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Transportation System Architecture for Intelligent Management

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ABSTRACT: The paper is focusing on transportation system architecture for intelligent management, especially in sea transport and transportation technology. Moreover control models of large-scale distributed enterprises systems and transport active knowledge base management model have been presented.

1 INTRODUCTION

Today the transportation organization systems, especially see transportation, are much complex and must be more safety and robustness for any internal and external disturbances resistance for any errors and human mistakes. Criticality factors, which have influence on each dedicated activity, are including: safety, technology, exploitation (operation and maintenance), revenues, availability, reliability, maintainability, and costs.

The market globalization place new challenges in management of peculiar man activities in particular in transportation activities. It is growing requirement on so-called intelligent transportation technology and transport service ITS type (*Intelligent Transport Services*), as well as dynamical type management of transportation devices DTM type (*Dynamic Traffic Management*), both on large distances and at integrated automated transportation worldwide industry (manufacture). Transport industry today is a large-scale distributed system.

Market globalization and an increase in customer demands have forced companies to produce more complex and individualized products in a shorter lead-time [Le Duigou et al, 2009]. The increasing needs for flexibility, reactivity and efficiency result in a growing complexity of any systems including transport industry and other manufacturing, and a necessity of integration of their control based on numerous and highly versatile dynamic data [Blanc et al, 2008]. To solve this paradox (refocus on the primary business and need of multiple specific skills), companies have adapted by regrouping in order to pool their mutual skills. When this is done over a short period and on a specific project, it is called *virtual enterprise*, and *extended enterprise* when it is done over a longer period. Companies is not structured enough to enable efficient cooperation.

Knowledge is now a major driving force for organizational change and wealth creation, and effective knowledge management is an increasingly important source of competitive advantage and a key to the success of modern organizations [Irma & Rajiv, 2001; Malhotra, 2002; Savvas & Bassiliades, 2009]. The core technological areas for the success of next generation manufacturing related to information and communication technologies have been expressed in paper [Nof et al, 2008]. As a result, companies are now implementing knowledge management processes and its supporting technologies. Knowledge management systems (KMS) are a class of intelligent systems (IS) developed to support and enhance the organizational processes of knowledge creation, storage/ retrieval, transfer and application [Alavi, & Leidner, 2001; Chang et al, 2005]. Recent advances in information and communication technologies have allowed both transportation and manufacturing systems to move from highly data-driven environments to a more cooperative information/ knowledge-driven environment [Panetto & Molina, 2008]. For many years, software has been developed to pool all this information. From the EDM (Electronic Document Management) in the 1980s to the PDM (Product Data Management) and the PLM (Product Life Cycle Management) in the late 1990s, the companies and particularly the contractors understand the benefit of such software. Today to generate a common language for communication between people [Studer et al, 1998] or interoperability between systems [Uschold, 1996], more and more researcher are looking for ontologies types ranging in their formality, structure and intended use. The term ontology comes from philosophy and signifies a systematic account of existence [Gruber, 1993] and defines a common vocabulary for researchers who need to share information in a domain [Noy & McGuinness, 2001]. Building Information Modeling (BIM) [Penttila, 2006; Succar, 2009] of any today transportation and manufacturing systems is a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the system life-cycle phases.

Due to the geographical and institutional separation between the different systems involved in the product (system) lifecycle, it is today difficult to query, to exchange and to maintain consistency of product information inside the extended enterprise. By analogy with the definition of *interoperability* as the ability of two or more systems to exchange information and have the meaning of that information accurately and automatically interpreted by the receiving system [Wegner, 1996; Panetto, 2007], the *product oriented interoperability* as the ability of different enterprise systems to manage, exchange and share product information in a complete transparency to the user and utilize essential human labour only has been introduced [Baina et al, 2009].

Transport modes (road, rail, water, air, manufacture) integration and interoperability in transportation systems is a key concept to face the challenges of new transportation environment. The integration and interoperability concepts need undertake under the consideration the following problems: miscellaneous transport enterprise integration and interoperability, transport system as distributed locally and globally organization that can be readily reconfigured, methodology for system synthesis and simulation for all transportation operations, possible transportation activities and devices monitor and control with use proper model-based methodology, possible heterogeneous environments of transportation activities, open and dynamic structure of transport system, internal and external cooperation between transport modes and devices, technologies that can convert information into knowledge for effective decision making, enhanced human - machine interfaces based on integration of humans with software and hardware involved in transportation activities with use in-build intelligence, continuous educational and training methodology that would enable the rapid assimilation of existing and future knowledge and practice, transportation system safety and availability keeping with use preventive maintenance methodology, processes that minimize energy consumption resulting new innovative-based solutions in transportation system design and exploitation.

The paper is focusing on transportation system architecture for intelligent management, especially in sea transport and transportation technology.

2 CONTROL MODELS OF LARGE-SCALE DISTRIBUTED SYSTEMS

The main target of any complex system is a transport execution system (TES). The TES aim is controlling the transport system: what and when to replace, how and when to use the available resources, which and when to launch orders. The proposal of execution system based on manufacturing execution system MES using the holonic manufacturing system (HMS) concepts is presented in publication [Blanc et al, 2008]. An HMS is a highly decentralized manufacturing system concept, consisting of autonomous and cooperating agents called holons (proposed by Koestler in 1969) that respects some flexible control rules forming a holarchy. Holonic architectures are based on a typology of manufacturing elements, where each one corresponding to a type of holons:

- products, product holons own reference models of products, for manufacturing execution and quality control,
- resources, resources holons are components used as bricks with local intelligent decision-making system embedded and based on characteristics of the tasks they perform a specialization of resource holons; resource holons corresponds to the physical devices of the manufacturing system (machine, workforce, transport device, etc.); they allocate, organize and control the production resources; each physical device of the manufacturing system is a part of a resource holon,
- orders, order holons are related to product demand in time, manufacturing task and product item; order holons correspond to a task in the manufacturing system; they control the logistics aspects of the production as much as the negotiations with other order holons or with resource holons in order for the task to which it corresponds to be performed correctly and on time.

In paper [Zachman, 1987] author propose two-dimensional classification complex system model based around the six basic communication interrogatives: what (based on data), how (based on function), where (based on locations), who (based on people and devices), when (expressed via time), and why (expressed on motivation base), intersecting six distinct model types which relate to stakeholder groups: visionary, owner, designer, builder, implementer and worker, to give a holistic view of the enterprise. The proposed view of the enterprise can be extended on product - driven control concept.

Product-driven control is a way to exchange the hierarchical integrated vision of plant-wide control for a more interoperable/ intelligent one [Morel et al, 2007; Pannequin et al, 2009] by dealing with products whose information content is permanently bound to their material content and which are able to influence decisions made about them [McFarlane et al, 2003]. This approach is applicable at the supply chain decision systems, such as MRP2 (Manufacturing Resource Planning II) [Vollmann et al, 1997] with newer distributed control approaches. Product-driven control may enable manufacturing companies to meet business demands more quickly and effectively. But a key point in making this concept acceptable by industry is to provide benchmarking environments in order to compare and analyze their efficiency on emulated large-scale industry-led case studies with regard to current technologies and approaches.

Over the last decade, agent technology has shown great potential for solving problems in large-scale distributed systems. By definition, in multi-agent systems, several agents work together and share their knowledge for achieving certain manufacturing objectives. One of the important features of these systems is that they facilitate integration and automation and provide benefits with several advantages, especially to the distributed manufacturing systems [Oztemel & Tekez, 2009]. However, the integration and coordination, as well as communication of these agents still need more attention and research.

The reason for the growing success of multi-agent technology in this area is that the inherent distribution allows for a natural decomposition of the system into multiple agents that interact with each other to achieve a desired global goal [Hernandez et al., 2002]. The multi-agent technology can significantly enhance the design and analysis of problem domains under following three conditions [Adler & Blue, 2002]: the problem domain is geographically distributed, the sub-systems exist in a dynamic environment, sub-systems need to interact with each other more flexibly.

A dynamic and demanding environment characterizes the modern society. Intelligent products normally need to provide services that require decision-making and goal-oriented behavior. This human as an intelligent being mirrors its product's, reflects corresponding reality while delegating all decision making to the intelligent agent Intelligent systems (IS) can be defined as systems which process input signals to actuate an output action, the form of which will depend on rules based on previous experiences where the system learned which actions best let it reach its objectives [Barton & Thomas, 2009]. Artificially intelligent systems (AIS) incorporate additional functionality, often through intermediary agents, to simulate, decide and control the output signal or action. AIS must be interoperable with other components, such as common sense knowledge bases, in order to create larger, broader and more capable AI systems. New technologies such as RFID (Radio Frequency Identification), Auto-ID (Identification), UPnP (Universal Plug - and - Play) enable identification and information embedding on the product itself. Moreover, technologies related to multi-agent systems make it possible to involve the product in decision making protocols at the shop floor level.

The concept of dynamic hierarchical control system architecture is presented in paper [Brennan et al., 1997]. This concept organizes multiple agents dynamically based on task decomposition of the system. To achieve dynamic organization, a number of heterogeneous agents are dynamically grouped into virtual clusters as needed.

Increasing flexibility and the ability of the transportation systems deal with the uncertainty in a dynamic environment. A stationary type agent executes only on the system where it begins execution, and the code of stationary agents, including control algorithms and provided services, cannot be changed during execution. The above inconvenience can be replaced by the introducing to the transportation system mobile type agents. Mobile type agent has the unique ability to replace itself from one system in a network to another and to move to a system that contains an object with which the agent wants to interact and then to take advantage of being in the same host or network as the object. Since mobile agents can be generated dynamically during the execution, new software components (control algorithms or operations) can be deployed as mobile agents and be executed on any sub-systems in a network [Hernandez et al, 2002]. The strength of mobile agents has great value for the application in traffic management systems. A traffic information system is usually distributed and the integration of data from distributed detection stations takes a long time. If a mobile agent can migrate to detection stations near incident scene and process data locally, it will significantly reduce the delay of incident response. Mobile type agent technology has been discussed by several researches [for example: Lange and Oshima, 1999; Gray et al., 2002; Szpytko, 2004; Szpytko & Kocerba, 2008]. The mobile type agents for example have strong influence on work in heterogeneous environments and disconnected operation supporting, network load reducing and network latency overcoming, as well as are able to deploy new decision making algorithms dynamically.

3 TRANSPORT ACTIVE KNOWLEDGE BASE MANAGEMENT MODEL

The transport system is mostly composed from three categories of agents: device, man-operator (device, service/ maintenance, general coordinator/ management), surrounding. Between each agent exist specified relation/controls, for example between operator and device attributes' exists several correlations: perception – information visualization, knowledge – monitoring, skills – operation realization ability, decision making ability – corrective auto-activity, reaction on external stimulus – safety device and strength.

Each agent is an object of supply and controls (IN). Man-operators are equipment with modules of knowledge and skills (with use of own in-build sensors), which make possible auto-correction of done controls as the results of undertaken activities [Smalko & Szpytko, 2008]. Moreover the device, depending on automation level, may be equipped in auto-corrective module (self-acting). The output products (OU) of activities undertaken by individual agents are shaping for decision-making needs in quality module.

The architecture of proposed integrated distributed agent-based transportation system has multiple levels as shown in figure 1: real enterprise based on nature type resources (RE), virtual enterprise (VE), supervisor (SU).

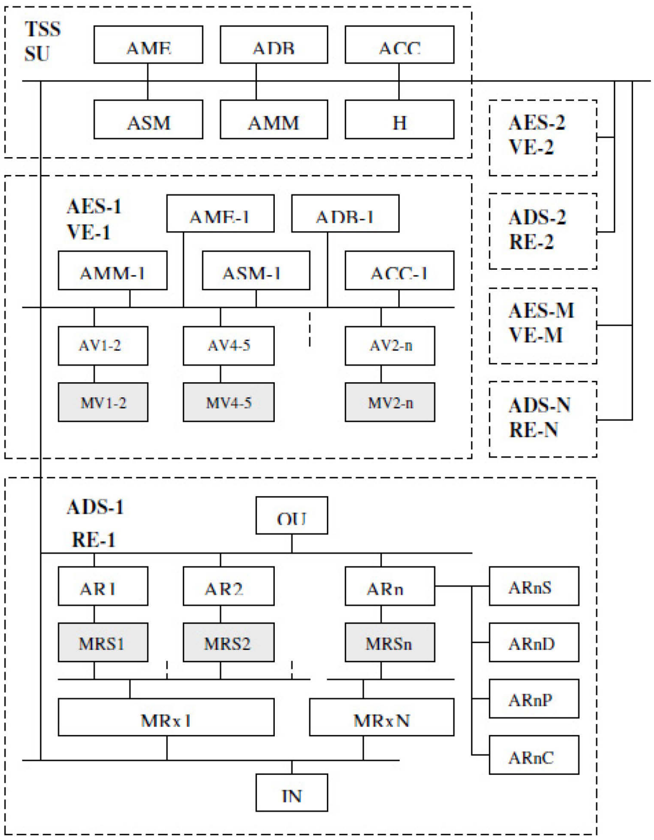

Figure 1. Integrated distributed agent-based dynamic type transportation management system (TMS)

Legend:

ACC - Agent Communication Channel

ADB - Agent Data Base

ADS - activities detection subsystems

ADS-N - activity detection subsystem, N-th type, (ST - stationary, MO - mobile type)

AES-M - activity execution subsystem M-th type, on particular geographical scope (ST - stationary, MO - mobile type)

AME - Agent Management/ Execution Engine

AMM - Agent Maintenance Manager

ASM - Agent Security Manager

Ax - activity supported by the x type agent, x = {R - real, V - virtual}

Axny - n-th activity of x-th type agent is composed from the following possible basic activities: y = {S - storage, D - displacement, P - processing, C - control}; to control one at least activity of S or D or P type must occur

ID - identification agent cod ID = 1....n

ID n.m - identification activity code n.m means that the activity is composed base on the two different activities with ID = n and ID = m

INn - input, which is composed by the following suppliers: ENIN-n - energy, KN-IN-n - knowledge and experience, IFIN-n - information/ data, FI-IN-n - finance; IN = {ENIN,KN-IN, IF-IN, FI-IN}

MR - agent real, types: ST - stationary, MO - mobile type

MRS - senor type agent of any operation parameters of real world

MRx - agent x type, x = {M - devices, E - environment, H - human}

MV - virtual type agent

OUn input, which is composed by the following suppliers: ENOU-n - energy, KN-OU-n - knowledge and experience, IFn - information/ data, FI-OU-n- finance; OU = {ENOU, KN-OU, IF-OU, FI-OU}

RE - resources (devices, environment, human, sensors/ detectors, energy, knowledge and experience, information, finance)

TSS - transport supervisory subsystem (ST - stationary type), system supervisor (SU)

VE - virtual enterprise subsystem (ST - stationary, MO - mobile type)

The control architecture of transport management system (TMS) has three layers: real devices operating in real enterprise type agent (lower layer level A), e-devices operating in virtual enterprise type agent (middle layer level B, electronic type platform), supervisor agent (highest layer C, with human support). Under certain scenarios, a number of various agents on A-th level are dynamically grouped and interact with each other to perform a given task. The performed task is based on possible defined activities: S -storage, D -displacement, P -processing, C -control. The activity execution subsystem (AES) agent coordinates agents operating on A-th level in a sub-network. The transport supervisory subsystem TSS type agent operation on C-th level can assign tasks to either AES agents on B-th level or to the lowest agents directly on A-th level. The communication between agents on all levels and inside each level is based on agent communication language and message exchange interaction protocols.

At the agent-level, the conformance includes agent communication language (ACL), message exchange interaction protocols, communicative acts, and content language representations. At the platform-level, Mobile-C provides an agent management system to manage the life cycle of the agents, agent communication channel to allow agent communication over the network, and directory facilitator to serve as yellow page services.

The lowest level is composed of various activity detection subsystems (ADS), which enclose various MR type agents stationary and/ or mobile types (e.g. transport devices) responding for particular activities AR types (e.g.: S - storage, D - displacement, P - processing, C - control types). Sensors (MRS) detect real agents activity parameters that can be a subject of monitoring for decision-making process. For example the useful information for the operation management is travel time, transport device speed, incident verification, and traffic volume and for the transport device technical state assessment - selected operation parameters of agents. MR type agents can dynamically group (taken under consideration overlooked necessary activities type) into any cluster according to the task assigned by the system supervisor. Integrating stationary type agents with mobile agent technology is leading to multi-agent subsystems for distributed transport management system. Mobile agents (operation base on dynamic adaptive type algorithm) enhance the ability to deal with the uncertainty in a dynamic environment and helps to achieve the cooperation between distributed agents response for various activities.

The second level so-called activity execution subsystem (AES) agent, either stationary and/ or mobile types, is a coordinator of lower level agents ADS type in a sub-network. All of the lower level agents register themselves and their services with an AES agent. The AES type agent has the knowledge of geographical distribution of lower level agents and their capabilities. The selected tasks of activity execution subsystem are: decompose tasks assigned by the AES to sub-tasks, multi-operation with other AES agents activities to solve inter-network problems (interoperability), serve as agent name server and maintain the available services of agents in a sub-network, dynamically group lower level agents activities into a cluster according to the task assigned, coordinate agents activities to accomplish the task resulting of planning, scheduling and tracking, integrate the information flow from lower level agents and report to the supervisor SU agent.

The transport supervisory subsystem TSS type agent (stationary) is designed to perform following tasks: generate transportation tasks dynamically and assign these tasks to lower level agents, analyze the information from lower level agents and generate reports or control proposals, create both stationary and mobile type agents and dispatch them to various activities undertaken via on purpose established companies, interface the transport management system (TMS) composed via both virtual and real enterprises to accept human commands. The structure of transport supervisory subsystem TSS type agent is composed on: Agent Communication Channel (ACC, to route messages between local and remote agents and realizes messages using an agent communication language), Agent Security Manager (ASM, to maintain security policies for e-platform and whole transport infrastructure), Agent Maintenance Manager (AMM, to provide preventive type maintenance base on agents' condition monitoring), Agent Management/ Execution Engine (AME, to manage the life cycle of agents and to serve the execution environment for the mobile agents), Agent Data Base (ADB, to store the data/ information and knowledge in electronic format) and human operator (H, to make the critical type decision). The same counterparts we can find in the activity execution subsystem (AES) agents.

4 FINAL REMARKS

The presented transport management system (TMS) is dedicated not only to manage the defined transportation target base on own distributed resources based on dedicated agents, but also to manage the life-cycle of the agents from operation and maintenance point of view.

Using the described system is possible to conduct the transportation system optimization taken under consideration the safety, availability, reliability, finance, time and others important aspects.

Proposed transport active knowledge agent base management model is possible to use to different transport systems (e.g. see, air, road, rail, manufacture) separately, but also in dedicated clusters.

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