Intelligent Agent Technologies Promises in Emerging Arena: Mass Customisation

ALI ORHAN AYDIN[1] and SEMRA TUNALI[2]
[1]Department of Industrial Engineering
Yasar University
Bornova, Izmir
TURKEY
http://aliorhanaydin.yasar.edu.tr
[2] Department of Industrial Engineering
Dokuz Eylul University
Bornova, Izmir
TURKEY
http://www.deu.edu.tr

Abstract: - Due to market conditions many production system begin to follow customer-oriented philosophy which leads to Mass Customisation Systems. Mass Customisation provides a framework for producers to produce a variety of products which are individually designed for each customer. Therefore, it requires dealing with an explosive number of product variations and customer orders and increases the complexity of activities. This paper provides a guideline on how intelligent agent technologies can be employed to deal with these complex issues.

Key-Words - Intelligent Agent Technologies, Mass Customisation

1 Introduction

Competitive market conditions force companies to develop and apply new planning approaches to gain competitive advantage [1]. Therefore, many approaches are put forward to use scarce resources efficiently.

Pioneer approach is Material Requirement Planning (MRP) which plans material requirements for the given period. In this manner, MRP reduces inventory levels and improves customer responsiveness [2].

In the 80s, in response to changing market conditions, new procedures were added to MRP and Manufacturing Resources Planning (MRP II) was founded. MRP II systems try to integrate MRP and some other functions. Moreover, MRP II plans capacity and schedules jobs [3].

Distribution Requirement Planning (DRP) and Computer Integrated Manufacturing (CIM) emerged from MRP and MRP II at the end of the 80s. DRP enables planning and managing product deliveries and distribution channels [4]. CIM covers the applications of integration of the manufacturing processes and technical functions like product development [5].

Afterwards, the idea of Enterprise Resource Planning (ERP) is born; since, integration is considered as a key factor for getting advantage [6]. Following, many advanced applications of ERP including Supply Chain Management (SCM), Customer Relationship Management (CRM) and E-Procurement are developed to provide further integration [7].

Today, the current market conditions are affected by new emerging factors like shorter product lifetimes, high quality requirements, demanding customers and availability of diverse product alternatives which lead to Mass Customisation (MC) [1]. MC provides the means to produce customised products through high process agility, flexibility and integration [8].

It should be noted that while implementation of MC brings flexibility to manufacturing environments, in the mean time, it increases the diversity of products [9]. This situation increases the complexity of management, planning, and controlling activities [10].

Although, current approaches are promising improvement in resource use, it became nearly impossible to manage, plan and control activities as expected by Mass Customisation Systems (MCS) [11]. This situation is forcing Mass Customisers to seek for better approaches and applications.

The use of Information and Communication Technologies (ICT) is key to the success of MCSs [9]. Today, intelligent agents (IA) represent a new way of designing and implementing complex systems [12]. Especially, Intelligent Agent Technologies (IAT) have potential to considerably improve the way in which management and planning activities are performed [13].

The aim of this study is twofold: (1) to present the current obstacles over success of MCSs and (2) to discuss how Mass Customisers can deal with these problems by employing IATs. In this frame, review on IATs is presented in the second section. The emerging problems of MC are elaborated in the third section. In the following section, a discussion on how IATs can be

used to overcome these problems is presented. Finally, the paper ends with concluding remarks.

2 Literature Review: IAs

The term agent, which is put forward by McCarthy, is conceptualised by Selfridge [14]. Both researchers state that agents are softbots that perform action in computer environment where they are situated [15].

In 1980s, some researchers proposed that the intelligence is composition of various different components of intelligent behaviour [12]. This led to a new domain Distributed Artificial Intelligence (DAI). It should be noted that the studies on agent technologies emerged from the concept of DAI [15].

Nwana [16] considers agent as an umbrella term that implies software entities covering a wide range of specific and limited types. Bradshaw states [17] that the agents are strange creatures each of which is designed to carry out its design purpose.

These definitions lead to weak and strong notion of agency. Agents that are autonomous, social, reactive and pro-active can be called as instance of weak notion of agency. For some researchers, the agent term has stronger meaning which implies entities that represent some aspects of human intelligence and this is stronger notion of agency [15]. In this study, the stronger notion of agency that infers intelligent entities is adopted.

Wooldridge and Jennings [12] try to explain IAs as situated autonomous entities that perform actions flexibility. The term situatedness implies entities that are capable of getting sensory data and performing actions to change its environment. The term flexibility is defined as the capability in performing flexible actions. Finally, the term autonomy infers entities that can perform action without assistance of other entities.

Today, there are some theories on formally representing these properties [15]. The most widely accepted theory to represent the properties of agents is to utilize intentional notion which coined by Dennett [18]. According to this view, agents are designed as intentional systems by ascribing some mental qualities.

It is more appropriate to use intentional stance when such ascription expresses the same information on a person [19]. Intentional stance is not sufficient for conveying IAs but it provides a useful frame [20].

For representing and reasoning about intentional notions, some formalism approaches, best known of which is possible world semantics, are put forward [15, 21]. Because of logical omniscience problem, alternative formalisms are put forward [22-24]. These formalism attempts resulted in the development of agent theories [15, 25, 26].

Agent architectures help to move from theory to practice. Agent architectures are defined as a particular methodology for building agents and architectures consist of a set of modules [27, 28]. There are mainly three different architectures: deliberative, reactive and hybrid [12]. In the beginning, the knowledge based systems are put forward to represent intelligent behaviour [29].

Inspired from these systems, deliberative agents are developed. This architecture contains explicitly represented symbolic model of the world. By symbolic manipulations and pattern matching, agents reason to decide their actions [30]. Planning systems are the first instance of deliberative architectures [15]. Pioneer of planning systems is STRIPS [31]. Some other instances are IRMA, HOMER and GRATE [15, 32, 33]. Deliberative agent architectures are criticized as not applicable in practical real world situations.

Rodney Brooks [34-36] criticised symbolic Artificial Intelligence (AI) stating that intelligence does not have explicit symbolic representations and does not reason according to explicit abstract reasoning. Subsequently, he suggests the first reactive architecture which is called as subsumption architecture. This architecture utilizes situation and action rules for mapping.

PENGI, situated automata and agent network architecture are some of the successors of subsumption architecture [20, 28, 37, 38]. These architectures do not employ models of their environment. Only current state and interactions define decisions and actions; therefore, problems are encountered in these types of agents [15].

In 1990's many researchers asserted that neither reactive nor deliberative architecture is suitable for real world problems, and in turn they suggested hybrid architectures [15]. Hybrid architectures have layered structure which contains at least two components: a deliberative and a reactive.

One of the pioneer hybrid architecture is Procedural Reasoning System (PRS) [39, 40]. PRS is based on the notion of beliefs, desires and intentions and explicit representations of those [26]. The other pioneer application of hybrid architectures is TouringMachines architecture [41] which has three control layers and two subsystems: perception and action. Another instance of hybrid architecture is called as Cosy [42] which has sensors, actuators, cognition and intention.

InteRRaP is one another instance which contains two vertical layers. The first layer consists of knowledge bases. The other layer contains control components that interact with the knowledge bases [42, 43]. Recently Bozinovski and Bozinovska [44] put forward an agent architecture which contains genetic control system, neural, and hormonal component. This architecture is based on a crossbar connectionist adaptive array.

When designing agent-based systems, it must be decided that if the system will include multiple agents [45]. Such systems are called as multi-agent system

(MAS). In MAS, data is usually decentralised; each agent knows a limited problem solving technique and has incomplete information.

Another issue in designing agent-based computer system is how to code the agents. Coding can be implemented in Concurrent object languages, concurrent METATEM, TELESCRIPT and also in AI tools like Prolog and Lisp [15].

3 Emerging Arena: Mass Customisation

In the last two decades, competition has become very fierce due to globalisation and demanding customers. Now, customers are said to be willing to pay more for products that satisfy their individual preferences [46]. So, in these changing market conditions, customised products are produced [47].

To ensure meeting individually customised demand, in recent years, the producers adopted the concept of Mass Customisation (MC). Da Silveria et. al. [9] explain MC as an information technology, flexible processes, and organizational structures using systems which deliver a wide range of products and services to meet particular needs of each of their customers.

By following customer-oriented production philosophy, textiles, candy, automotive, aviation and medical equipment industries become the instance of MC [48, 49]. Moreover, Pine [50] argues that anything that can be processed through ICT can be customised. This implies that in the near future, more and more producers start changing their business processes according to MC concept.

While some states that customers are willing to pay more for customised products, others emphasises that people sacrifice their preferences to achieve quality at lower prices [51, 52]. The awareness on this issue leads producers to seek ways to produce at lower costs. Therefore, one another major aim of MC is to deliver an increased product variety to customers in a most cost efficient way, but MC results in data explosion [53, 54].

The use of ICT is key to the success of production systems in reducing costs and improving efficiency [55]. Therefore, it is essential for MC systems to use applications of ICT [56]. However, these applications provides little support to MCSs [47].

Existing applications are unable to meet requirements of MC in five fronts: (a) getting customised product orders (b) defining bills-of-materials; (c) scheduling efficiently; and (d) tracking and routing materials (e) managing suppliers.

The most commonly stated problem is how to define bills-of-materials (BOM) [10]. For this purpose generic BOMs are put forward [57]. Wedekind and Müller [58] introduce a Grammar-Based method to construct a Generic BOM-Graph. Afterwards, Variantengenerator is put forward to represent all variants of each component [59]. Van Veen and Wortmann [60, 61] improved it by introducing new structure.

In 1991, Generic Bill-of-Material (GBOM) is introduced as a new product model [62]. This method gives liberty of design for product variants and gives flexibility to use alternative components in a single BOM. In this approach, set of inheritance rules are used in order to establish the parent-child connection [10].

Jiao et. al. [63] extend GBOM by combining it with routing information and they form Bill-of-Materials-and-Operations (BOMO). Ramabhatta et. al. [64] use an object-oriented, open group technology-based product model. Chung and Ficher [65] also used Object-Oriented Modelling for BOMs but did not generalize to a GBOM.

Olsen et. al. [54] represented a Procedure-Oriented GBOMs in 1997. This approach proposes a generic structure based on a programming language notation. Graph theoretic approach for automated GBOM generation is put forward [49]. Tseng et. al. [66] aim at reducing the cost of design by using Case-Based Reasoning algorithm. For multi-product and multi-process production systems, Aydin and Gungor [67] put forward a new approach to generate GBOMs by using a relational database specifically for customised products.

Simao et. al. [56] attempted to integrate the managerial systems and shop floors by utilizing manufacturing execution system. They used holons to support this customised e-manufacturing concept. Naidu et. al. [68] suggest using Radio Frequency IDentification (RFID) technology for tracking and routing of parts in MCSs.

Scheduling is complicated NP-Hard problem especially in MCSs [69]. The only attempt to solve scheduling problem of MCSs is proposed by Gerodimos et. al. [70]. However, the scheduling problem involved just a single machine.

4 Promises of IAT

Management, planning and controlling activities require intelligence; since, decision-making is at the core of these activities. From this point of view, to enhance efficiency of MCSs, it is advantageous to develop new approaches which employ intelligent agent technologies (IAT). Due to having following advantages, intelligent agent technologies seem to be very promising to deal with various problems in MCSs: IATs can

(a) process information much faster and more accurately by providing automation,
(b) respond to changing market conditions quickly by flexibility,
(c) preserve skills by using learning from experience,
(d) minimise the cost of managing, planning, and controlling activities by autonomy,
(e) handle data more efficiently, and

(f) provide integration by interacting between systems and other entities.

As stated earlier, one of the important issues in MCSs is related to the processing of customised product orders. In this respect, agents can be designed to assist consumers in selecting suitable product by generating variants of products. By applying the concept of learning from experience, agents can be developed to understand preferences of customers from the previous purchase orders. By enabling internet technologies and integrating e-commerce applications, based on needs of its users, agents can search, select, and order a product.

Allowing agents to collect data from the existing information system of the enterprise, automatic variant generation can performed so that customised product orders can be easily received.

Explosive number of products can be better defined by agents through bills-of-materials. Agents can be used in automatically generating generic bills-of-materials. Besides, BOM generation can be integrated with customer orders. With the help of intelligent agents, each customised product order can be generated automatically.

As mentioned earlier, another problem in MCSs is related with scheduling and planning activities. In job scheduling front, agents can be used for selecting different scheduling heuristics and search for better solutions.

It should be noted that data is decentralised in planning activities of MCSs and each functional branch of the MCSs has incomplete information. Therefore, by developing multi-agent systems in which each agent knows limited but sufficient problem solving technique can be used to plan activities of MCSs asynchronously.

Since the scheduling in MCSs is NP-Hard, population based algorithms can also be very useful in solving this problem. Population based algorithms cover particle swarm, ant colony, and bees algorithm. These algorithms can be realised a collection of agents each of which represent a single swarm, ant, or bee.

Planning activities can be further enhanced by using agents for monitoring production environment. Agents are currently used in patient monitoring. In similar manner, machines and shop floors can be controlled by using intelligent agents.

The movement of inbound and outbound material is another important issue in MCSs. Newly emerging technologies like Radio Frequency IDentification (RFID), Positioning Systems and General Purpose Radio Service (GPRS) can be integrated to provide information to agent-based systems.

For inbound material movements tracking, especially RFID is very beneficial. By combining Positioning Systems like American Global Positioning System (GPS), Russian Global Navigation Satellite System (GLONASS), or European Global Navigation Satellite System (GNSS) and GPRS outbound material movement can also be traced.

Intelligent agents can monitor inbound and outbound movements and whenever it is necessary, an agent can warn relevant personnel to take necessary actions. Moreover, agents can provide guidance to workers by showing them paths and routes to follow.

Agents can also be very beneficial in Supply Chain Management (SCM) front. When a customer order is received, agents can determine when and which raw-materials are required and provide information to the vendors and give the purchasing orders.

Other applications for SCM purposes can be developed according to multi-agent concept. In such systems each supplier can be represented by an agent. Those agents can collaborate on managing procurement processes to establish cluster assemblies and demand and supply networks (DESNET). These models help to increase impact on the market by creating cooperation.

Finally, it must be emphasised that each of the issues discussed in this section are closely linked with each other. Hence, social agents can be designed to achieve integration throughout the whole system.

5 Conclusion

It is expected that, in the near future, more and more producers will start applying MC concept. Costs of customised products must be reduced by developing and implementing emerging ICT applications. Unfortunately, the current applications provide little support in implementation of this concept. Therefore, in this study we first identified emerging issues in the area of MCSs and then explained how employing IATs can help to deal with these problems effectively. It should be noted that main idea behind employing agents is based on intelligence notion; since, decision-making is at the core of all functional areas.

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