRODUCTION

Purpose of this paper is to analyze the impacts of intelligent large scale distributed computing systems with highly reliable and *adaptable architecture* on dynamics of structures, information flow control and behavior of future complex human organizations facing rapidly changing environment.

The first two chapters describe modern approaches to design of reliable and adaptable distributed computing systems which is base for future computing systems and characteristics of intelligent distributed computing systems.

Chapter 3 explains briefly basic phenomena concerning structure, internal information flow and environment of complex organizations.

Chapter 4 tries to summarize and extend general aspects of structure and internal behavior of organizations with respect to their dynamics.

Based on the synthesis begun in chapter 4, chapter 5 attempts to formulate impacts of large scale intelligent distributed computing systems "diffusion" into organizations from abstract point of view, which brings to the light new qualitative factors of human organisms in general.

Chapter 6 contains some conclusions.

1. RELIABLE AND ADAPTABLE DISTRIBUTED COMPUTING SYSTEMS

Increasing pressure to improve organization efficiency in present very changeable and dynamic environment appears to be providing the forcing function especially for the geographically discentralized organizations to move towards distributed computing systems. In addition to increases in processing power which have been a principal motivation to more advanced systems, the other main objective in the application of distributed computing techniques is to provide increased data and processing functions to the end user and reduced probability of total system failure due to malfunction in hardware and software resulting from modularity of the system from multiplicity of its resources and thus implicit redundancy.

With the advent of microprocessors during the past decade and rapid hardware components cost decrease including new cheap communication subsystems (utilizing optical fibers) and certain standardization efforts, it may be expected that the existing giant national and multinational computer networks will be continuously refined with minor participant user networks which will further support his own computers in his organizations at all levels, using local area networks as a medium to connect heterogenous computing facilities. Distributed computing systems together with other computing facilities are becoming substantial part of our life (e.g., viewdata) and decision-making (e.g., expert-systems).

From present state-of-the-art in this area follows that today's distributed computing systems have the following properties:

- they consist of two or more computers (processors) having own software equipment
- the computers are linked together by a communication subsystems
- application programs and data structures are allocated to individual computers according to their processing capability
- the whole system is controlled by means of a predetermined set of protocols and programs implemented in hardware and software (distributed operating systems).

Under these rather free assumptions we can consider as a distributed computing system a network of geographically separated computers, local area network, a single module containing a set of interconnected microcomputers with a task allocation subsystem for parallel execution of specialized tasks, or the same structure on one chip or combinations of these categories. Distributed computing systems range from dedicated (to one class of applications) to general purpose (e.g., for public services).

As a result of analysis of developments in computer industry of the past decade we may identify one of the most important trends of the near future: *design of distributed computing systems with high reliability and adaptability*. This will form necessary base for developing "intelligent" distributed computing systems, probably in the nineties. The eighties will be years of intensive research towards complete reevaluation of present computing systems design strategies in the light of new building blocks, redundant chips and modules (Eichelberger *et al.* 1977), and at the same time investigation of distributed systems architectures based on them.

It is apparent that future users will require that the distributed systems have extremely high degree of reliability, availability, and maintainability of the system (Ng and Avizienis 1980). These requirements will be even broader. They will expect high performance related reliability — probability, that a given distributed computing system will be able to provide required computation capabilities in some time interval and high performance-related availability, i.e., probability that the performance capability will be at their disposal at a given time instant. To express their requirements even more globally, they will view their distributed systems also from the point of "performability."* (Meyer 1978).

How to comply with such very stringent requests? The answer is unique — by changing concepts of design of distributed computing systems:

* Performance of a system S over a specified time period T is a random variable Y_S making values in a set of A. Elements of A are "performance outcomes" for a given system. With respect to Y_S, the performability of S is the probability measure indicated by Y_S, where for any measurable set B, $B \subseteq A$, the performability is the probability that the system performs at a level in B.

- implementation of perfectly diagnosable chips
- implementation of redundancy in hardware (i.e., introduction of a number of spare modules)
- implementation of redundancy in software (i.e., special diagnostic and recovery routines including reliable self-reconstructuring data structures)
- implementation of error detection and correction codes.

Future distributed computing systems will have thus possibility of ***graceful degradation*** with respect to their computational capabilities. In presence of a failure in hardware, error in software or data structures, the system will be required to continue processing its tasks in spite of lower performance.

Such a capability requires immediate fault or error detection, application of various recovery strategies from temporary or permanent faults, self-reconfiguration of resources to create computationable structure from the remaining modules of hardware or software, and restart of execution of a set of tasks though under lower performance or functional capabilities.

Thus the "crash" of the whole system is extremely improbable. The system continues its work even though maintenance at various levels (hardware, software, data) is carried on.

But VLSI technology affects computation in another two ways. First, it leads to the cost-effective computerization of small processes by assigning them to microcomputers and microprocessors — that is, it has shifted the lower bound of computerization downward. Second, by allowing the construction of complex modular computer systems that can *adapt* their architectures not only in software level but also in hardware level *to the problems being computed*, VLSI technology lights the way to supercomplex parallel processing —that is, it is raising the upper bound of computerization.

Computer architectures thus can be static or adaptable. Static architectures do not adapt via software to the programs being executed — adaptable architectures do.

At present, adaptable architectures may be partitioned into three classes:

— microprogrammable

— reconfigurable

— dynamic

depending on the level of reconfiguration performed.

The first adaptable architectures appeared in microprogrammable computers in which it was possible via software to reconfigure interconnections between different devices such as registers, adders, and counters. The net effect was the better tuning of microprograms to the executable algorithms.

Further performance improvement has been achieved by introducing reconfigurable interconnections between various functional units such as processors, memories, and input/output. In these architectures, which we called reconfigurable it is now possible to improve performance by enhancing data parallel processing by partitioning each processor of the array into several small-size processors, minimizing the communication times between memories and processors by establishing direct processor-memory interconnection networks, establishing different topological configurations such as star, closely connected graph, pyramid, binary tree — in multimicrocomputer networks, depending on the structure of the executing algorithm.

With the advent of VLSI chips with high throughput of on-chip architectures it now becomes possible to reconfigure not only interunit but also intermodule connections (Kartashev *et al.* 1979). As a result, the hardware resources available can be redistributed among programs computed by the same hardware. This can be accomplished by partitioning the system's resources into a number of independent computers that match the number of program streams required. Such architectures are called *dynamic*.

A properly designed modular architecture can perform all three classes of adaptation mentioned above. The architecture can reconfigure interconnections on a microlevel, accomplishing microprogrammable adaptation. It can reconfigure on the level of separate functional units performing a reconfigurable adaptation, finally it can reconfigurate on the level of separate modules, performing a dynamic adaptation.

By means of these enriched architectural adaptations to algorithms it is possible to switch the system architecture to those states that match the peculiarities of computed algorithms. This dynamic match between the algorithm and architecture *results in an additional performance gain from the same resource.* But it is possible only with use of specialized high density multipath, modifiable interconnection networks realizable only by means of VLSI technologies.

The adaptable computing systems will therefore be capable of adaptation to:

- instruction and data parallelism
- different types of computations (by dynamic self-reconfiguring into array, pipeline, multi-computer and multiprocessor system)
- different program structures and languages

Such adaptations will not be confined only to processing nodes of a distributed computing system but will be extended in the near future to local and geographically distributed networks. At present there are experiments with adaptable distributed computing systems having thousands of microcomputers, in the near future so-called cellular architectures are being projected containing millions of microcomputers and special reconfigurable interconnection networks (Siegel *et al.* 1979).

Construction of adaptable architectures however cannot be feasible without deep understanding and implementation of protective redundancy, i.e., diagnosis and reliability aspects at all levels of system architecture, with special attention to diagnosability and reliability of interconnection networks, communication protocols and reliable task reallocation algorithms design.

It may be concluded that both aspects of the evolution of distributed computing systems of the future cannot be considered separately. We may expect beginning of extended use of highly reliable and adaptable distributed computing systems in late eighties. Their influence will however be so great — from the point of view of performance and functional capabilities given to the users — that a new generation of computer age will begin — age of computer intelligence. This extension will be described in the next section.

2. TOWARDS INTELLIGENT DISTRIBUTED COMPUTING SYSTEMS

Application of high-speed technologies of VLSI structures, new architectural design approaches enabling to construct highly reliable (performable) and adaptable distributed computer systems are substantial for new information processing tasks for future business, scientific, and social activities. Examples of office automation utilities which these systems are to contain will include (Duda and Gasching 1981):

- capabilities of processing and semantics interpretation of natural languages
- irregular or nonfixed job processing systems capable of freely handling non-numerical data such as documents, graphics, images and speech
- consultation and expert support having inference and learning mechanisms of their own and capable of storing knowledge and providing adequate information as desired
- various data bases for providing high-level information necessary for decision making and machine interfaces supported by artificial intelligence technology for making and supporting decisions.

The computing systems will be capable of converting the incomplete description into a complete description (Jain and Haynes 1982) using knowledge about problem domains and to generate an answer to the description. At this time, operations such as effective utilization (inference) of the knowledge about problem domains and storage (learning of new knowledge are effected). The generated answer will then be converted into a summarized answer by removing unnecessary self-evident information. Thereafter this summarized answer is converted by the interactive system into an internal expression, which in turn is converted into an understandable external expression. In this way one conversational cycle is completed. During this cycle, a management system oversees a variety of knowledge bases used in effecting common operations of inference and learning.

In traditional terms, the knowledge-based management function is characterized as being equivalent to an integration of main memory, virtual memory facilities and a file system. This function is to be capable of retrieving within several seconds a knowledge-base required for inference. A main database system supporting this is expected to have a capacity of 100G to 1000G bytes.

The problem solving and inference function can be regarded as equivalent to the central processing unit of a traditional computer. Its maximum performance target is 100M to 10G logical inferences per second — that is, inference operations of syllogism per second. One such operation is assumed to be equivalent to approximately 100 -1000 instructions on a conventional computer. Such a computational capability is evidently unfeasible by one processor. Such processor is physically impossible to construct. So *it must be replaced by a network of thousands of processors (computers)* working concurrently and the overall system is *dynamically adaptable* to the structure of workload. Thus ultra high speed adaptable distributed architectures with high reliability are justified and are the only (hardware) solution to practical design of the systems described.

Construction of such "supersystems" will have to be preceded by large *standardization* and *compatibility* efforts so that it may be possible to build user tailored systems economically. This standardization must be based upon preservation of high reliability requirements so that quick recovery can be ensured in the environment of ultra high speed computations when error damage effect spread very quickly.

Among the other features belong (Martin 1981):

- making distance transparent to the users
- fault transparency to the users
- security, cryptography
- office of the future intelligent support
- flexible restructuring due to standardization and compatibility during application evolution

Generally —the systems under discussion will break through the barriers of man-machine communication inefficiency and will sift and distile (by principles of information relaxation, abstraction) the information available and present it in an optimum form *for human assimilation*. It will however require equal developments of software techniques based on results of the theory of artificial intelligence.

3. STRUCTURE AND BEHAVIOR OF COMPLEX HUMAN ORGANIZATIONS IN RAPIDLY CHANGING ENVIRONMENT

So far we have discussed related aspects of future intelligent distributed computing systems and necessary bases for their design, the bases that are new and being developed at present.

Now let us consider the topic of this paper: impact of intelligent distributed computing systems application on structures and behavior of complex human organizations which have to face rapidly varying influences of their environment and which must rapidly *adapt*, *restructuralize*, *reconfigure* to maintain their "value," and their purpose. We eliminate from our study organizations with relatively simple structures and those having relatively stable environment and secured long term activity plans. Before we try to formulate some new, future qualitative aspects of such organizations, it is necessary to analyze general structures and behavior of human organizations.

3.1 Structural Aspects of Complex Organizations

From the modern system theories of human organizations structures follows that they consist generally of five basic subsystems (Mintzberg 1979): the operating core ensuring collecting (production) inputs, transforming inputs to outputs, distributing the outputs, and carrying on various maintenance activities; technical subsystem (technostructure) of analysts and other personnel; middle line managers, support administrative staff (the three former categories are often called "middle level") and strategic apex — the leadership carrying on main supervision (upper level), developing strategies of the whole system and its relations with environment.

Internal activities of a complex organization are coordinated by several mechanisms: mutual adjustment, direct supervision, and various forms of standardizations (skills, processes, outputs). Mutual adjustment is the least formal and natural form of coordination of activities and becomes one of the essential factors for successful organizations as their complexity increases.

A complex organization is also a collection of internal flows: flows of formal authority, maintaining hierarchical structures, dynamically changing regulated flows of work operations, control information for middle and upper level (management information system — MIS) and decisions, flow of staff information (among members of middle level) and very important flow of informal communication again being natural and thus important in complex organizations and in their critical situations.

In real functioning organizations especially at present, utilizing computing support, managers tend to build their own information systems, selectively bypassing implemented MIS, relying on a certain degree of informal communication and forming "constellations" of individuals who work on decisions appropriate to their own level in the system hierarchy. This is substantial attribute of complex and adaptable organizations.

From the point of view of tasks, missions to be fulfilled, working "groups" are formed. The formation is based on knowledge and skill, on work process, on output product (client), on market targets, on place where the task is done, on function assigned. At the same time, vertical and horizontal specialization is necessary with optimal depth and width.

As substance of a mission change, a complex organization must more or less formalize its internal activities by applying predetermined rules and standardizations. The more such formalization the less adaptable in the organization to sudden changes in its environment, the more bureaucratic it is. The highest degree of formalization can be generally formed in the operating core. At strategic apex, contacting the environment, more flexibility must be ensured, the structure is more *organic*. (Burns and Stalker 1966). In general, as goals and missions of an organization change, internal restructuralization is initiated from the top down, as the technical system of the operating core changes, it proceeds from the bottom up. At the same time spans (scopes) of control of managers change from flat (wide) to tall (narrow) and vice versa.

Complexity and interdependencies of tasks strongly determine internal interdependencies in an organization, among internal activities (processes), work flows, scopes of control and in social sphere. The more interdependent structure of tasks, the higher increase in mutual adjustment and internal communication to achieve required coordination that cannot be fully supported by direct supervision and standardization.

Any modern complex organization cannot realize its mission without *supporting*, encouraging informal contacts by creating a variety of liaison devices (Mintzberg 1979, Galbraith 1973) allowing to bypass vertical and horizontal channels. Examples are direct contacts among specialists who share a problem, task force meetings, etc. They form one of the key mechanisms enabling quick adaptation of an organization to change in environment. The extensive use of them is characteristic in organizations where work is horizontally specialized, complex, with many parallel and highly interdependent subtasks. The liaison devices are most frequent in the middle level of organizations.

An organization (or subsystems of an organization) solving complex and highly interdependent tasks require utilization of specialized resources in an environment that requires integration of programs. Therefore the organization needs greater integration of specialized resources. In this case modern organizations introduce *matrix structures* based on dual authority relations. Such structures can be relatively permanent, where the interdependencies become more or less stable, or "shifting," geared to project works, where the interdependencies, groups and people in them shift around frequently. Organizations designed to handle unique or custom tasks base specialists in functional groups for "housekeeping" purposes but deploy them into task forces for operational purposes (Thompson 1967). It seems at present that matrix structure is one of the most effective for developing new activities and for coordinating complex multiple interdependencies.

Effective structuring of organizations requires a consistency among their design parameters and situational, *contingency factors* (Galbraith 1973) as the *age and size* of organizations, their *technical subsystem used* in their operating core, external power influences (this factor is not subject to our analysis) and various aspects of *environment*, notably stability, complexity, diversity, and hostility. In another words, the successful organization designs its structure to match its situation, maintaining internal consistency among the structure design parameters. For instance, comprehensibility of work determines intellectual load on the organization which influences most strongly its design parameters of specialization and decentralization. Degree of predictability of work has greatest influence on three design parameters that correspond to the three forms of standardization — behavior formalization, planning and control and training. Work diversity influences organization's choice of its bases for grouping as well as its ability to formalize behavior and use of liaison devices.

From observations of organizations (Thompson 1967) follows that the age of organization reflects in relatively more formalized behavior; the larger the organization the more elaborate its structure — the more specialized its tasks the more differentiated its groups and the more developed its administrative component. The growing size of an organization requires development of informal communications, organic structure and use of liaison devices to preserve its adaptability, particularly, use of matrix structures. It seems to be a present trend for such organizations.

As far as technical subsystem of an organization is concerned it the age of automation, an interesting general observation can be made: automation appears to place an organization to a state where the technical subsystem in the operating core is fully regulating (but of machines not so much the people), while the social relations — largely outside the operating core — need not be controlled by formal rules and so can emerge as an organic structure, using mutual adjustment among the experts, encouraged by the liaison devices to achieve coordination. So the automation in the operating core seems to transform a bureaucratic administrative structure into more adaptable, organic one.

Now, let us focus our attention on influences of environmental factors.

3.2 Structures of Complex Organizations and Their Environment

The *environment* comprises virtually everything outside the organization —its "technology" (i.e., the knowledge base it must draw upon), the nature of its products, customers and competitors, its geographical setting, the economic, political and even meteorological climate in which it must operate and so on. We however focus on certain factors only, on four already mentioned in the previous section, i.e.,

- *Stability* —An organization's environment can range from stable to dynamic, from the organization that has customers demanding the same product decade after decade to that one which never knows what to expect next. A variety of factors can make environment dynamic: unpredictable shifts in the economy, unexpected changes in customer demand, rapidly changing technology, etc. Dynamic environment means uncertainty and unpredictability for the organization's work.
- *Complexity* — An organization's environment can range from simple to complex, from that of the manufacturer of folding boxes who produces his simple products with simple knowledge to that of the space agency which must utilize knowledge from various most advanced scientific fields to produce extremely complex outputs. In other words, an environment is complex to the extent that it requires the organization to have a great deal of sophisticated knowledge about products, customers or

whatever. It becomes simple, however, when that knowledge can be rationalized, that is, broken down to easily comprehended components.

— *Market diversity* — The markets of an organization can range from integrated to diversified, from that of an organization that sells its one product to one customer to an organization that seeks to promote all of a nation's individual products all over the world.

— *Hostility* — Finally, an organization's environment can range from munificent to hostile, from a prestige organization that chooses its clients, through that of a firm that must bid on all its contracts. Hostility is influenced by competition, by availability of resources to it, etc. Hostile environments are typically dynamic ones. But it is convenient to distinguish it because extreme hostility has a special effect on a structure.

Important general observations concerning influences of environment factors on structures of organizations are summarized below (Mintzberg 1979):

— *The more dynamic the environment, the more organic the structure.* In a stable environment an organization can predict its future conditions and so, all other things being equal, can easily insulate its operating core and standardize its activities there — establish rules, formalize work, plan actions — or perhaps standardize its skills instead. But this relationship also extends beyond the operating core. In a highly stable environment, the whole organization takes on the form of a protected or undistributed system, which can standardize its procedures from top to bottom. Dynamic conditions have more influence on structure than static ones — a dynamic environment will drive the structure to an organic state no matter what its age, size, or technical system.

— *The more complex the environment, the more decentralized the structure.* There are two kinds of bureaucratic and two kinds of organic structures, in each case a centralized one for simple environment and a decentralized one for complex environment.

— The more diversified the organization's markets, the greater propensity to split it to market-based units.

— *Extreme hostility in the environment drives any organization to centralize temporarily* no matter what other contingency factors are present.

No organization has ever existed in an environment uniformly dynamic, complex, diverse, or hostile across its entire range. So we may conclude that real organizations must handle these factors simultaneously, they differentiate their structures to create work constellations to deal with different aspects of the environment (different "subenvironments"). Each constellation is located according to the impact of its subenvironment on the organization, *near the top if the impacts are universal, farther down if they are local.*

3.3 Environmental Factors and Flows of Information in Organizations

In this paragraph we shall analyze impacts of environmental factors on internal flows of information in a general complex organization.

The simplest method of coordinating interdependent subtasks is to specify the necessary behaviors in advance of their execution in the form of rules or programs. In order to make effective use of programs the organization's employees are taught the job-related situations with which they will be faced and behaviors appropriate to those situations. If everyone adopts the appropriate behavior the resultant aggregate response is an integrated or coordinated pattern of behavior. The use of rules and programs as coordination devices is limited, however. It is limited to those job related situations which can be anticipated in advance and to which an appropriate response can be identified. As the organization faces new and different situations, the use of rules must be supplemented by other integrating devices.

As the organization encounters situations it has not faced before, it has no ready-made response. When a response is developed for the new situation it must take into account all the subtasks that are affected. The information collection and problem solving activities are substantial. To handle this task new roles are created, managerial roles and arranged in a hierarchy. The occupants of these roles handle the information collection and decision making tasks necessitated by uncertainty. Then as unanticipated events arise, the problem is referred to the manager who has the information to make a new decision. That is, the new situation, for which there is no preplanned response, is referred upward in hierarchy to permit the creation of a new response. *As task uncertainty* *increases the volume of information from the points of decision making overloads the hierarchy. In this situation it becomes more efficient to bring the points* of *decision down* to the points of action where the information originates. This can be accomplished by increasing the amount of discretion exercised by employees at lower levels of the organization. However, as the amount of discretion exercised at lower levels of the organization is increased, the organization faces a potential behavior control problem. The organization can improve the situation by increasing professionalization and partial goal setting (planned targets). However, as the uncertainty of tasks still increases, decisions must be made and remade each time new information is discovered. The information channels become overloaded again.

The organization must adopt a strategy to either reduce the information necessary to coordinate its activities or increase its capacity to process more information. There are generally four such strategies (Galbraith 1973):

— An organization core reduce the number of exceptions to be handled by simply *reducing the required level of performance.*

— The second method for reducing the amount of information processed is to *change from the functional task design to one in which each group has all resources it needs to perform its task.*

— The organization can *invest in mechanisms and information processing systems* which allow it to process information acquired during task performance without overloading the communication channels.

— The last strategy is to *selectively employ lateral decision processes which cut across lines of authority i.e., liaison devices.* The strategy moves the level of decision making down to where the information exists rather than bringing it up to the points of decision. *It decentralizes decisions but without creating self- contained groups.*

The organization must adopt at least one of the four strategies when faced with greater uncertainty. If it does not consciously choose one of the four, then *the first*, reduced performance standards, *will happen automatically*. (Uncertainty is conceived as the relative difference in the amount of information required and the amount possessed by the organization). Selection of a balance among appropriate strategies depends on decision frequencies or timing of information flows to and from the decision mechanism, the scope of database available to it, on the degree of formalization of the information flows to and from the decision mechanism, the capacity of the decision mechanism to process information and select the appropriate alternative. However practical analysis again shows that application of liaison devices to solve problems of information overload is very important in facing dynamic environment, especially matrix structures, when multiple authority can be advantageous in proper decision making.

4. DYNAMICS OF STRUCTURES AND BEHAVIOR OF COMPLEX HUMAN ORGANIZATIONS IN RAPIDLY CHANGING ENVIRONMENT — SELECTED ATTRIBUTES AND PROBLEMS

Let us now try, from our point of view, to summarize and extrapolate the most important properties of an abstract complex organization in very quickly changing environment.

We assume primarily highly dynamic environment, being further highly complex, ill-structured (highly and irregularly interdependent), and diversified. In other words, such an organization faces tasks being extremely complicated and directions of their solutions cannot be planned or scheduled in advance and furthermore their mutual interdependencies are irregular. So there is a high degree of uncertainty the organization must face.

From the preceeding two sections and under the assumption above, we can logically *formulate the following properties:*

- The organization must rely on mutual adjustment as a primary coordinating mechanism. It therefore must use all the spectrum of liaison devices, informal communications among managers and experts and have generally matrix structure. The structure must be organic, flexible to allow for facing highly dynamic environment.
- As a result of high complexity of the environment we may expect that its structure is highly decentralized. This decentralization is random but selective, according to strength of various disparities of the environment.

- High degree of decentralization breeds high degree of horizontal specialization which in turn requires a sophisticated (and very complex) information flow network in the organization.
- The information flow network must support full utilization of liaison devices and matrix structuring, dynamic creation of teams, integrating positions and work constellations for problem solving and decision making under uncertainty, at all levels of organization hierarchy.
- The operating core of a modern organization is expected to be highly automatized and therefore its control does not require much attention. With the development and implementation of computerized production control, industrial robots, microprocessors, etc. we may expect this property as more and more substantial. Automatized can be not only (more or less routine) production but also design and engineering processes in all their phases. The operating core is thus becoming more and more independent in the sense that people can devote much more time to creative thinking, decision making and strategy planning, leading back to sophistication of production processes.
- The organizations cannot exactly plan their activities, they cannot create exact action plans but only guidelines for work constellations being permanently redefined by the process of trials and errors. Furthermore, the control and strategies formulation cannot be placed only at strategic apex. It is dispersed throughout the middle level, too (De Greeene 1982).

- Managers must play roles not only functional but also integrating, projects oriented and negotiating and laterally coordinating. Direct supervision is no longer their primary task. They must intelligently regulate flow of information.
- To maintain high degree of selective adaptability to changes in the environment, the organization must be internally reconfigurable to subsystems with different degree of formalization, hierarchical and information flow structure as well as decision making. The organization possesses dynamically adaptable hybrid structure.
- The dynamic strategy and guidelines changing together with handling problems of internal structure reconfiguration matching the problems being solved are the main activities of not only strategic and middle level but also of operators supervising automated operating core. Middle level managers are even members of project teams together with experts.
- The organization must develop sophisticated and quick system of training of its employees so that they can be shifted among various projects and problem solving activities and be prepared to work in changing teams with different "communication protocols."

It is evident, from the description above, that the organizations have to face several *potential* and serious *problems*:

- High cost of communication because of high complexity of internal communication flows, high frequency of communications and necessity of their dynamic reconfigurations and adaptations to effective control and decision making. The high cost is influenced also by efforts towards maintaining high reliability of communication.
- High cost of decision making — this problem is caused not only by a high degree of uncertainty (e.g., due to ill-structured problems) but also by the necessity of dynamical arrangements of meetings and decision groups and their coordination.
- The organization in highly changing environment has problems of assignment and balancing workloads among dynamically created work constellations, which may evoke unstability. This could be avoided by introduction of formalization (bureaucratic structure) but it would not reflect aspects of changing environment.

5. IMPLEMENTATION OF INTELLIGENT DISTRIBUTED COMPUTING SYSTEMS — IMPACTS ON STRUCTURE AND BEHAVIOR OF COMPLEX ORGANIZATIONS IN THE FUTURE

Under the assumptions and arguments in the last paragraph we may try to formulate impacts of intelligent distributed computing systems.

- Distributed computing systems give full and overall support to mutual adjustment mechanisms and form a technical background to utilization of the whole scale of liaison devices. Because the systems will be adaptable, they can be *dynamically* *tailored* to support the immediate requirements of changing structure of liaison devices.

— The distributed, decentralized and adaptable nature of the systems fully complies with the request of high and selective decentralization of organization structure. Possibility of adaptive distribution of computing resources (power) complies also with the requirements of high degree of horizontal specialization.

— Adaptability of computational requirements and high reliability ensures dynamic logical creation of reliable communication networks according to momentary information flow demands in the internal structure of an organization. Knowledge processing enables at the same time to control information aggregation and relaxation thus helping to prevent information overload of information channels.

— Use of distributed knowledge processing together with the possibility of dynamic reallocation of processing power helps to create strategies and guidelines for work constellations which are dynamically formed and dissolved. It supports dispersed decision making at various levels of structure and substantially contributes to maintain its overall integrity. This in turn can solve the problem of structure instability under varying workloads. Distributed knowledge processing further reduces costs of distributed decision making.

— Utilizationg of other future information communication aids (such as teleconferencing) together with intelligent distributed computing systems with give emergence to qualitatively new groups — we may call them *cooperative man- machine problem solving and decision making groups*, without respect to geographical distances. Distributed knowledge processing capabilities will enable *overlapping* of information scopes of groups or individuals at the middle level and strategic apex. This is necessary for dynamic regrouping and *mutual substitution* of decision makers and moreover for *"fault- tolerant" decision making*, because overlapping of information scopes enables to create multiple variants of decisions and multiple verification of the selected one and its further refinement in dynamically changing structure. Cooperative decision making is more reliable and reduces complexity of information flows.

— Utilization of powerful communication facilities of intelligent distributed computing systems enables to use another qualitatively new approach to dynamic decision making and problem solving — *contractation cooperative approach*. Manager sends a description of his problem to be solved to distributed network, other participants (managers, groups) can "hear" it and respond rapidly with a contribution to the solution when it is relevant to them.

Another powerful form of cooperation that can be dynamically utilized is possibility of selective *sharing relevant partial decisions* of the other managers. This contributes to rapid assessment of various complicated situations.

In general, cooperative decision making and problem solving in the sense, that managers or experts form cooperative groups *with help and together with* intelligent distributed computing systems, is a powerful instrument enabling to further reduce and coordinate information flows in complex organizations and thus helps to eliminate problems discussed in Section 3.3.

— Implementation of intelligent distributed computing systems gives full possibilities to utilize *computer aided education and instruction*. It is substantial for dynamic dissolving and formation of new work constellations which is, as stated above, important factor of structural adaptability to dynamic environment.

— Intelligent distributed computing systems will implicitly support dynamic analysis of failures in decision making and problem solving, in communication channels especially during quick dynamic reconfigurations of information flows because of own sophisticated hardware and software redundancy and self-checking facilities.

— Under severe internal or external influences, the organization must temporarily centralize its structure to respond to the situation quickly and possibly by changing overall structure. Necessary concentration on the problem solution requires also increased intelligence power of adaptable distributed computing system which can be temporarily centralized, too.

If we carefully examine the observations in this paper, we can conclude: *The adaptability nature of distributed computing systems will* *enable to dynamically create and maintain high degree of structural correspondence between the morphology of a human organization and the computing system itself. The stronger this correspondence the higher degree of man- machine cooperation, the higher viability of the organization in rapidly changing environment.*

6. CONCLUDING REMARKS

First we attempted to describe structural view of adaptable distributed computing systems and their properties as high reliability, extremely high computation power, properties that are determined not only by characteristics of VLSI building blocks but also implicitly by network, cellular architectures with possibility of regrouping individual "cells" (processing elements) to the most suitable working subsystems according to requirements of tasks. The subsystems can cooperate and thus form a hybrid cooperative architecture capable of dynamic reconfiguration and change of the degree of cooperation. This nature is the base for emergence of intelligent adaptable distributed computing systems.

Then we attempted to analyze structural and behavioral changes in human organizations in rapidly changing environment. We found out that classical, static, distributed computing systems with poor abilities of processing reallocation cannot fully support such organizations because their internal structure is extremely dynamic. We therefore concluded that such organizations have to be equipped by adaptable computing facilities to utilize the most powerful tool — cooperative man-machine groups, constellations and to overcome fatal problems of survival.

Examples of organizations facing primarily dynamic environment can be found directly in research institutions. Impacts of computer systems utilization can be observed *especially in research institutions in computer industry* because they face many unpredictable problems and, at the same time, *they know best how to utilize computing facilities*. They may serve as objects of further studies from the point of view of systems analysis, decision theories as well as technologies impacts assessments.

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