

COMPLEXITY Section

INTELLIGENT ENTERPRISES – A CAPABILITIES ORIENTED MODEL

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Abstract. *The present requests for the enterprises competitiveness and survival determine the necessity for its development as intelligent systems able to respond to the complexity of problems to be solved, and of conditions to be fulfilled imposed by the globalism and expansions of our world. To use only the IT&C solutions becomes insufficient if the enterprise, itself, has not corresponding capabilities to adapt and to evolve such that its responses (i.e., products and services) satisfy the society, markets, and to support its positive existence.*

From these point of views, in the present paper a model of the enterprise as intelligent system oriented towards its capabilities is developed.

Thus, the main behaviors in solving different problems will be considered, and the specific competitiveness problems will be identified and the context for which the intelligent enterprise concept will be defined. According to the previous results the capabilities oriented model of the intelligent enterprise will be determined by establishing the corresponding capabilities and the capabilities maps as the expression of the integrated abilities of the enterprise.

The results will be useful in building the new enterprise as an intelligent organism able to integrate the human factor in a global adaptive and intelligent context compatible to the future mutations induced by globalization.

Keywords: *intelligent enterprises, competitiveness, enterprises management, complexity, multi-agents, systems of systems, capabilities maps.*

1. Introduction

Competitiveness represents a complex request for the modern enterprises, focused both on its internal environment (i.e., functions, structure, organization, and relations) and its external context determined by competition, society, markets, collaborations etc.

Thus, the enterprises must face a multidimensional problem that must be solved beyond the algorithms and procedures, and requesting the ability to use specific knowledge, such that the final results fulfill the global target

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regarding the *enterprise's integrated quality* defined as [1] the integrated set of properties that build an observable, significant, and dominant existence of the enterprise in the external environment through its technical, economic and financial leadership abilities, and through its integration in the society, such that the enterprise's dynamics positively contributes to the external environment evolution.

To realize the above goals, specific capabilities must be implemented in the enterprise's 'organism' that defines the intelligent dimension in solving different problems.

2. Algorithms, procedures, knowledge

For any type of enterprise that acts in an operational context or working environment, a problem is defined as the transition, necessary to be determined, from a given configuration $C_i = C(t_i)$ to desired one $C_k = C(t_k > t_i)$, as in figure 1.

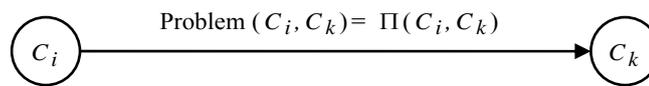


Figure 1. The general representation of enterprises' problems.

Solving a problem may be based on a succession of phases or on deductions and demonstrations acting upon information in a knowledge context. Thus, the following main types of solutions are identified:

- a. **The algorithm** defined as a finite and ordered succession of phases or steps that solve a given type of problems. The correctness of every algorithm must be mathematical or logical demonstrated, not by experience, such that when the given type of problem is presented at its detailed specifications, applying the algorithm will surely lead the solver to the correct and optimal solution. Also, it should be considered that algorithms encapsulate in an invisible manner knowledge, such that the operators that apply it, must not detain expert knowledge in the problem field.
- b. **The procedure** represents also a finite and ordered succession of steps that solves a given type of problems, but that is not abstractedly demonstrated to be correct, and is adopted and modified according to the experience. In applying a procedure, specific knowledge may be necessary at different levels. Using a

procedure does not warrant that the solution is a correct or an optimal one, such that, with every experience, procedures evolve and are continuously modified in order to obtain better solutions. Thus, the procedures represent heuristics, which encapsulate previous experience in the field.

An enterprise uses a large spectrum of procedures, from production, finance, quality management to relations with clients, and internal relations between the members of the organization.

- c. ***The reasoning based on knowledge*** solves complex problems that cannot be included in any crisp type regarding the specifications of the initial and final configurations, C_i and C_k . In establishing the solution for the problem $\Pi(C_i, C_k)$ knowledge of an expert in the field is necessary, and thinking processes must be deployed without having warranty that a solution exists or will be found. Almost all management problems in an enterprise are of this type, and this is why management solutions use not only given information, experience and knowledge, but also other human abilities as intuition, prediction etc.

Considering the above discussed tools, it becomes necessary to determine the main classes of problems that may be encountered by an enterprise.

Algorithms, procedures, and knowledge represent the main methods in solving the problems of an enterprise and in creating its behavior. The first two approaches are presently widely used, but the conditions for further developments request to create the abilities to use also the knowledge – based approach, respectively the reasoning capabilities of the enterprise.

3. The competitiveness induced problems for an enterprise

Competitiveness is the main goal of any enterprise, characterized by dimensional and structural complexities of the corresponding problems that determine the insufficiency of algorithms and procedures in attaining the attached objectives.

Considering the competitiveness dimensions regarding the internal and external environments [1] the following categories of problems may be identified and specified for the enterprise as an intelligent system [2, 3] according to figure 1 as in table 1, were: the problem $\Pi(C_i, C_k)$ has as

configuration components: C_i – the configuration of the enterprise at t_i for the internal and external environments, C_k – the desired configuration for the enterprise at t_k according to its competitiveness requests for the internal and external environments.

Table 1.
Definitions and specifications of the main problems of the enterprise's competitiveness

1. THE CONTROL PROBLEM	
Definition	Considering the enterprise's configuration at any moment, t , a desired behavior is the goal to be attained.
Configurations	<ul style="list-style-type: none"> • $C_i = C_f(t)$ – the current configuration of the enterprise, represented at its level; • $C_k = C_{fM}(t)$ – the desired configuration for the enterprise, according to the competitiveness model.
Goal description	<p>If the following situation appears: $C_f(t) \xrightarrow{-} \otimes \xleftarrow{+} C_{fM}(t) > D$, where D is the accepted deviation from the target configuration, and $\xrightarrow{-} \otimes \xleftarrow{+}$ represents the evaluation and comparison operation developed as a process at the enterprise's internal level, then the goal is the realization of the relation $C_f(t) \xrightarrow{-} \otimes \xleftarrow{+} C_{fM}(t) \leq D$.</p>
2. THE CLASSIFICATION PROBLEM	
Definition	The assignation of the current configuration of the enterprise, or of its components, to a class, the set of classes being already established.
Configurations	<ul style="list-style-type: none"> • $C_i = C_f(t)$ – the current configuration of the enterprise; • $C_k = (C_f(t) \in S_i \mid S = \{S_1, \dots, S_i, \dots, S_n\})$ – the assignation of the enterprise's configuration to a specific class from a previously established set of classes.
Goal description	<p>For a current configuration of the enterprise, $C_f(t)$, considering a previously established set of classes $S = \{S_1, \dots, S_i, \dots, S_n\}$, based upon the knowledge at the enterprise's level, the following assignation is determined:</p> $S = \{S_1, \dots, S_i, \dots, S_n\} \Big C_f(t) \rightarrow C_f(t) \in S_i$

3. THE DIAGNOSIS PROBLEM	
Definition	The causes' identification for a configuration of the enterprise, representing a deviation from the normal or accepted states, according to the competitiveness model.
Configurations	<ul style="list-style-type: none"> • $C_i = C_f(t)$ – an abnormal / unaccepted configuration of the enterprise; • C_k – causes of $C_f(t)$ as abnormal / unaccepted state.
Goal description	<p>Considering the desired or normal configuration of the enterprise at moment t, as $C_{fN}(t)$, according to the competitiveness model, and N the accepted deviation from this state, if the current configuration $C_f(t)$ represents an abnormality, such that $C_f(t) \xrightarrow{-} \otimes \xleftarrow{+} C_{fM}(t) > N$, then the corresponding causes will be determined as $\text{CAUSES}[C_f(t) \xrightarrow{-} \otimes \xleftarrow{+} C_{fM}(t) > N]$.</p>
4. THE RECONFIGURATION / REORGANIZATION PROBLEM	
Definition	The identification and implementation of a new configuration of the enterprise compatible to the objective or normality, respectively to the desired or normal behavior of the enterprise.
Configurations	<ul style="list-style-type: none"> • $C_i = C_f(t)$ – the current configuration of the enterprise, that doesn't correspond to the desired / normal state or behavior; • $C_k = C_{f_1}(t_1), t_1 > t$ – the new configuration of the enterprise, compatible to the desired / normal state or behavior.
Goal description	<p>Let $C_f(t)$ be the current configuration of the enterprise, and $C_{fQ}(t)$ its normal or desired configuration according to the competitiveness model, such that $C_f(t) \xrightarrow{-} \otimes \xleftarrow{+} C_{fQ}(t) > W$, where W is the accepted deviation, then the objective is to determine and implement a new configuration, $C_{f_1}(t_1), t_1 > t$, compatible with normality or competitiveness targets, such that $C_{f_1}(t_1) \overset{\varepsilon}{\approx} C_{fQ}(t_1), t_1 > t$, where $\varepsilon > 0, \varepsilon \rightarrow 0$ is the compatibility degree.</p>
5. THE DECISION PROBLEM	
Definition	For a given configuration of the enterprise, a solution is determined according to the specific models, in order to attain the set of established competitiveness goals.

Configurations	<ul style="list-style-type: none"> • $C_i = C_f(t)$ – the current configuration of the enterprise; • $C_k = C_{f_1}(t_1), t_1 > t$ – the configuration representing the solution for the set of established goals.
Goal description	Let be a set of objectives described by specific parameters, P , and the relation between these, $Q:(P,Q)$, and $C_f(t)$ the current configuration of the enterprise, then based on the specific models, M , the corresponding solution, S , actions, A , and resources, R will be determined in order to attain in a new configuration $C_{f_1}(t_1), t_1 > t$ the objectives (P,Q) .
6. THE PLANNING PROBLEM	
Definition	For a desired configuration, considering the current configuration of the enterprise, the necessary succession of pre-established actions is determined.
Configurations	<ul style="list-style-type: none"> • $C_i = C_f(t)$ – the current configuration of the enterprise; • $C_k = C_{f_1}(t_1), t_1 > t$ – the future desired/established configuration.
Goal description	Let $C_f(t)$ and $C_{f_1}(t_1), t_1 > t$ be the current and respectively, desired configurations, and A the set of necessary actions, then the succession graph of the actions of A and the corresponding intermediary configurations are determined such that the desired configuration to be attained from the current one.
7. THE PREDICTION PROBLEM	
Definition	The identification of a future configuration of the enterprise considering the current state and the environmental solutions.
Configurations	<ul style="list-style-type: none"> • $C_i = C_f(t)$ – the current configuration of the enterprise; • $C_k = C_{f_1}(t_1), t_1 > t$ – the future configuration of the enterprise determined by internal and external evolutions.
Goal description	Let $C_f(t)$ be a current configuration of the enterprise, M the competitiveness model, and I information regarding the internal and external environments, then the future configuration of the enterprise, $C_{f_1}(t_1), t_1 > t$, will be determined.
8. THE SUPERVISING PROBLEM	
Definition	The configurations of the enterprise will be determined at different moments in a time interval, corresponding to the competitiveness model and the information regarding the internal and external environments.
Configurations	<ul style="list-style-type: none"> • $C_i = C_f(t)$ – the current configuration of the enterprise, considered as the initial one;

	<ul style="list-style-type: none"> • $C_k = C_{f_1}(t_1 > t) (I_1, M), C_{f_q}(t_q > t_{q-1}) (I_q, M), q = \overline{2, n}$ – the successive configurations of the enterprise determined based upon the corresponding information $I_q, q = \overline{1, n}$ at $t_q, q = \overline{1, n}$ moments, and the competitiveness model M.
Goal description	For a given competitiveness model M , and an initial configuration of the enterprise $C_{f(t)}$, according to the information $I_q, q = \overline{1, n}$ determined at different moments $t_q, q = \overline{1, n}, t_1 > t, t_q > t_{q-1}$, the corresponding configurations of the enterprise, $C_q, q = \overline{1, n}$, will be determined.
9. THE VERIFICATION / AUDIT PROBLEM	
Definition	For the current configuration of the enterprise is established if it satisfies the set of previous defined requirements or the set of competitiveness requests.
Configurations	<ul style="list-style-type: none"> • $C_i = C_{f(t)}$ – the current configuration of the enterprise; • $C_k = C_{f(t)} \cap \Gamma$ – the degree in which the enterprise satisfies a set of requests or conditions.
Goal description	For a current configuration of the enterprise, $C_{f(t)}$, and a set of previously specified conditions or requests, Γ , the degree in which $C_{f(t)}$ satisfies Γ , $\alpha = C_{f(t)} \cap \Gamma, \alpha \in [0, 1]$, where $\alpha = 0$ for not fulfillment of Γ , and $\alpha = 1$ for total fulfillment of Γ , will be determined.
10. THE IDENTIFICATION PROBLEM	
Definition	For a set of information regarding the enterprise or its external environment, acquired in a time interval, the corresponding model of the enterprise or of the external environment are determined.
Configurations	<ul style="list-style-type: none"> • $C_i = C_{f(t)} = \{I(t), t \in [t_0, t_f]\}$ – the information set regarding the configuration of the enterprise, or of the external environment; • $C_k = M$ – the model of the enterprise or its external environment.
Goal description	Let be a set of information, $\{I(t), t \in [t_0, t_f]\}$, that describes the configuration of the enterprise or of its external environment, the corresponding model, M , will be determined.

4. The intelligent enterprise

According to the identified effective problems (see Table 1) the intelligent enterprise will be defined as an intelligent system (see [2]) as following:

Definition 1. The intelligent enterprise is the enterprise able to solve in a non-algorithmic manner the fundamental effective problems in various combinations, such that:

- acquires information by communication and evaluations from its internal and external environments;
- processes the information based on knowledge, experience, and models, and thus, constructs representations of the competitiveness environment;
- identifies the effective problems to be solved in order to attain its goals, and finds the corresponding solutions based upon reasoning;
- implements the establishes actions in order to attain its goals and develops the desired evolution in the multidimensional competitiveness environment.

In these conditions, an intelligent enterprise is an intelligent agent, due to its action possibilities, such that autonomy in the competitiveness environment is a main characteristic in the evolution of the enterprise accordingly to its solutions in reacting to the specific phenomena and events, and in considering a proactive behavior.

The interconnections between intelligent enterprises in following a common goal determine structures as:

- a. *intelligent systems of systems* in which individual intelligent enterprises functionally cooperate in solving the corresponding problems according to an organizational structure and an accepted protocol, but preserving its individuality and autonomy;
- b. *intelligent multiagents* as open structures in which many intelligent enterprises interact by cooperation and/or competition, according to an agreed protocol, related to a common competitiveness environment in attaining a global target or goal, but maintaining their individual goals and targets.

5. The capabilities oriented model of the intelligent enterprise. Capabilities maps

In order to develop the abilities for solving different types of effective problems as combinations of the fundamental effective problems determined

in Table 1, the intelligent enterprise must have corresponding capabilities that will determine its functions and organizational structure. Considering the analogy with the intelligent systems design (see [2]) the main capabilities of the intelligent enterprises will be identified as in Table 2.

Table 2.

The main capabilities of the intelligent enterprise

Capability	Description
<i>Lg</i>	Use and understanding of multiple languages with different levels of complexity (i.e., from formal to natural languages)
<i>Inf</i>	The recognition, understanding, and representation of data and information from the competitiveness environment (i.e., internal and external environment of the enterprise).
<i>Com</i>	Communication with and within the competitiveness environment.
<i>Rn</i>	Reasoning developments regarding different problems specific to the competitiveness environment.
<i>Ln</i>	Learning from experience, interactions with other agents etc.
<i>Ctr</i>	Control at its internal and external levels.
<i>Krm</i>	Knowledge representation and management.
<i>Mem</i>	Internal memory development and use.
<i>Adf</i>	Adaptation and flexibility in the competitiveness environment.
<i>Evl</i>	Evolution in the competitiveness environment.
<i>Itr</i>	Internal representations of the interactions with the external environment.
<i>Rct</i>	Reactivity
<i>Pct</i>	Proactivity
<i>Act</i>	Action
<i>Cwo</i>	Co-working with the human factor and other entities from the competitiveness environment.
<i>Itg</i>	Integration of the human factor, technical resources and other agents.
<i>Cin</i>	Compatible interfacing with the external environment, such that a specific image of the enterprise is created, that can be considered as the enterprise's avatar in the competitiveness environment, and interfacing with the human factor.
<i>Tem</i>	Temporal estimations.
<i>Rst</i>	Response to stress and risk management.
<i>Prs</i>	Processing resources, abilities, and other resources.
<i>Ikw</i>	Internal knowledge about the enterprise, its structure, goals, and specific processes.

Thus, a capability map of the intelligent enterprise can be developed related to its main dimensions: P – the problem or goal environment; H – the integration of the human factor and of other specific internal agents; E – the external context of the competitiveness environment. In these conditions, the capabilities map will be developed as in figure 2, where an identification of capabilities for a planning problem is presented. Also, in Table 3 the corresponding specifications are developed.

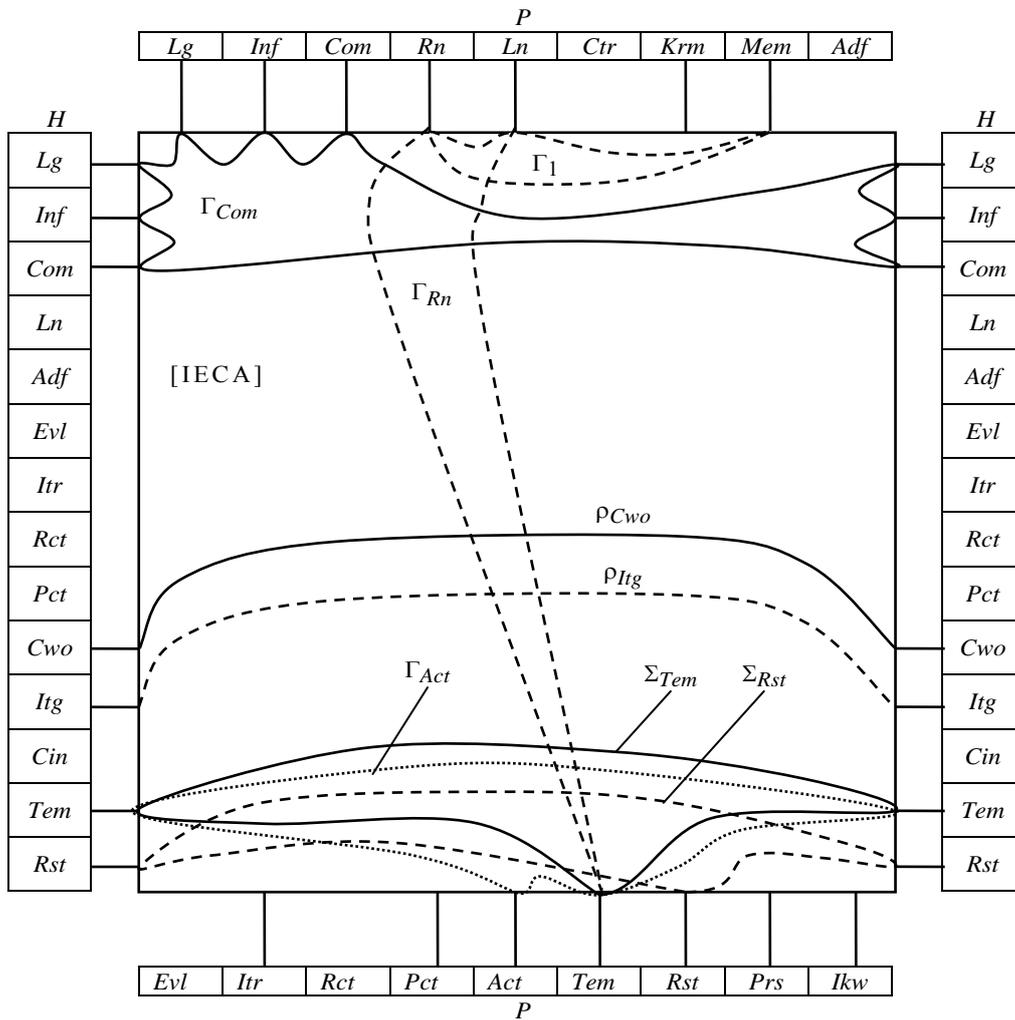


Figure 2. The capability map of the intelligent enterprise. The capability map for a planning problem [IECA] – Intelligent Enterprise’s Capability Area.

Table 3.*Specifications for the elements of the capability map from figure 2.*

Element	Capability	Dimensions	Specification
Γ_{Com}	Communication area	$P - H - E$	Communication context realization.
Γ_1, Γ_{Rn}	Planning areas	P	Reasoning for planning and corresponding temporal estimations.
ρ_{Cwo}	Co-working	$H - E$	Co-working between the human factor and the external context, that can introduce supplementary conditions.
ρ_{Itg}	Decisional integration	$H - E$	Integration of the human factor and the external context at the level of final decision.
Σ_{Tem}	Temporal estimations	$P - H - E$	Temporal estimations of the interactions with the problem environment, the human factor, and the external context.
Γ_{Act}	Temporal action area	$P - H - E$	Temporal estimations of the enterprise's actions considering P, H, E dimensions.
Σ_{Rst}	Risk management	$P - H - E$	Risk management in planning, by considering the specific aspects at P, H, E levels.
Itr	Internal representations	P	Internal representations of the interactions with the external environment
Ikw	Internal knowledge	P	Internal knowledge regarding the enterprise.
Pct	Proactivity	P	Proactivity in planning.
Prs	Resources	P	Resources for planning problem solution, processing and implementation.
Krm	Knowledge	P	Knowledge representation and management for planning.

In the development of the capability map, the following interconnections between the capabilities are considered:

- μ_i – open curves connecting different capabilities of the intelligent enterprise;
- ρ_i – open curves between different dimensions considering a common capability;
- Σ_i – closed curves between the same capabilities considered for different dimensions;
- Γ_i – areas that connect different capabilities at the same dimension, or from different dimensions.

6. Conclusions

The complexity and dynamics of the competitiveness environment determine a new frame of requirements for the enterprise's ability to solve problems, to implement solutions in order to survive and evolve in a global context.

The present paper proposes the model of the intelligent enterprise in order to attain these goals and for this context develops a capability oriented model for intelligent enterprises.

From this point of view, the fundamental effective problems determined by the competitiveness environment, are defined, and the corresponding solving approaches are discussed, highlighting the necessity to implement and develop the intelligent dimension of the enterprise.

Thus, the intelligent enterprise is defined, and accordingly the intelligent systems of systems and intelligent multiagents are considered as interconnecting structures of intelligent enterprises.

In this context, the capabilities of the intelligent enterprise are identified and the capability map for the intelligent enterprise design is developed as a management tool in creating the new generation of economic systems – the intelligent organizations.

Thus, the results of the research are oriented towards the construction of a global economic environment in which enterprises are intelligent organisms able to respond and to act proactively, in which the human factor will be integrated at its highly level of abilities, such that the new intelligent enterprises will have corresponding capabilities to be social integrated in the globalized world.

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