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Study of Multi-Behavior Agent Systems for Supply Chain Planning In Bearing Industry

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Abstract*: For any industry or company, to be a competent in market needs increase in performance in all possible ways. Quick response to market and sufficient production as per requirement is the only way to increase the returns, which require critical planning and production systems. For this co-ordination between business units or workstations is essential. Many of the executive managers in industries has to instruct only the task flows to its subordinates, that is a single straightforward production planning process is followed as executed from top level of organization; their capacity as per their education level is not utilized more than 10%. The use of multi-agent system allows physical distribution of the decisional system and procures a hierarchical organization structure with decentralized control that guarantees the autonomy of each entity and flexibility of network. Our study focuses on managers/partners that adapt together their local planning process to face different requirements of supply chain environment using different planning strategies, when decisions are supported by distributed planning systems. The agent based system has the advantage of making collaborative management of disturbances in supply chain as the agents has the advantage of making autonomous decisions in a distributed network. Because each partner can choose different behavior and all behavior has an impact on the overall performance, it is difficult to know which is preferable for each partner to increase their performance. Thus, in this paper study of Multi-behavior planning agent model is done using different planning strategies when decisions are supported by distributed planning system.
Keywords: Multi-agent, agent-based planning systems, collaborative supply chain planning.

I. INTRODUCTION

The bearing industry is highly distributed, with many production units interacting in all activity levels. Traditionally, companies used to view themselves as separate entities and did not devote efforts to collaborate with other echelons of the extended enterprise. The main problems of this industry lies in the large amount of stochastic disturbances in many aspects of the supply chain, mainly due to the highly heterogeneous aspect of the resource, uncertain process output, production of co-products and by-products, price variation in the spot market, and demand variation in commodity markets. Collaboration among entities in the supply chain can have a great impact on the system performance. The various OR techniques were applied to improve planning, coordinating, transporting between the manufacturing units and workstations within units. But all are centralized controlled and this may result in much of the system being shut down by a single point of failure, as well as plan fragility and increased response overheads.

Agent technology provides a natural way to address such problems, and to design and implement efficient distributed intelligent manufacturing systems. Agent technology has been recognized as a promising paradigm for next generation manufacturing systems. Researchers have attempted to apply agent technology to manufacturing enterprise integration, enterprise collaboration (including supply chain management and virtual enterprises), manufacturing process planning and scheduling, and shop floor control. Our study focuses on application of distributed supply chain planning. Multi-agent systems are becoming more and more a paradigm recognized as important in the context of the manufacturing world, not only at the high level aspects of the Enterprise Information Technology but especially at the lower level aspects that include shop floor control, which is the focus of the work being presented here..

II. PROBLEMS IN SUPPLY CHAIN PLANNING

The industries related to mass production systems are dependent on suppliers and distributors of raw material, semi-finished and finished products. The supply chain involving different companies or multiple site units are controlled by centralized management systems. Collecting the proper Information and distributing the plans as per requirements is a challenging task for a person or a group. Many techniques are there to plan the supply chain but them uses lots of time to be processed as the quantity of information is large and planning become more complex to handle. In a dynamic environment, as in a production plant, as soon as a plan is released, it is immediately subject to random disruptions that quickly render the initial plan obsolete; these disturbances can take different forms, such as change in demand, machine breakdown, late delivery, employee sickness, etc. In these systems planning, scheduling and coordinating are not adaptable at high frequency to react to rapid changes in demands of customer. Traditionally, to overcome these they keep large inventories, but again it's a costly approach. While costly, this approach also considerably reduces flexibility, because stocked products must be sold even if demand has changed. In contrast, less stock means reducing the overall inventory investment, freeing up available cash flow, and improving end customer service [6]. Thus companies must have close collaboration and ensure proper information flows on time. For example if there is a breakdown in machine of a supplier then it can delay for many days in shipments of end product. Another aspect is, if there is a change in demand then every demand plan exchanged between each partner must be updated. If it is not done in a very short period of time, inventories will pile up and money will be wasted.

In fact, currently available software solutions generally do not provide the necessary support to network organizations and are clearly insufficient in planning and coordinating activities in heterogeneous environments.[16] [17] **.** To overcome these problems, in recent years there has been a trend of new management systems; i.e. collaboration and coordination mechanisms are applied to insure synchronization and consistency throughout the supply chain. Much work has been done for dealing with disturbances and uncertainty in a production context. Using artificial intelligence and various OR techniques are developed to overcome these disturbances. Also different frameworks related to management and organization is provided to improve supply chain.

III.AGENTS & MULTI BEHAVIOR PLANNING AGENTS

Previously, manufacturing system uses calculations and pessimistic principles for finding out uncertainties rather than assuming, this leads the requirements of decision makers at each and every stage of supply chain, from this stance there follows a system structure with distributed responsibilities, tasks and resources. Accordingly, manufacturing systems should be organized as loosely coupled networks of communicating and co-operating components of agents. A new trend of distributing decisions has resulted in the development of planning systems with agent-based architectures. Agent-based approaches for managing supply chain are not new it goes back more than quarter of century when research in distributed artificial intelligence (DAI) has been initiated.

Agent-based systems are computer systems made from a collection of agents in a dynamic environment and capable of exhibiting autonomous and intelligent behavior; these agents operate typically in environments that are only partly known, observable and predictable. These autonomous agents have the opportunity and ability to make decisions of their own.

An agent may have an environment that includes other agents. The community of interacting agents, as a whole, operates as a multi-agent system. These are the rational agents act in a manner most appropriate for the situation at hand and do the best they can do for themselves. Hence they maximize this utility given their own local goals and knowledge. Multi-agent systems are helpful in applying distributed artificial intelligence, social network theory and operational research

Agent-based technology has already been applied to different areas in SCM. Parunak [10] presents industrial applications and case studies of agent-based systems, and Shen and Norrie [18] describe more than 30 research projects addressing scheduling, planning, and control. More recently, Caridi et al. present a survey and a classification of the different application domains of published multi-agent projects, denoting their degree of maturity [4]. More specifically, agent-based planning systems have been proposed to manage supply chains and deal with disturbances. Montreuil et al. [8] present the Net Man architecture, an operation system for networked manufacturing organizations that aims to provide a collaborative approach to operations planning. Although the authors created architecture able to manage unplanned events, they do not present specific behaviors to solve problems. Pascal Forget [20] proposes the extension of the representation of coordination mechanisms in order to increase supply chain agility and synchronization. Weiming Shen [19] explores the various issues regarding implementations of agent based manufacturing like organizing coordinating, agent encapsulation, agent learning, optimization, security and privacy.

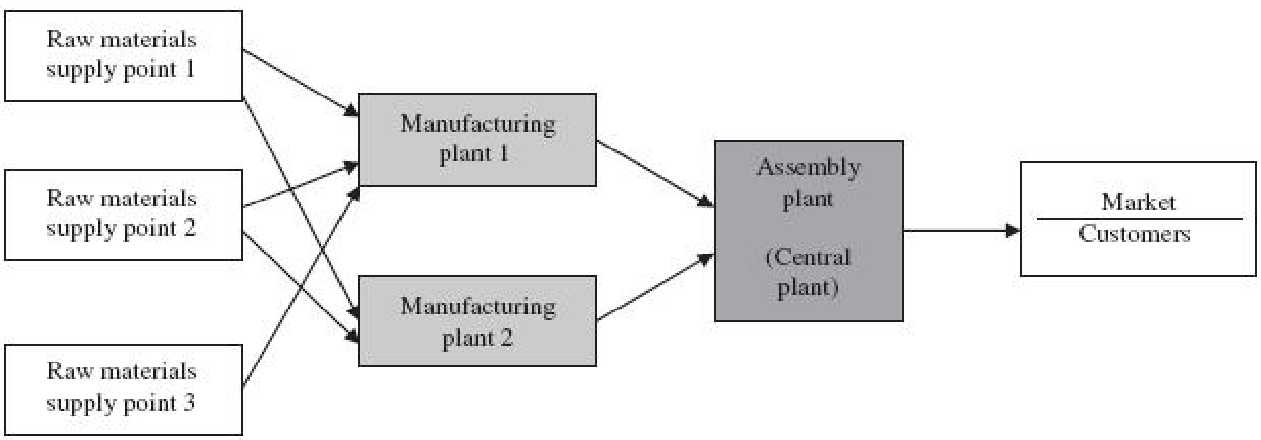
Various frameworks for agent based advanced supply chain planning are elaborated by Luis (2011-23) like non-agent and agent oriented approach, agents for supply chain management and supply chain planning. He focuses on methodological aspects for modeling the framework of 'agents for supply chain planning'. The latest research is on two criteria. The first one is related to the social aspects, which are associated with how the society is organized and what agent's relationships are, also they includes rules and negotiation between agents. The second one related to the individual aspects of the society i.e. ability of agents for planning, scheduling, controlling etc which comes under internal agent architectures. Agents can be designed in various ways, following the internal description of their functions and the connections between them. Basically, three main architectures are prominent: reactive, deliberative, and hybrid agents. Reactive and deliberative agents represent extreme cases of behaviors, whereas hybrid agents are positioned somewhere between the two.

IV. AGENTS IN BEARING INDUSTRIES

Ball bearings are at the heart of almost every product with a rotating shaft. Due to irregular supplies of raw material and every stage of manufacturing process requires 100% checking, repeatability and frequent feedback to the internal suppliers creates inherent complexity of forecasting production throughout. Many parts are supplied in bulk, standard sizes and grades are to be maintained, and also this industry requires lots of inspection and quality control processes which make this industry of high disturbances and large inventory in supply chain. In order to compensate for the lack of control over the stochastic elements related to bearing production, an increase in the exchange of information between quality control department and different production centers is necessary as is their ability to react quickly in a coordinated manner to changes. In other words, instead of producing a maximum of products and offering them to the clients, specific client orders can be produced, with the objective to produce what is needed. Thus basic requirements of this industry are (1) open system architecture to accommodate new sub-system or dismantle existing subsystems, (2) Efficient and effective communication and cooperation among departments within an enterprise and among enterprises and (3) Quick response to external order changes and unexpected disturbances from both internal and external manufacturing environments.

The bearing industry involves many companies; different parts are produced by different companies makes this as a multi-site manufacturing industry (Fig. 1) and hence coordination between supplier and customer should be there for proper supply at time. There are number of suppliers which supply different parts like rollers, balls, outer, inner, cage and rivets. Many bearing manufacturer like SKF NBC doesn't manufacture rollers and balls these are purchased from other companies like KB (Kansara Bearing, at Jodhpur Rajasthan).

V. MULTI BEHAVIOR AGENT MODEL FOR BEARING INDUSTRIES



The multi-behavior agent is an adaptive agent model and has been designed to give the agents alternative behaviors to face different situations more efficiently, individually or as a team. While mono-behavior agents construct plans using the same planning behavior continuously, multi-behavior agents can learn which planning behaviors to adopt in many different situations, depending on the environment, and change its behaviors when needed. The agent-based architecture for roller manufacturing based on the natural division of the planning domains. Planning units divide activities between specialized production planning agents: header agent, heat treatment agent, finishing agent and assembly agent. Each agent is responsible for supporting the planning of its production center. Other agents are also the part of the architecture as deliver agent, source agent and warehouse agent (Fig. 2).

The planning sequence used in a planning unit to plan the internal supply chain upon the receipt of a new demand plan (from outside the planning unit) is divided in two distinct planning phases: the infinite supply plan and the finite supply plan. During the first phase, the deliver agent receives a demand plan from one or many customers. These customers can be part of the same company or different companies. Upon reception, the deliver agent sends a demand plan to the warehouse agent to verify if products are in stock. For unavailable products, it sends a demand plan to assembly. Using this demand plan, along with resource constraints and lead times the assembly agent builds its plan considering infinite supply and transmits it to the finishing agent. Again, using the demand plan, local constraint and considering infinite supply, the finishing agent transmits its preferred plan to the heat treatment agent. This

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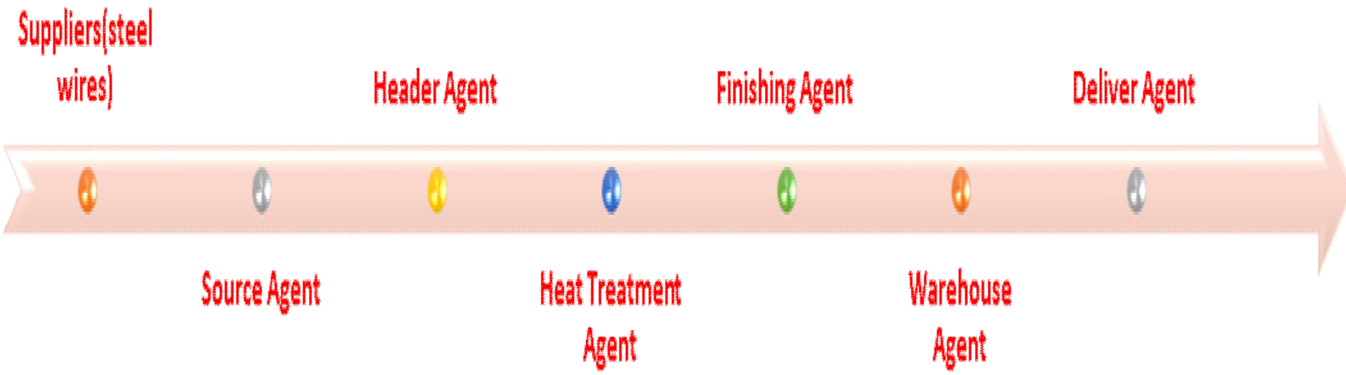

Figure 2 Planning Unit for roller Manufacturer

process continues until suppliers outside the planning unit receive the infinite demand plan. When suppliers answer the demand plans, the source agent receives a supply plan and starts a return loop. This represents the second phase of the planning process, the finite supply plan. The process is largely the same, however plans are built with finite supply, which is the information transmitted by the immediate supplier. If an event occurs in the internal supply chain operations, any agent can initiate collaboration with its internal clients and suppliers by sending a revised demand or supply plan. This can be triggered by an agent who needs some products to fulfill inventory, lost production or new demand. This explains why agents are also responsible for continuously monitoring their environment and reacting to disturbances. Because of the interaction context, an agent's environment is also made up of all messages received from other agents specifying a new or modified requirement plan, a new or modified replenishment plan, a contingency situation, or a high priority requirement to process. The agent meta-model (Fig. 3) is a high level view of interactions between a planning agent and its active environment. Before actually building an operational plan, the agent must decide which task flow, or sequence of tasks, will be used, with the ultimate objective to build the best operational plan possible. Because the agent is not controlled by a central planning system, it is free to decide what it will perform, using its own preferences. In this meta-model activities are presented as boxes and results are ovals.

Using the agent Meta-model as a basis, the Multi-behavior agent model (Fig. 4) is an evolution of the concept. The model presents three basic behaviors to react to a new state in a planning context. These are negotiation, anticipation and reaction. Any task flow planned by the agent can be characterized by one of these behaviors. The agent does not choose a specific behavior, but chooses an adapted task flow, which can be associated to a distributed planning behavior.

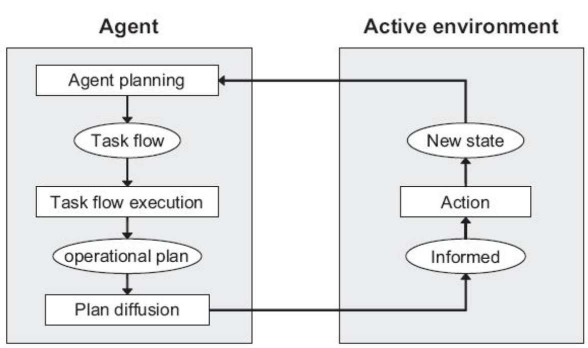

Figure 3 Agent Meta-Model

The Negotiation behavior describes task flows sending proposals to partners, in the form of alternative plans. When the agent is not able to respond to partner's needs, it can offer changes in delivery dates or alternative products. Following this, an iterative exchange of proposals is started, where both agents try to find a compromise. While both anticipation and reaction behaviors are non-convergent planning strategies, where the agent does not search for a compromise, the agent using a negotiation task flow is fully informed and tries to reach an agreement. These proposals can take the shape of new constraints, which can be used by partners to re-plan production and send a new demand plan. Before undertaking a negotiation protocol, the planning agent must determine a negotiation space, which specifies what parts of the plan can be changed. This way, the negotiation is narrowed and leads to a compromise faster.

Then ticipation behavior is a planning strategy using a partner model in addition to its local model. Basically, it is about integrating information about partners into its optimization model. Depending on the situation, emphasis can be placed on local or collective goals. Collaboration between planning partners through anticipation has been studied in hierarchical relation types (also called upstream planning) and in a distributed context. The partner model is used to plan production in a way to maximize partner satisfaction, especially for production that has not been specifically asked for (push production). When no full disclosure is possible between partners (because of confidentiality needs), a partner's models are still used but represent a more approximated anticipation.

The Reaction behavior is about using Task flows where no new information is collected during processing. The agent knows a certain number of Task flows and can use one of them to respond to a disturbance. Different optimization algorithms and objective functions can be used, depending on the situation and on the available time. This behavior can be qualified as greedy, because the agent use only what is the best for him. No knowledge about partners is used and there is no way to check if the proposed plan will satisfy the partner. These task flows are mainly used in well-known situations where no mutual adjustments are required. A large variety of task flows can be available, some of them taking much time but leading to optimal solutions, others finding acceptable (but not optimal) solutions in a very short period of time.

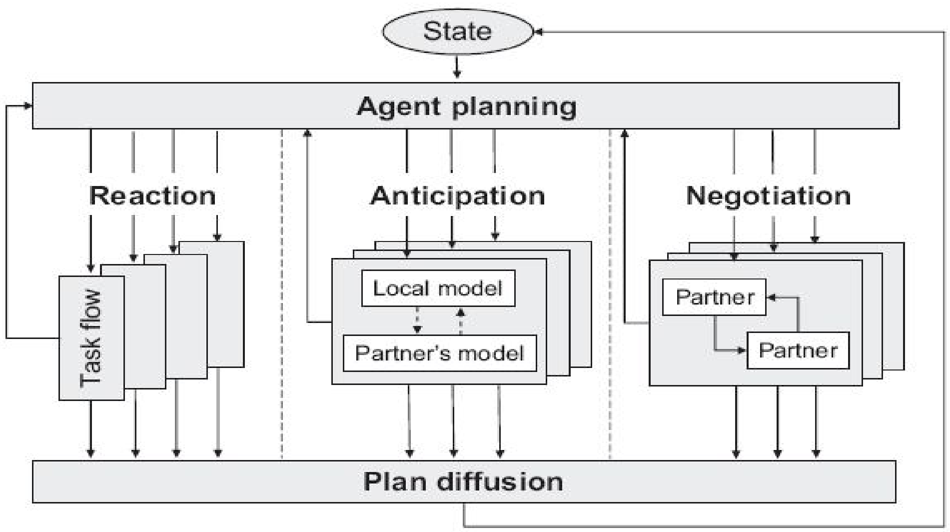

Figure 4 Multi-behavior agent model

VI. ADVANTAGE OF MULTI BEHAVIOR AGENT

Compared to a purely reactive or deliberative agent, the Multi-behavior agent presents advantages similar to hybrid agents. For well-known situations, reaction task flows are used, but in situations where more information can be advantageous, the agent is able to demonstrate mutual adjustment capabilities, using anticipation or negotiation. The Multi-behavior agent is a hybrid agent designed specifically to answer production planning problems, using different behaviors. The main advantage is the possibility of adjusting the behavior according to external factors. For example, when a client sends a demand plan and requests an acceptance or a refusal in a short time frame, the agent is able to use its fastest respond, which is one of the reaction task flows. In this case, instead of entirely preplanning the production plan (that would take a certain amount of time), it would use on-hand inventory and try to satisfy the client's needs. In contrast, if a large amount of time is available, the agent would take time to send new demand plans to suppliers. Another advantage is the possibility for the agent to use collective goals in addition to local goals. Anticipation task flow use inputs from a partner's model in order to integrate both local and collective goals. Depending on the relative importance of these goals, a balanced solution can be reached. The possibility of anticipating collective goals when communication is not possible (or too long to achieve) represents an appreciable advantage, as better decisions can be taken with limited knowledge. Also, negotiation task flows use direct input from a partner. Instead of using an approximate model of collective goals, real local goals of partners are integrated in the final solution; this utilizes the planning capabilities of executives and reduced centralized planning problems.

VII. CONCLUSIONS

Software agents and their applications in intelligent manufacturing have been studied for about two decades. However, industrial applications are still rare because some difficult problems remain unsolved, e.g., full integration of manufacturing process planning, scheduling, and control, particularly integration with real time information from data collection systems. But if correctly synchronized with computer technology, the agent technology will fulfill future demands for industries. This paper has attempted to analyze a multi-behavior planning agent and this seems to be an important tool for managing the supply chain. The mutual adjustment approaches between planning agents help find better solutions that would increase collective performance instead of only individual performance.

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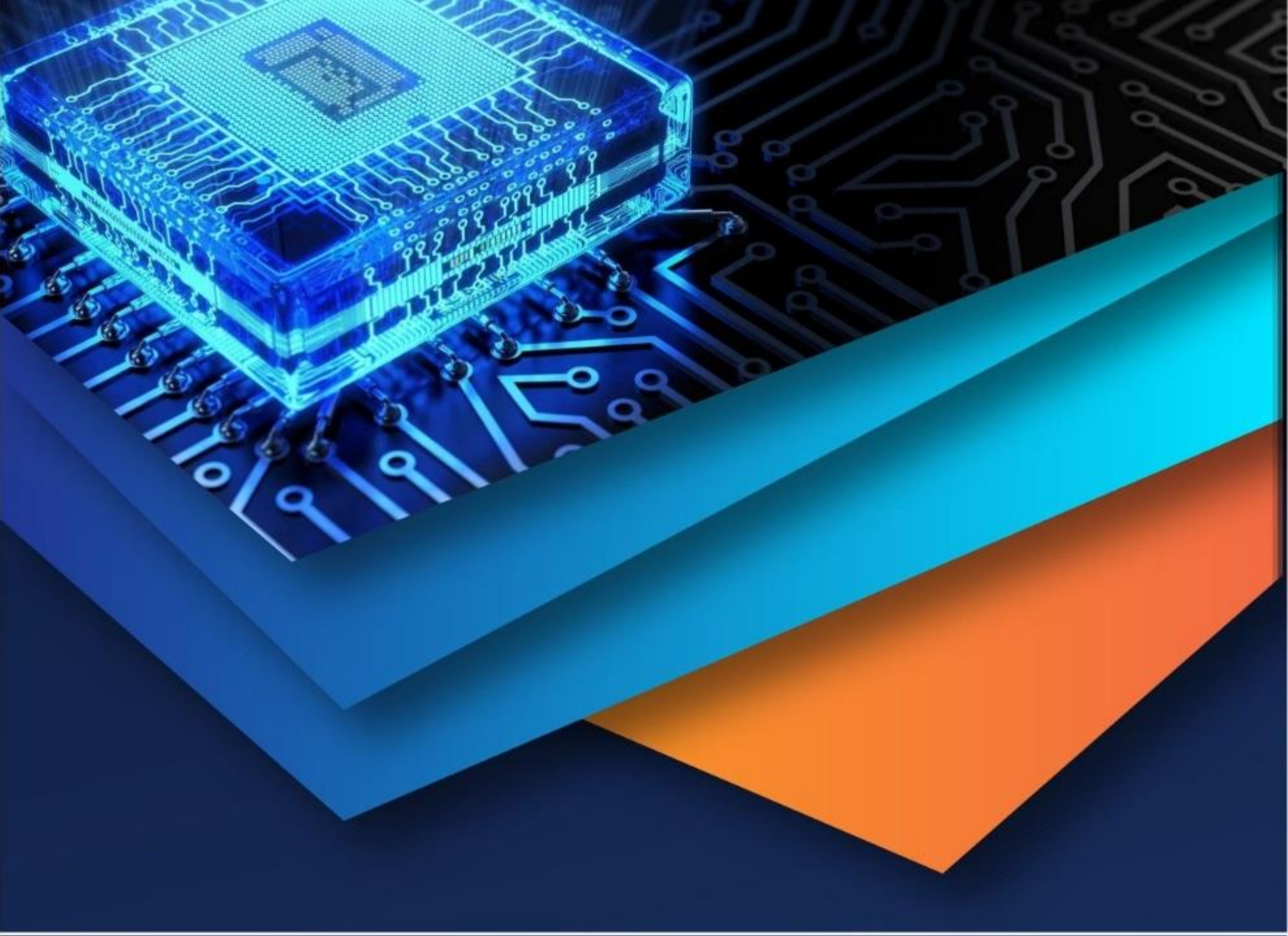

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