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Intelligent Controllers: A Review of the Implications of Design Business Organizations under Intelligent Controller's Mechanisms

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Abstract

The increase in the complexity of the environment requires that business organizations develop mechanisms that allow them to increase the agility in making decisions to respond to changes in the environment that is highly competitive today. One option to achieve this, little addressed in the business context, is intelligent control, which has been widely applied in electronics, computing and mobility. The present document makes a revision that allows to indicate the benefits of application of the intelligent control, as well as to identify the structural, dynamic features and limitations. The review considers research results in the fields in which intelligent control has been widely addressed. Finally, the implications of designing business systems with intelligent control mechanisms are discussed.

Keywords: Intelligent control, adaptive control, distributed control, intelligent system, intelligent agent

INTRODUCTION

The control is a field of study of engineering, in particular of control engineering, focused on the control of dynamic systems through the principles of feedback to ensure that the outputs of them are as close as possible to a predefined behavior or reaches the planned goal. The engineering of the control is associated mainly with works in electronic engineering, mechanical engineering and computer science, although their applications also have been widely approached in fields as the management of the organizations.

In fact, control has been considered a fundamental part in administrative and organizational theories; although it has not evolved with the same speed as it has done it in engineering. Traditionally, in administrative theory, control has been characterized by seeking the achievement of objectives through mechanisms that involve reducing the complexity of the system, homogenizing the behavior of the parties, and broadly trying to make a system stable. Levels of interaction with the environment are highly changing [1] [2] [3].

In engineering, on the contrary there are different types of control: optimal control, aimed at optimizing certain performance measures; Robust control, focused on the design of feedback systems that minimize the effects of uncertainty; stochastic control, which involves the study of control and the estimation of resource problems in which uncertainty is modeled by random processes; adaptive control, in which the stability of the system is sought from the adjustment to the behavior of external variables; and intelligent control that is oriented to systems characterized by high levels of uncertainty and interaction with the environment [4].

The present investigation is based on the premise that the approach that historically has had control in the administrative and organizational theory is no longer relevant to apply in the organizations of the current business environment. This is due to the high levels of uncertainty and broadly the complexity that characterizes both the organizations and the environment in which they operate.. To date there are several investigations that show the precariousness and lack of response of the approach that the control has had in the administrative and organizational theory [1] [5]. The main criticism is in the reduction of the complexity of the system through mechanisms that seek to standardize and homogenize diversity, an aspect that due to the high levels of interdependence of the business sector and its environment, instead of facilitating compliance with the objectives has generated totally contrary results [6].

The limitations of business control systems allow us to intuit that intelligent control systems widely worked in engineering, could provide new alternatives for the understanding of control in the business context, in which recent research has drawn attention to the design of organizations capable of solving agile problems in the environment [7]. Organizations without bosses [8], autonomous organizations and / or with high levels of self-organization [9], adaptive organizations [10], among others are some of the expressions that in the recent literature on business management show the need to study control from other perspectives such as intelligent control.

Therefore, the purpose of the present investigation is to identify from a literature review, what are the features and performance measures of intelligent control systems applied in engineering and in other fields in which it can have broad levels of development and application. The identification of traits and performance measures will allow to project lines of research regarding the design of business systems characterized by the use of intelligent control.

Intelligent control is a type of control that seeks to imitate certain characteristics of biological systems [11], arises from the combination of automatic control, artificial intelligence and computer systems. His focus has been on the automation of tasks, work under uncertainty, the design of systems capable of learning and solving environmental problems which implies that the system develops the capacity of learning and knowledge management [12] [13] [14], becoming the opportunity to identify failures early before they result in disastrous failures, as well as the ability to continue operating after a failure occurred when switching to a safe state [15].

Intelligent control systems are designed to achieve an objective autonomously, even though their objectives and control rules are not fully defined, because they change unexpectedly due to the interaction with other systems [16] [17].

The intelligent control systems are made up of agents, that is to say, by physical or abstract entities that perform automatic actions, and perceive their environment through sensors, they have the capacity to evaluate environmental conditions and make decisions through reasoning mechanisms and interaction with other agents, proposing negotiation processes to achieve a specific objective [18] [19]. Agents act as mediators between the specific tasks performed by the user and the replication of specific software [20], being able to monitor the objectives and learn to anticipate needs to become more and more helpful. [21] [22].

METHODOLOGY

The methodology used is based on the Kitchenham method [23], developed through 3 stages. In stage 1 called planning the need for revision is established, the research questions and the methodology to be followed are posed. Stage 2 known as realization is aimed at defining the keywords to perform the search in specialized databases in order to make a selection of texts, assess their suitability and extract the relevant information according to inclusion criteria. To finalize stage 3 presentation of the review report, it is aimed at recording the results, validating the report and sharing through its publication.

Stage 1. Planning: For the development of this article is part of the following questions: ¿Is it possible to design business organizations supported in intelligent control systems? ¿The application of intelligent control mechanisms in business organizations could improve business performance? The emphasis on intelligent control arises from the ability to facilitate compliance with the objectives of a system characterized by high levels of uncertainty.

The questions are the most important part of the systematic review, since they are the filter that ensures that the bibliographic material found meets clearly defined inclusion criteria. The research questions posed are: **P1**: *¿What measures of performance does the application of intelligent control bring?*, where it is intended to identify which are the advantages, benefits or criteria with which the level of success of the systems supported in control has been evaluated intelligent; **P2:** *¿What are the dynamic features of systems with intelligent control?*, they refer to the emerging behaviors exhibited by the systems, they are not predefined and arise from the structure adopted by the intelligent control system. **P3:** *¿What are the structural features of systems with intelligent control*? , refers to the ways in which agents are organized in the system: forms of interaction, existence or not of one or several decision-making agents, as well as the ways in which the information. **P4:***¿What are the restrictions that systems with intelligent control have?* , those aspects that are not covered by intelligent control systems; it includes the disadvantages and risks of its application.

Stage 2. Realization: According to the context of the research questions formulated, some key terms that will facilitate the search in the databases. Given the areas of knowledge that we require is done through the use of digital sources, such as: IEEE, IOP Science, CENAGE Learning, Science Direct, Proquest, additionally, Google Scholar is used.

In this phase 3 inclusion criteria are applied to ensure that automatically retrieved articles (136) contribute to the solution of research questions. The criteria are found in the reading of: 1 the title of the document; 2 the summary and introduction; and 3 the results and conclusions. The suitability of the articles is verified by a complete reading of the text, from which 51 documents result. After making the review, the articles were classified by fields of application, giving rise to four categories: electronic, computer, mobility and others in which articles that address the subject of intelligent control without a specific field are framed.

Table 1 presents the list of articles selected for the review

Table I: Articles Selected for Revision

Title	Camp
A Distributed Control Paradigm for Smart Grid to Address Attacks on Data Integrity and Availability. (2018) [24]	Computing
A Smarter Method for Self-Sustainable Buildings. (2018) [25]	Computing
Distributed SDN Control: Survey, Taxonomy, and Challenges. (2018) [26]	Computing
Distributed intelligent urban environment monitoring system. (2018) [27]	Computing
Redes inteligentes en el sistema eléctrico colombiano: Revisión del tema. (2017) [28]	Electronic
Communication Middleware Technologies for Industrial Distributed Control Systems: A Literature Review (2017) [29]	Computing

Multiobjective distributed model predictive control method for facility environment control based on cooperative game theory. (2017) [30]	Electronic
Fixed Point Learning Based Intelligent Traffic Control System. (2017) [31]	Mobility
Intelligent Control of Micro Grid: A Big Data-Based Control Center. (2017) [32]	Computing
Intelligent control system of autonomous objects. (2017) [15]	Others
Intelligent Home Control System Based on Single Chip Microcomputer. (2017) [33]	Computing
Intelligent Traffic Light Based on PLC Control. (2017) [34]	Mobility
Large Efficient Intelligent Heating Relay Station System. (2017) [35]	Electronic
The processing of information from sensors in intelligent systems. (2017) [36]	Computing
Control adaptativo para optimizar una intersección semafórica basado en un sistema embebido. (2016) [37]	Mobility
Implementación de un controlador de posición y movimiento de un robot móvil diferencial. (2016) [38]	Electronic
Multi-agent for manufacturing systems optimization [39]	Computing
A review on intelligent sensory modelling. (2016) [40]	Electronic
Intelligent traffic control system using PLC. (2016) [41]	Mobility
Identificación del estado de madurez de las frutas con redes neuronales artificiales, una revisión. (2015) [42]	Computing
Sistemas de control para mesas vibratorias: una revisión crítica. (2015) [11]	Electronic
Smarth: Plataforma abierta de tutoría inteligente como soporte a los procesos de B-learning en matemáticas. (2015) [43]	Otros
Intelligent control of non-linear dynamical system based on the adaptive neurocontroller. (2015) [44]	Electronic
Análisis energético y ambiental de alumbrado inteligente: Instalación en la faculta de Derecho de la Universidad Santiago de Compostela. (2013) [45]	Electronic
Dynamic traffic light controller using machine vision and optimization algorithms. (2013) [46]	Mobility
Análisis y diseño de software para la sincronización de intersecciones semafóricas. (2012) [47]	Mobility
Sistema de Control Distribuido para la gestión de la demanda del sector residencial. (2012) [48]	Computing
Control de tráfico vehicular usando ANFIS. (2012) [49]	Mobility
Reconfiguración Dinámica de Sistemas Distribuidos en Tiempo-Real Basada en Agentes. (2012) [19]	Electronic
A real-time algorithm for intelligent control embedded in knowledge based systems. (2011) [50]	Others
Un enfoque aplicado del control inteligente. (2011) [16]	Electronic
Sistema adaptativo de control y optimización del tráfico de un corredor vial semaforizado. Aplicación a la ciudad de Medellín. (2011) [51]	Mobility
Un sistema de control inteligente de entrada y salida de humanos a un recinto siguiendo la metodología vigilagent. (2010) [18]	Mobility
Sistemas heterogéneos adaptativos basados en el contexto. (2010) [52]	Computing

Solución de un problema Job Shop con un agente inteligente. (2009) [53]	Others
Sistemas tutoriales inteligentes un analisis crítico. (2009) [20]	Others
Modelado y Control de un robot móvil tipo newt en la tarea de seguimiento de trayectoria. (2008) [54]	Electronic
Sistemas complejos adaptables y cooperación. (2008) [55]	Others
Sistema experto para control inteligente de las variables ambientales de un edificio energéticamente eficiente. (2005) [56]	Computing
Sistemas tutores inteligentes: Propuesta de una arquitectura para aprendizaje en salud pública. (2004) [12]	Others
The myth of intelligent agent. (2000) [21]	Computing
Sistema de control automático integral de generadores de vapor pirotubulares. (2000) [57]	Computing
Sistema de control distribuido con supervisión centralizada para el sistema de riego de Güira de Melena. (2000) [58]	Electronic
Distributed intelligent monitoring and reporting facilities. (1996) [59]	Computing
What are the intelligent sensors. (1996) [22]	Others
Mediator: an Intelligent Information System Supporting the Virtual Manufacturing Enterprise. (1995) [60]	Computing

Stage 3. Presentation of the review report: At this stage, interpretations and positions are generated to answer the research questions asked. The contribution of the categories of analysis to the different research questions will allow glimpsing the possible implications of its application in the management of business organizations.

DEVELOPMENT

A. Main performance measures

The results of the different investigations show that the development of intelligent controllers has facilitated the integration of areas such as control, communication theory, computer science, artificial intelligence, operational research and neuroscience, making possible the use of new techniques and advanced programming environments, new hardware systems and advances in electronics and communications [16]. They also allow demonstrating significant improvements in the quality of the control system compared to conventional or classical control methods [17]. Decrease in the consumption of resources, decrease in operating times, decrease in the amount of waste, reduction of costs and increases in yields, are some of the advantages of intelligent control systems.

Table II: Performance Measures

Referent	**Evidence**
[35] [35] [48][46] [57] [58]	In applications, the savings and availability of resources are evident, as well as the reduction of waste compared to other systems, promoting sustainable development.
[35] [39] [53] [60]	The review indicates that the systems supported in intelligent control allow to improve the effectiveness of the process and the management of the information by the integration and interaction of devices that allow a global vision of the system
[19] [25] [37] [48] [57] [58]	It is possible to increase system components or improve the rule base during operation. In addition, it allows multiple simultaneous processes that improve the performance of the system.
[29] [48] [57]	The simplicity of the application structure shows reductions in costs and risks through development, integration, implementation and periodic maintenance; stimulating an increase in reliability and safety in its operation.
[31] [34] [37] [46] [47] [49] [51]	The intelligent control in mobility has been oriented mainly to increase the speed of the vehicular flow; it is identified that by regulating the lighting times of the traffic

	lights, the maximum waiting time of the vehicle to advance and the length of the row is reduced, ensuring a disciplined movement of the participants in the traffic.
[11] [30]	The use of intelligent control mechanisms allows an increase in accuracy when achieving a balance considering the objectives of each agent in the system.

B. Main Dynamic Features of Intelligent Control Systems

The dynamic features are those behaviors that develop according to the execution of the proposed control system. The review carried out allows to identify the following dynamic features: adaptability, understood as the ability to modify the configuration of the system to respond to changes in the environment; flexibility, which refers to the ability of agents to adapt to changing conditions; autonomy, which corresponds to the ability of agents to make agile decisions; Robustness, defined as the ability of the system to recover from failures that may occur at the individual level in the agents and continue operating while troubleshooting; Feedback, which refers to the ability to abstract information from an activity carried out in order to evaluate it, evaluate it and execute it better later; and cooperation, understood as the coordination between agents to meet a specific objective.

Table III. Dynamic Traits

Referent	**Evidence**
[16] [20] [24] [28] [29] [30] [34] [36] [43] [51] [52] [55] [57] [60]	Intelligent control applications are highlighted by the ability to perceive, understand and respond appropriately to the changes presented inside and outside the system by automatically reconfiguring, if required, in order to achieve its objective.
[20] [25] [26] [28] [37] [39] [43] [60]	The systems are able to adapt to different application domains, through the recognition of objects and events. The objective of flexibility is to define the properties of: Reactivity, the ability of an agent to perceive changes in its environment and react accordingly to achieve its design objectives. Proactivity, behavior of an agent aimed at an objective that, in spite of unjustified changes in its environment, the agent tries to move in the direction of satisfying his design objectives. Social Capacity highlights the bidirectional communication that exists between agents.
[19] [25] [38] [39] [43] [50] [53] [57]	The intelligent agents used in the process are able to autonomously code valid alternatives to work in different media and make effective decisions. Achieving its objectives through initiatives and interacting with other agents to achieve a specific objective
[15] [19] [24] [25] [29] [44] [50]	Intelligent control systems are able to respond quickly to any failure presented; generating a behavior that allows it to recover from events that affect its operation without suspending its execution and facilitating its performance in different areas in an effective manner and maintaining stability.
[10] [34] [38] [43] [41] [55]	The system is able to analyze and learn from its actions and behaviors, in such a way that when facing the same or a similar task, it will improve its performance, improving the chain of effects and reducing the performance error, in such a way that control is optimized
[15] [18] [19] [26] [37] [39] [60] [55]	The system works thanks to the communication, collaboration and coordination of agents, allowing them to adapt to increasingly hostile media, since these interaction networks are the factor that allows them to teach and learn from each other at the same time to achieve objectives individual and collective generating results that although they do not benefit an individual will be the most appropriate solution for the entire system.

C. Main Structural Features of Intelligent Control Systems

The revision of the different applications of intelligent control allows recognizing techniques and behavioral characteristics used for the fulfillment of the objectives set out in the investigations. At the level of the conformation of the system, central control is identified, when the system has only one control body in charge of organizing the work of the rest of the system, generally constituted by a computer, In this type of control it is common to divide the structure in a hierarchical or layered way; Distributed control is made up of different agents, geographically dispersed, in which the control is carried out by a group of coordinators who direct a group of agents who perform specific tasks and; **distributed control with centralized supervision** that combines distributed control with a centralized monitoring system, benefiting from the advantages of these two structures and minimizing their drawbacks. On the other hand, in terms of communication, bidirectional channels created by the agents are identified as they are required by the fulfillment of their tasks, which is why they are non-linear.

Table IV: Structural Traits

Referent	**Evidence**
[22] [29] [33] [56]	**Mediator** The proposed systems provide a module that acts as a mediator, is organized hierarchically, and is able to handle dependencies and

	bidirectional interactions between components assigning specific tasks to each agent. A single controller operates all aspects of the process, responsible for making decisions, making communications transparent and allowing interoperability between applications in networks in heterogeneous and homogeneous environments.
[12] [19] [24] [25] [27] [28] [30] [31] [33] [36] [40] [43] [46] [54]	**Distributed control** In this structure the control is divided into layers, levels or subsystems according to the control purposes; in which each subsystem, with specific objectives, considers not only its interests but that of others to achieve a balanced result. These subsystems communicate bi-directionally through a method of interaction in a common network, generating a solution that benefits the entire system. The objectives set out in each subsystem, to ensure simplicity, are met through tasks assigned to a particular agent, which have the ability to collect information in real time and communicate it to make decisions. Some authors raise the need to have a planning agent that is responsible for organizing access to the communication channel when an agent requires to transmit information, avoiding collisions and overloading the network.
[26] [39] [48] [51] [58] [59]	**Distributed control with centralized supervision** This architecture is composed of two fundamental blocks: a distributed one divided into subsystems and a centralized one that coordinates the system in a general way. In the distributed one, the subsystems, not hierarchized, are in charge of specific objectives supervised by a coordinating agent that allow the fulfillment of the global objective of successful way. The centralized block allows each subsystem to transmit the planning to the coordinator; which develops a global plan and communicates it to each coordinator of the subsystem so that it transmits it to the agents performing their tasks simultaneously.

D. Restrictions or Limitations of Intelligent Control Systems

The review carried out in the different fields of application allows to see that sometimes the systems characterized by a high level of interdependence between the parties, which act in complex ways can present wide and sudden failures, despite all the actions that have been taken to prevent them.

That is, the aspects that allow us to understand the robustness that intelligent control systems exhibit also allow us to understand their fragility. Intelligent control systems because they were designed to operate in environments characterized by uncertainty present high performance, and can cope with faults that occur at the individual level in any of its components, but the same interdependence can cause a failure to occur. propagate generating a major fault within the system.

An example of a robust and fragile system is airplanes. Most of the time as soon as flaws are detected in the design of an airplane, its causes are identified and it is sought that all aircraft of the same model in the world are revised and adjusted. However, carrying out this procedure on a recurring basis does not prevent air accidents [61].

From the above it can be stated that the robustness of intelligent control systems decreases the probability of system failure, but due to its complexity it cannot be avoided.

DISCUSSIONS AND FUTURE RESEARCH LINES

The advantages and dynamic features that intelligent control systems exhibit are consequences and behaviors that are usually difficult to control and predict, and that result from the interactions between agents. That is, they are directly related to the structural features of the system: the ways in which agents interact, how information flows, etc. Consequently, in the design of systems, structural features are one of the most relevant aspects to conside. In fact, in business management research, there is ample evidence about the impact of the structure on the performance of the system [62] [63].

The different applications of the intelligent control allow to demonstrate the advantages that it presents, with respect to the classic control systems, in aspects such as the decrease in the use of the resources (times, costs, etc.), the improvements in the quality of the system, the reduction of waste and waste, and in general the improvement in the performance of the system.

These advantages are provocative in the design of any system, including business organizations, in which since the late nineties there is literature [64] [65] that require changes in the classical paradigm for business management due to the problems generated by changing environmental conditions. Slowness in decision making, difficulty in change, inflexibility, are some of the problems that, the present investigation suggests, could be overcome if the design of business organizations is supported in intelligent control systems.

The literature review carried out in the present investigation allows us to argue that the adaptability, flexibility, autonomy, robustness and cooperation of intelligent control systems make it easier to explain the advantages of these systems. Thus, for example, to the extent that these systems are autonomous and adaptive, agility in decision making is increased; or to the extent that cooperation between the parties is favored, and the feedback cycles can reduce times, costs, waste, etc. It is important to point out that these approaches are coherent with the results of research focused on the design of intelligent systems [66] [67].

However, as it was stated at the beginning of this section, one of the relevant aspects in the design of the systems is the structure. The ways in which agents interact and communicate, facilitates the emergence of dynamic features, and allows us to understand the advantages generated and the dynamic features that it exhibits.

In the present investigation it is stated that the structural features are the ones that generate the most implications in the design of business organizations. Hierarchical control structures are highly precarious in information processing: the apex of the structure or central controller tends to be saturated with information, and the hierarchy generates slowness in the information flows, usually through regular channels.

The distributed control that characterizes the intelligent control systems highlights the need to rethink the traditional hierarchies of control in business design, and to direct efforts towards the construction of heterarchies where several central controllers coexist.

The heterarchies are structures where power changes depending on the circumstances. The change or rotation of power is closely related to the capabilities, knowledge, experience, or other features of individuals within the organization. At the moment when an event arises in the environment; the individual or individuals who, regardless of the reason, show greater information processing capacity assume the power, and this in turn is considered legitimate by the other members of the system [68].

To date there are different investigations that show the advantages of the heterarchies compared to the traditional hierarchy of control [69]. Some research shows the increase in the capacity of self-organization of the system, as well as the benefits for innovation and the promotion of creativity required for performance in complex environments [70].

However, in spite of the importance of distributed control, and especially of the benefits that the heterarchies could present, to date there are ample spaces tending to investigate how to design and implement heterarchies in business organizations. While the control may be in different nodes of the system, a problem in human systems (as opposed to artificial systems) is how to generate the legitimacy of the agent; that is, how to ensure that individuals, regardless of the role they play, can be seen as valid by the other members of the organization; While the control may be in different nodes of the system, a problem in human systems (as opposed to artificial systems) is how to generate the legitimacy of the agent; that is, how to ensure that individuals, regardless of the role they play, can be seen as valid by the other members of the organization

The applications of intelligent control evidence the existence of mediators that provide support to all agents of the system, facilitate communication and coordination, and avoid saturation in the flow of information. The role of mediators in intelligent control systems leads to rethinking the role of management as a facilitator of resources, of interactions, among other aspects, rather than as a central decision control.

The advantages of intelligent control systems allow us to state that distributed control allows them to absorb higher levels of complexity of the environment, and consequently reduce times, costs, among other aspects of decisions. However, the application of intelligent control in the business context requires projecting other lines of research in relation to the relationship between the distributed control structure with centralized supervision or not, and the uncertainty, or better yet the complexity of the environment. The above considering that there are investigations that show the success of the hierarchies of control in stable environments or of little change [71] [72]. That is, is it applicable to distributed control in all areas of the company, or only in those with high levels of complexity?

The structural features of intelligent control systems are clearly different from the approach that the dominant paradigm for business management has had over control. In the dominant paradigm the importance of hierarchical control structures is exalted as the mechanism that reduces the risks derived from the limited rationality of individuals. However, the failures currently presented by business organizations allow us to intuit the need to rethink control from perspectives such as those of intelligent control.

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