



Project Coll-Plexity: Collaborative Complexity – Collaborations as Complex Systems Project is co-financed by NEST Programme, FP6, under Contract no. 12781

## The Coll-Plexity Project

The abstract of the original proposal has read as follows:

**F**ailure rate in collaborations in production industry is more than 50%. Major reason for it is the lack of problem-oriented understanding of the required systems set-up and underlying control mechanisms. Academic research in management science has expanded on models accounting for the individual company as an entity. Complementary approaches to address the characteristics of enterprise-networks are therefore required.

This project will move away from existing approaches to collaboration and targets the interdisciplinary development of a generic model of complexity as basis for a problem-to-system match framework for

collaborative systems in production industry. The on-going specialisation and differentiation indicates the need for a more dynamic approach to describe the development of collaborations and their exploitation. Starting point of research is the understanding of collaborative enterprise networks as complex systems that can only assure their viability through adaptation in inter-organisational networks.

more information is available at our website-

[www.coll-plexity.net](http://www.coll-plexity.net)

The project's interdisciplinary research approach is the application of principles of complex systems theory from natural sciences to collaborative enterprise networks as socio-technical systems. Within the scope of the research these

contributions have been identified and combined into six themes: dynamic description, coordination possibilities, radical/integrative innovation, path dependency, information sharing, modelling & representation. This project will expand the available knowledge on the underlying mechanisms of collaborations by the acquisition of knowledge on complexity science (a field of science poorly present in the EU's scientific base), new perspectives on collaboration avoiding traditional pitfalls (culture, leadership, trust) by using models from natural science, and an integrated approach of science and industry working together.



# Editorial

We are pleased to launch the Project Newsletter and to have you one of our first subscribers to it. We shall attempt to produce this Newsletter every quarter or so.

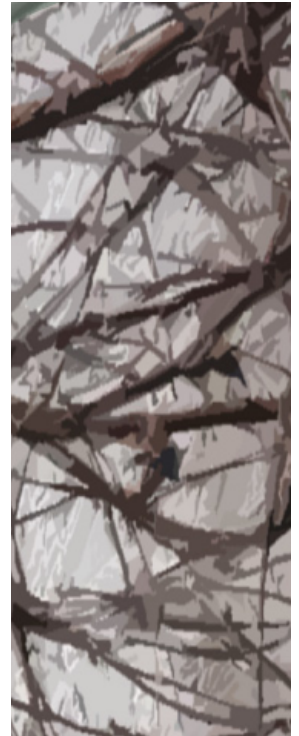
The content of the newsletter, as we have envisaged it, includes news about the project and theoretical contribution which pertains to the overall subject-matter of the project, namely, complexity in management or even more particularly: management in environment characterised by complexity based networks.

The project aims at the better understanding of such environments and solutions of problems arising from them. Our first premise is that management requires the consideration of numerous variables, some of which are highly intangible, like culture, environmental atmospheres, political and regulative conditions etc. To tackle problems of management in today's complex environments, it is necessary to create a model that would allow the contribution of such elements. Project "Coll-Plexity" is indeed about this.

We shall value your comments and contributions and we shall be happy to send the Newsletter to such people and organisations that you would be so kind to recommend.

You are always welcome to contact me directly, at my E-mail: [benasher@global-financing.net](mailto:benasher@global-financing.net) or by telephone: +972-54-6848845

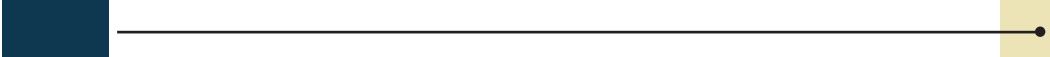
Prof. Zohar Ben-Asher, Editor  
Global Research & Financing



## Inside this issue

Pre-Survey: complexity-related problems	2
Workshop: the basic premise	3
Work Package 2: Multi-disciplinary hypotheses	4
Industrial application of VITAL results	5-6
Design of COMPLEX ADAPTIVE SYSTEMS	7-9

## Work Package 0: Pre-Survey: complexity-related problems



The pre-survey is the first work package in the project. It has been conducted by a team of University of St. Gallen (Switzerland), headed by Prof. Thomas Friedli assisted by Ms. Julia Kotch. The survey explores major complexity-related problems faced by the responding companies, concerning design and management of their collaborative networks. The expected results will shed light on aspects concerning variety and diversity, dynamics, dependencies, environmental uncertainties, design-oriented criteria, collaboration framework and the use of the IT-systems. In this manner the pre-survey will lay a broad foundation for initial understanding of what complexity really means to networked producing companies.

This section of the pre-survey focuses, in the main, on European middle and big producing companies from such industry sectors as automotive, mechanical engineering, electronic and pharmaceutical. Since these industrial sectors are heavily organized in networks (e.g. supplier networks, R&D networks, etc.) it is likely to successfully address relevant target group. The quest of COLL-PLEXITY to use of interdisciplinary know-how is answered by the accentuated focus of the other part of the survey on cultural and managerial behaviour issue. This part is carried out among high technology companies by a team from Global Research and Finance (GRF) of Israel, led by Prof. Ben Asher.

Data is collected by means of online questionnaire, to be distributed by all consortium partners. This will enable to get in touch with more managers and more industries so as to get a first broad overview about the main issues in the practical discussion. The results obtained will be analysed carefully and become raw material for the development of a generic model of complexity, which is the prime objective of the project, to be done in coming work packages.

The results of the pre-survey will also be important inputs to following work packages. Firstly, they will be used in the workshop meetings with industry partners and the researchers of WZL in the stage of the expert interviews. In this sense they will influence the modelling activities of work packages 1, 3, and 4. Apart from this, discussions between partners about respective findings will contribute to synchronisation of experience, expectations and available industry and research knowledge.

# Work Package 1 - Workshop: the basic premise

WP1 aims at the development of a comprehensive descriptive model of problems in network setup and management of collaborative R&D, particularly in manufacture. To this end, workshop is to be organized, together with the industrial partners. As preparatory work, relevant problems pertaining to R&D collaboration and other related issues should be identified and classified. This, of course, requires some identification and classification of the elements of the problems .tackled which would be, of course, their determinants

The survey done in WPO should offer us a thorough analysis that will have been completed by the expert interviews and the pre-survey, prior to the workshop. This will be put to test at the workshop, where our industrial partners could scrutinise the "expert analysis". The synthesis emanating from the workshop will become a significant contribution in the creation of the descriptive model, aiming at structuring of the problems associated with network based complexity as manifested in collaborative production and R&D. It is hoped that this model will offer solution for classifying .identified problems within a scientifically valid structure



The model developed allows two different views on complexity problems, as represented in the following figure:

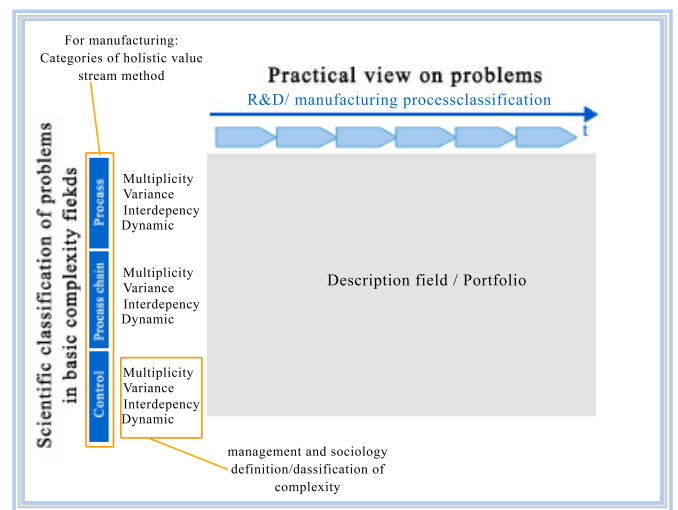


Figure 1: Problem description model

Practical view of problems (x-axis) R&D and manufacturing processes in industry can be classified in sequential structure. R&D projects can be said to schematically be organised in a sequel of idea, proposal, design, design verification, product validation and production. Manufacturing processes can be divided between production system design phase and production system operation.

Scientific view on problems (y-axis) Identified complexity problems are categorised into scientific classification model. The problem description model supports the holistic definition of complexity as described in management and sociology literature. Here such parameters as multiplicity, variance, interdependency and dynamic enter the complexity paradigm as major drivers, along with interdependency. This can assist in analysing such complex phenomena as time loss between production processes, etc.

## Work Package 2: Multi-disciplinary hypotheses drawn from network and complexity research

The aim of this work package is to construct a generalised model of system complexities out of existing multi-disciplinary network theories.

At the basis of the model, common understanding of "complexity" must be developed. To this end, definitions from various sciences will be considered. However, some main aspects - and common grounds - have to be considered within each science. A brief description must be produced, of the development of the science-specific complexity and its current standing. From this, different properties of the specific understanding of complexity can be elaborated. In researching complexity, the main focus should be on identifying the parameters used to define complexity, e.g., kind and number of elements, their interrelations or the system's dynamic. The definition of complexity within the project will emanate from this, affecting other WPs. WP1 will be assisted in as much as assignment of actual verification of the level of complexity any given reality problem should be assigned. WP2 will benefit in its classification attempts of theoretical approaches examined, showing the extent to which they contribute to actually respond to complex problems in reality.

WP2 is, in the main, a multidisciplinary desk research on existing theories, models and approaches to complex systems. Their synthesis should be able to contribute to the construction of a Generic Model of Complexity (GeMoC). This effort has been divided into several parts and allocated to the scientific project partners. Each partner summarises the theories, models and approaches corresponding to his assigned fields of science. A short summary of the considered theories is shared as well as a comprehensive description on a project server. This will on the one hand help to avoid that some partners are working on the same theory that is related to more than one science, on the other hand it provides a continuously review process within the consortium. The resulting synthesis will be reviewed and evaluated in terms of its contribution to GeMoC in designated workshops, with the more successful amongst them making up the corner stone to GeMoC.

## Industrial application of VITAL results

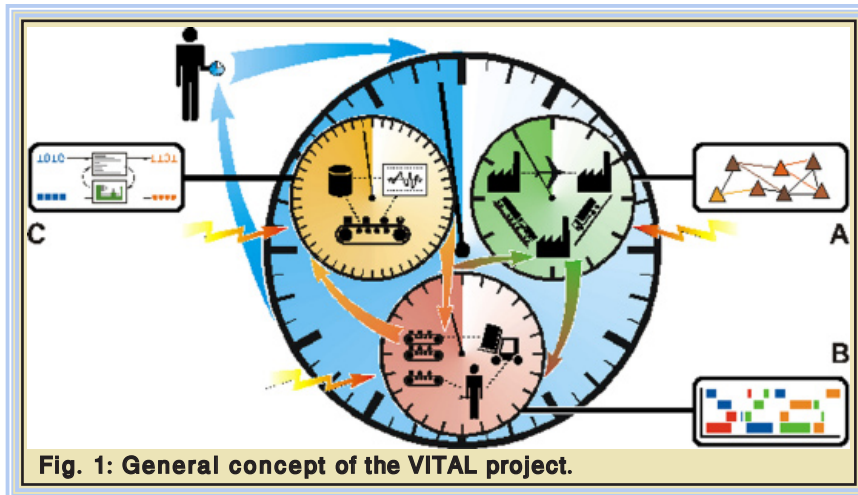
One of the most important trends in manufacturing is manifested in the paradigm of *customised mass production* (at a price near to the level in mass production of customised products) Project *VITAL: Real-time Co-operative Enterprises*, led by Coll-Plexity partner *SZTAKI*<sup>1</sup> aims at the development of IT-solutions for enterprises producing mass customised products and working in networks. Other issues to be dealt by the project include globalisation & increasing competition in frequently changing uncertain environment; increased complexity in production processes, manufacturing systems and enterprise structures and autonomous, partly competing - partly cooperating production structures.

The challenges and the answers offered by VITAL can be summarised as follows:

<b>Challenges</b>	<b>VITAL's answers</b>
Complexity	Autonomy & cooperation
Changes and disturbances	Intelligence
technical-economic solutions	Integration & optimisation
Quick reaction ability	Real-timeness

The project is set to research and develop new methods for the real-time management of complex technical and economic systems that work in changing, uncertain environments. Since the methods come from various, novel areas of informatics, operational research and knowledge-based systems, their integration balances optimisation, autonomy and cooperation.

The project seeks solutions originating at the level of production networks, through single enterprises to production lines, which can ensure optimal / near-optimal behaviour of the entire system, in real-time fashion required by the level of production. The following figure represents the general concept of the project:



Orders are to result in good quality, at the agreed price and on *time*. The customers may not necessarily realise that in fact, they deal with a number - at *time* large of production networks. The importance of the time is illustrated by the watches in the figure, which relays the different levels (network, enterprise, production line) of the production expected to react on the external and internal changes, demands and disturbances (indicated by the lightning signs) with a *reaction time* corresponding to that of the query. The problems to be solved are as follows:

- Integrated production planning and scheduling (B);
- Real-time production control (C);
- Management of distributed, cooperative systems (A).

This sequence derives from the fact that high-level resource-management and scheduling of enterprises can give the basis, on the one hand, to reliable, optimal or near- optimal management of supply chains and production networks. On the other hand, it allows for handling changes and disturbances on shop floors or production lines.

The SZTAKI developed scheduling system was successfully integrated in the information system of one of the factories (the largest one of such kind in the world) of the main industrial partner. This can be regarded as a highly successful result of the entire project. The automatic scheduling system is in use by the industrial partner - which operates in the field of customised mass production. It handles some 1,000 orders a week for the more than 100 production lines, resulting in some 3,000 pallets of finished goods. The quick reaction time of the system enables it to be a nearly interactive decision support tool. The tool allows better utilisation of the technical and human resources, increase of productivity, better customer service and improved effectiveness of the entire value creation chain.

## Design of COMPLEX ADAPTIVE SYSTEMS: Introduction

### László Monostori & Kanji Ueda

Holland's theory of *Complex Adaptive Systems (CAS)*\* is a new paradigm aimed at the study of the structures, systems dynamics and the question of how adaptability of systems creates complexity. A CAS can be considered as a multi-agent system with seven basic elements in which "a major part of the environment of any given adaptive agent consists of other adaptive agents, so that a portion of any agent's efforts at adaptation is spent adapting to other adaptive agents". The first four concepts of Holland's seven basic elements, aggregation, nonlinearity, flow and diversity, represent certain characters of agents and are very important in the adaptation and evolution process. The other three, tagging, internal models and building blocks, are mechanisms of agents for communicating with the environment.

Environmental conditions change due to agents' interactions as they compete / cooperate for the same resources or to achieve a goal. It changes the behaviour of the agents. CAS reveals the emergence of highly structured collective behaviour over time by the interaction of simple subsystems without centralised control. Typical characteristics of complex adaptive systems include dynamics of interrelated spatial and temporal effects, long length and time correlations, system elements that are both free and non-interchangeable, etc. Both the CAS and its environment simultaneously co-evolve in order to maintain themselves in a state of quasi-equilibrium, i.e., on the edge of chaos\*\*.

Designing CAS involve non-linear phenomena, incomplete data and knowledge, combinatorial explosion of states, dynamic changes in environment, the frame problem, etc. These are merely few difficulties. The central question is realising an artefact system that achieves its purpose in unpredictable conditions. Existing principles, like analysis and determinism will not suffice in approaching problems like this.

A chief concern is if and when completeness of information could be achieved in describing the environment and in specifying the purpose of the artefact-based system. Incomplete information on environment, or specification, can yield 3-class difficulties in synthesis:

- *Class I*: Complete description: if all information concerning the environment and specification is given, then the problem is completely described. However, it is often difficult to find an optimal solution.
- *Class II*: Incomplete environment description: the specification is complete, but the information on the environment is incomplete. Since the problem is not fully described in this case, it would be difficult to cope with the dynamic properties of the unknown environment.
- *Class III*: Incomplete specification: both the environment description and the specification are incomplete. Problem solving, therefore, has to start with an ambiguous purpose and the human interaction becomes significant.

---

\* *Computer and Automation Research Institute, Hungarian Academy of Sciences & Dept. of Production Informatics, Management and Control, Budapest University of Technology and Economics, Budapest, Hungary.*

\*\* *Artefacts Research, Centre for Engineering (RACE), University of Tokyo, Japan.*



Recognised the importance of the synthesis of CAS triggered a series of international workshops on Emergent Synthesis (IWES) starting in 1999.<sup>4</sup> Also, some works relating to the issues raised here need to be mentioned.

Integration of process planning and production control in multi-agent system described by *Tim, Scholz* and Herzog, is based on allowing resource agents to infer about their own capabilities, representing a step to overcome the gap between process planning and production control. The approach introduced referred to ontology-based capability management, enabling the dynamic organisation of agents by subsumption-based match-making within ontologies.

*Valckenaers* et al. presented a design of emergent generation of short-term forecasts in multi-agent coordination and control systems, inspired by food foraging behaviour in ant colonies. A key advantage is the limited exposure of the software agents in the coordination and control system. The approach makes non-local information available without exposing the software agents beyond their local scope. The research team applies this design to multi-agent manufacturing control systems and to supply network coordination systems, but the authors outline its broader applicability.

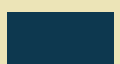
*Csáji, Monostori* and *Kádár* described an adaptive iterative distributed scheduling algorithm that operates in a market-based production control system. Every machine and job is associated with its own software agent. Each agent learns how to select schedules that reduce the search efforts. In order to get adaptive behaviour and search space reduction, a triple-level learning mechanism is proposed. The paper suggests a cooperation technique for the agents, as well. It also analyzes the time and space complexity of the solution and presents some experimental results.

Correlations between problem classes and their potential solutions have been investigated by *Lengyel* and Ueda by presenting a job shop model in a make-to-order manufacturing environment. The problem frame of the control and planning in the model is identified as Class III with solutions based on all three classes.

Methodology for fault-tolerant autonomous multi-robot system (MRS) has been introduced by *Yasuda, Ohkura* and Ueda. They focused on the design of on-line autonomous behaviour acquisition mechanism capable of developing cooperative roles and assigning them to a robot appropriately in a noisy, embedded environment. Reinforcement learning is applied to simultaneously adapting the Bayesian discrimination method for segmenting the continuous state and action spaces. In addition, a neural network is provided for predicting the average of the other robots' postures at the next time step in order to stabilize the reinforcement learning environment. Computer simulations are conducted to illustrate the fault-tolerance of the approach against system changes occurring after the MRS achieves stable behaviour.

Because of the underspecified nature of some Class III problems, a continual human interaction is significant while not always ample. Its coping problems of incompleteness was described by *Kampis* and *Gulyás*. The problem of persistent species evolution in an artificial evolutionary system is treated and the authors argue that a species evolution process can help in addressing design problems, especially, design innovation and in changing function spaces. The simulation technique introduced is based on the theory of "fat" phenotype applied to the dynamic generation of new evolutionary tasks.

It is illustrated that "fat" phenotypes can yield changing interaction spaces to define new selection forces which recursively give rise to new 'species' that solve new selection tasks.



In their paper, Takenaka, Ogata and Ueda describes some cognitive psychological experiments to elucidate human temporal co-creation with environments or other people. Their findings can be considered as the underlying basis of the design for natural temporal communication between human beings and artefacts.

Naturally, production structures can be considered as complex adaptive systems. That is why the ratio of manufacturing applications in the papers selected is high.

Current manufacturing systems work in *fast changing environment full of uncertainties*. Increasing *complexity* is another feature showing up in production processes and systems, furthermore, in enterprise structures, including supply chains and production networks, as well. The complexity of the problem and the associated uncertainties necessitate the application of *artificial intelligence (AI) and machine learning (ML) techniques to get closer to working Intelligent Manufacturing Systems (IMS)*.<sup>5</sup> The further integration of more traditional AI and ML techniques with the agent-based approach in this field is expected to result in systems with emergent behaviour.<sup>6</sup>

According to a recent, comprehensive survey on agent-based systems for manufacturing, the further evolution of multi-agent systems and manufacturing<sup>7</sup> will probably proceed hand in hand: the former can receive real challenges from the latter, which, in turn, will have more and more benefits in applying agent technologies, presumably together with well-established or emerging approaches of other disciplines.

1. Holland, J.H. (1992). *Complex adaptive systems*, Daedalus, Boston, Vol. 121, No. 1, pp. 17-30; Holland, J.H. (1995). *Hidden order: How adaptation builds complexity*, Helix Books, Addison-Wesley, New York.
2. Waldrop, M. (1992), *Complexity, the emerging science at the edge of order and chaos*, VIKING, Penguin group, London
3. Ueda, K., Vaario, J. (1998). *The Biological Manufacturing System: Adaptation to growing complexity and dynamics in manufacturing environment*, CIRP - Journal of Manufacturing Systems, Vol. 27, no. 1, pp. 41-46; Ueda, K., Márkus, A., Monostori, L., Kals, H.J.J., Arai, T. (2001). *Emergent synthesis methodologies for manufacturing*, Annals of the CIRP, Vol. 50, No. 2, pp. 535-551
4. Ueda, K. (1999). *Synthesis and emergence*, Proceedings of International, Workshop on Emergent Synthesis, IWES 99, Kobe, pp.7-12; Ueda, K., Monostori, L., Márkus, A. (2004). *Proceedings of the 5th International Workshop on Emergent Synthesis, IWES'04, May 24-25, Budapest, Hungary, (as Editors) p. 147. Emergent synthesis concepts for tool management have been analysed and discussed in the paper of Teti and D'Addona where the design and functioning of Flexible Tool Management Strategies (FTMS) were illustrated. The FTMS paradigms have been proposed as dependable and robust tool delivery time forecasting methods, founded on knowledge evolution, for the solution of this synthesis problem belonging to Class II. The methods are integrated in a multi-agent tool management system as domain specific problem solving functions of the agent responsible tool inventory sizing and control*
5. Monostori, L. (2003). *AI and machine learning techniques for managing complexity, changes and uncertainties in manufacturing*, Engineering Applications of Artificial Intelligence, Elsevier, The Netherlands, Vol. 16, No. 4, pp. 277-29
6. Ueda et al. (2001); see above
7. Monostori, L., Váncza, J., Kumara, S.R.T. (2006). *Agent-based systems for manufacturing*, Annals of the CIRP, Vol. 55, No. 2. (to be published)