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Complex Event Processing Technology Approach for Battlefield Decision Making

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Abstract: ***Decision Making plays a crucial role in battlefield. Right Information in right time and at right place is the mantra to make better decisions. While decision making, one has to process various kinds of data originating from various sources in least possible time in order to get advantage over enemy. In this paper Complex Event Processing (CEP) technology is used as an approach for battlefield Decision Making. Various CEP tools are described. Architecture and method is provided for IPB using CEP.***

Keywords-Complex Event Processing (CEP), Decision Support System, OODA loop

I. INTRODUCTION

In the competitive business environment, success mantra is Right Decision in Right Time and at Right Place [5]. Intelligence Preparation of the Battlefield (IPB) is a systematic, continuous process of analyzing the threat and environment in a specific geographic area. It is designed to support military decision making. In battlefield, decision making plays a vital role. It requires analyzing situations quickly and need to react to them in real time [1]. Life time of information in battlefield is very less. If one cannot identify the threats and opportunities and not reacts to them then the penalty could be huge number of lives.

The OODA loop (for observe, orient, decide, and act) is a concept applied to the combat operations process, at the strategic level in military operations. The OODA loop has become an important concept in military strategy. According to Boyd, decision-making occurs in a recurring cycle of observe-orient-decide-act. Conceptual diagram of OODA loop is given in figure 1.

Components of OODA loop can be classified into two categories. Observation-Orientation-Decision components are information centric. Action is kinematic centric. Observation-Orientation-Decision deals about information gathering, distributing information, analyzing and understanding information and deciding how to act using this information. Networking improves operational tempo by accelerating the Observation-Orientation phases of OODA loop [1].

An entity that can process this cycle quickly, observing and reacting to unfolding events more rapidly than an opponent, can thereby "get inside" the opponent's decision cycle and gain the advantage. In other words, the player with the faster OODA loop, all else being equal, will defeat the opponent with the slower OODA loop by blocking or pre-empting any move the opponent with the slower OODA loop attempts to make. In this paper a methodology is provided to accelerate Observe - Orient – Decide phases of OODA loop to get combat advantage [1].

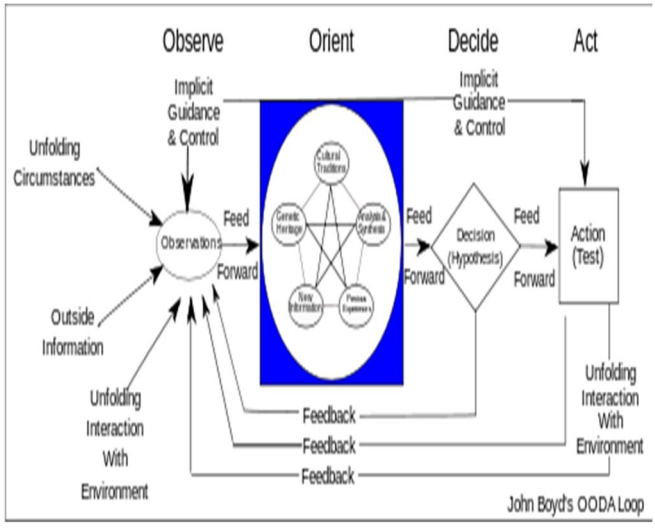

FIG: 1 CONCEPTUAL DIAGRAM OF OODA LOOP

Information in battlefield is heterogeneous. Different kinds of information come from various sources. It will be in various forms. For example Information related to friend force may come from GPS sensors. Enemy Information may come from various sensors or radars or through other sources. Weather information may come from weather sensors. Such information may come as information streams. Other information may be present in the persistence storage. For example geographic information related to roads, hills and lakes etc. In battlefield, decision makers are interested in identifying situations. When interesting situations occur they need to identify them, asses them and react to them. Battlefield situations are complex situations. It means, identifying such situations require lot of effort. The required information to identify will not be available readymade. We need to correlate and analyze information coming from multiple sources (which will be heterogeneous in nature) in order to identify such situations. There is a thirsty need for systems to analyze such battlefield situations and to react to them in real time. In this paper one such system is proposed using complex event processing.

Section 2 describes the Complex Event Processing technology and its applications. Section 3 describes the methodology of the proposed system.

II. COMPLEX EVENT PROCESSING

Complex Event Processing (CEP) is an emerging network technology that creates actionable, situational knowledge from distributed message-based systems, databases and applications in real time or in near real time. CEP is a best choice for applications that require near-real-time responses to dynamic, multifaceted, rapidly changing business situations [3]. CEP can serve an organization with its capability to define, manage and predict events, situations, exceptional conditions, opportunities and threats in complex, heterogeneous networks [9].

CEP plays vital role in Detect and Inform Applications, Detect and Act Applications and in Event Processing Architectures [3]. CEP is favorable choice for applications that detects events, filters events and correlate events to identify complex events and to react to events in real time or in near real time[6]. CEP applications have been widely used in Business Activity Monitoring, Business Process Management and Automation, finance domain for Fraud Detection and Risk Management, Network and Application Monitoring and in Sensor Network Applications .etc. These applications require analyzing and reacting to events in real time or in near real time.

Numbers of CEP tools (open source and commercial) exist in the market. They are developed based on various approaches and they are working in various domains. Some of the CEP tools/ technologies are describes below.

WestGlobal Vantify provides a CEP solution to detect anomalies in the behavior of processes and underlying software services. It proactively alerts business and technical operations before customers are impacted [20]. Progress Apama uses rule based approach to process event streams. It also provides the graphical editor to edit the rule logic. It mainly works in financial data streams [14]. SQLStream uses SQL concept. It processes data streams using SQL like rules[18]. RuleCore CEP Server facilitates location aware CEP rules. It provides XML based configuration and fits for Service Oriented Architecture (SOA). It supports Geo-Spatial Event Processing [15].

WebSphere Business Events from IBM offers GUI to specify If-Then Expressions to express interesting events. It also facilitates graphical editor to create event flows [8]. Tibco Business Events offers Rule Core CEP. It follows model driven approach with UML based modeling. It provides connectors to integrate with other Tibco products [19]. Sybase's Aleri provides 3 different ways to describe event processing logic. They are using SQL, using XML and using SPLASH language [24]. Senactive uses SOA approach for processing event streams. It provides graphical editor for modeling event processing flows and rules. It also provides visualization tools to visualize historical events. Senactive became a part of UC4 [21]. RTM Real time Monitoring offers a java based CEP platform. RTM analyzer follows library style approach by providing different modules to meet enterprise CEP requirements [25].

Siddhi is open source software under Apache license. It uses Siddhi query language to express interesting events. It captures the input events during capturing phase. Siddhi Manager dispatches the captured events to Event Processors. Event processors will look for matching conditions and process the events [17]. ActiveInsight is open source solution. It provides real time, value based detection & reaction to events and patterns. It offers a framework for processing distributed event streams [7].

Esper is an open source software solution [22]. It is favorite CEP tool for java developers. It provides java based approach to process streams of data. In Esper, events can be defined using POJO classes, using XML and using java Maps. Esper uses EPL statements to express rules. It offers high scalability. It offers efficient data structures like length and time windows to filter uninterested events. It offers high performance with less reaction time. It has a commercial flavor solution named EsperTech [23].

ETAILS is open source tool. It works based on logic programming paradigm. It uses a rule based declarative language "ETAILS Language for Events" to express interesting events. It offers easy integration with databases. It also provides inference capabilities [10]. Intelligent Event Processor (IEP) is java based solution for CEP. It processes all kinds of events which are supported by Open

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ESB. It uses CQL (Continuous Query Language) to express interesting events. Oracle Event Processing is a standalone event stream processing Platform and a component of SOA Suite. JBoss DROOLS Fusion is open source CEP solution. It is based on DROOLS engine. It adds event processing capabilities to DROOLS engine [13].

Truviso processes both historical and real time data. It visualizes the analyzed content using web based dash boards, report and alerts. Microsoft Stream Insight is a part of SQL Server. It models events using .NET language. Its CEP applications are also written in .Net language [12]. Corol8 CEP Engine is designed for high volume, low latency applications. It has 3 components. Corol8 is the runtime server for Corol8 applications. The Corol8 Studio is an interactive graphical environment for developing Corol8 components. Corol8 Portal is a dashboard and visualization server to display CEP output. RulePoint is CEP software from Informatica. It provides proactive monitoring and operational intelligence through real time alerts [16]. EVAM does CEP using events and action management. It contains real time event processing. It also offers a decision engine [11].

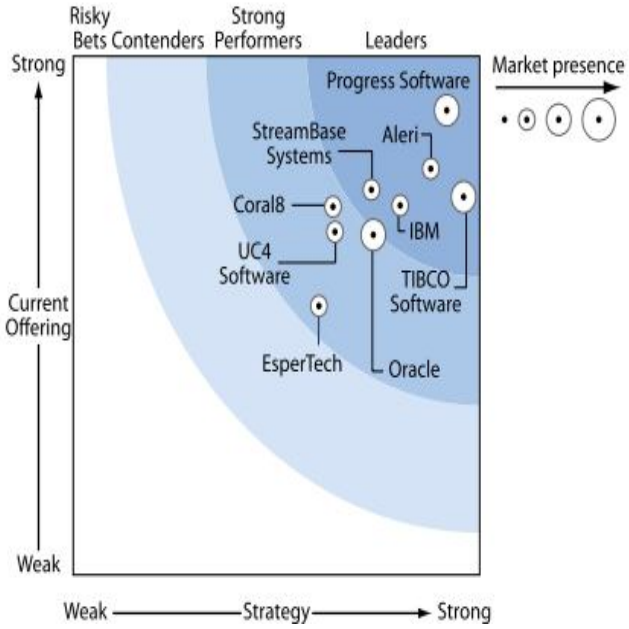

FIG: 2 FORRESTER RESEARCH'S CEP TOOLS EVALUATION

Forrester evaluated Tibco Business Events, Esper CEP, WebSphere Business Events, Oracle CEP, Aleri platform, Coral8 Engine, Progress Apama, StreamBase platform and UC4 CEP products in its research [3]. They have considered product features like event processing features, architecture, standards, interoperability, development tools, platform management and end user experience. They have also analyzed the current market of these tools. They have described the collaborations among these products. They have also analyzed the business strategy and road map of said CEP tools for future. Forrester Research's CEP evaluation is visualized in the figure 2. The picture shows the scores of CEP products where x- axis represents strategy and y-axis represents current-offerings.

ESPER got good marks for CEP capabilities. It got strong scores for platform administration, runtime architecture and event processing features [3, 4].

In [4] the place of CEP in Service Oriented Architecture (SOA) and Event Driven Architecture (EDA) is described. It also presents a survey on CEP tools. Focus is mainly on open source tools. Various features of tools like comfort, intuitive specification of events, integration of event streams & static data, ease in modifying event specification, multiple event streams processing capability, recovery, logging, time-model, consuming approach, data extraction from events, pattern detection, temporal relations, accumulation, aggregation and negation, actions, performance and high availability are compared. Survey states both ESPER and DROOLS have rich features. Additionally ESPER offers good performance and high availability. It is stated as good choice for mission critical applications.

We have chosen Esper for its open source nature, high availability and high performance [2, 6]. A system is proposed for IPB using Esper.

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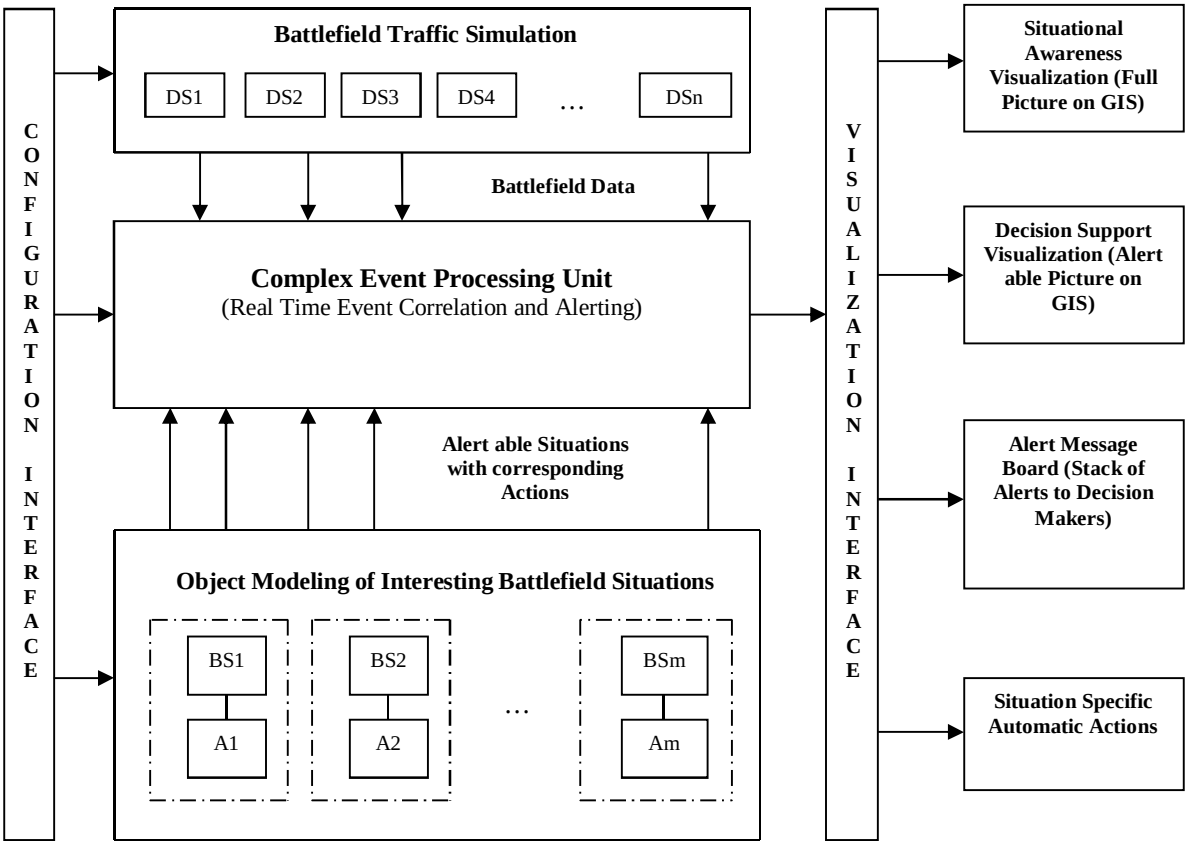

FIG: 3 BLOCK DIAGRAM OF THE SYSTEM

III. METHODOLOGY

In battlefield situations, various kinds of data come from various sources. For example data regarding friend force positions may come from one source, data regarding enemy positions may come from various radars or sensors and so on. In order to indentify the threats and opportunities, decision makers need to collect those pieces of data and correlate them in a particular fashion. Block diagram of the system is given in figure 3. The proposed system is aimed to fuse data streams originating from different sources to identify and respond to interesting situations. Battlefield data traffic is simulated. Battlefield traffic simulation unit simulates the various kinds of data streams. DS1 to DSn are data sources. Object-Orientation concepts are used to model data pieces as objects of various classes. Each such data object contains various properties and methods. For example “FriendPositionInfoObject” contains friend-type, id, latitude, longitude, timestamp and other details. Battlefield Traffic Simulation module will simulate such data streams and feeds them to Complex Event Processing Unit.

In battlefield situations decision makers will be interested about particular situations. When such situations occur they need to be informed about their occurrence. They feel better if that situation is visualized on the GIS map or they may be interested in taking some automated actions when such situations happen. But identifying such situations in real time by fusing huge data traffic originating from heterogeneous sources is a challenging task to the decision makers. The proposed system models the interesting situations as complex events. Each complex event will have complex pattern matching rules. In order to match a rule we may need to collect multiple data streams and correlate them in a particular fashion. For example decision maker may be interested in situation “Friend is found within the firing range of Enemy”, In order to check whether the situation occurred or not, he need to analyze the data streams related to friend position information, data streams related to enemy position information and other details like firing ranges of various kinds of enemy (which is the knowledge base about the vehicles). When such situation is identified, user may be interested in taking some action. The action could be receiving an ALERT saying the situation has happened, or displaying the situation on GIS map for effective visualization and further planning, or taking any other automated action, or the action could be any combination of above actions. “Object modeling of Interesting battlefield Situations” module will model the interesting

battlefield situations as complex events. BS1 to BSm are various kinds of Battlefield Situations that the decision maker is interested in. A1 to Am are corresponding action parts which need to perform when corresponding situation happens.

Complex Event Processing module is the core of the system. It processes incoming data streams and looks for interesting battlefield situations which are modeled as complex events. It continuously monitors the data streams to check the occurrence of complex events. The moment such situations occur, it identifies them in real time and performs corresponding actions. It is designed based on Esper CEP library. ESPER contains complex data structures to represent live data and to support faster correlation. It supports monitoring various situations in parallel. It is highly scalable. It means, huge number of new data streams and new situations can be added. It responds to the situations in real time or in near real time.

User can configure all above mentioned modules using Configuration Interface. User can say the system to process specific data streams for a specific period of time. User can say the system to monitor specific situations at specific period of time. User can configure the knowledge base which contains details like firing range, sensing range, speed of vehicles ...etc.

Visualization Interface visualizes the outcome of the system in an easily understandable manner. Situation Awareness Visualization depicts the full operational picture. It displays all the things that are happening in the battlefield environment. That full data may not be of interest to the decision maker. It is displayed to bring awareness about the situation and to do effective planning.

Decision Support Visualization depicts only situations that are of interest to the decision makers on GIS maps. It is of most interesting to the decision makers. When some interesting situation is identified by the Complex Event Processing module, it will be depicted on the GIS map with corresponding entities in easily conceivable manner.

Alert Message Board stacks the alert messages which indicate the occurrence of specific situations. These messages describe situations in textual form. For example, the message “Friend of type: Aditya ID:f106 at position Lat:13.1605 Lon: 77.629 is near to Enemy of type: CMT ID:e102 at position Lat:13.1695 Lon:77.643 by distance: 1.74Km” says the friend f106 is in 1.74 km distance(within the firing range of e102) to enemy e102. Data mining and post-mortem analysis on the log of these messages can uncover interesting hidden patterns or it can be used for effective planning.

Situation Specific Automatic Actions module performs automatic actions (specified by the domain experts) when specific situations occur.

IV. CONCLUSION

Challenges of battlefield decision makers are described. Various CEP tools have been analyzed and decided to use ESPER for its open source nature, good performance and high availability. Architecture and method is provided for Battlefield Decision Support using ESPER.

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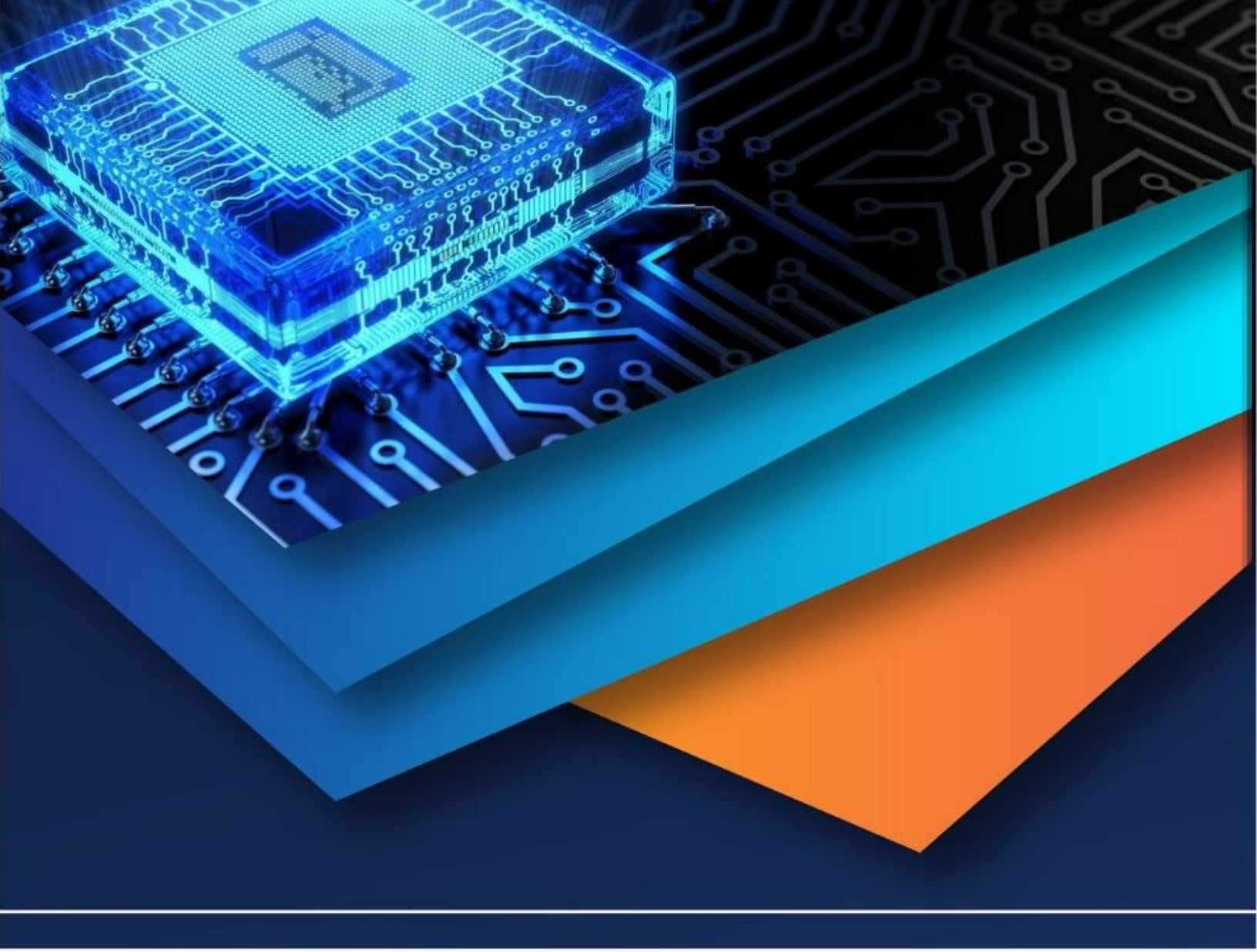

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