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Design for Sensor based Waste Segregator System

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Abstract: ***The effects of growing population, urbanization, and industrialization has started showing its detrimental effects on the environment as well as the human being. The rising waste generation is the direct consequence of population explosion. The waste generation rates are attaining new records every year and is a tickling bomb for mother earth and human beings. Integrated solid waste management is a technique for effective management of solid waste across all levels of waste management process. The segregation of waste is the first and the most crucial stage of solid waste management process. The segregation of the waste can be done either at the source of waste generation i.e. households, commercial establishments etc. or at the waste processing site or disposal site. The mixed waste becomes difficult to handle and manage because of its non-uniform composition. Waste is generally sorted using manual operations like employing the ragpickers to segregate the waste, but this turns out to be an intensive process in terms of both labor as well as cost. Due to high input costs involved in the segregation of wastes, many urban local bodies, municipal authorities and waste management agencies restrain themselves from segregating the waste and opts for direct disposal of waste which not only increases the toxicity burden on the land but also on the environment as poorly managed landfill sites are potential sources of land, air and water pollution. However, newer techniques for waste sorting is gaining momentum which is automatic sorting of waste by the means of sensor, the device used for automatic waste sorting is called as waste segregator. If the waste gets sorted at source, it will result in increased efficiency of solid waste management process, better waste recovery and waste recycle rates, lower carbon footprint and greenhouse gases emissions. There is a need to design a cheaper waste segregator system which should be financially viable enough to be adapted at office levels as well as household levels. In the present study, a design for the waste segregator system has been proposed which can sort the dry waste into glass, paper, plastic and metal by the means of sensor. The design proposed can be used to sort the waste at the source of waste generation like in the commercial establishments, households etc. and can turn out to be a de-centralized approach to waste sorting.***

Keywords: Solid waste management, waste segregation, greenhouse gases, waste generation

I. INTRODUCTION

The population explosion has now become a universal problem and the effects of the same can now be seen all around the world, especially in developing countries [1]. The growing population is not only increasing the burden on the planet but also on the environment and its resources as well. The increasing population brings certain problems with itself like profligate depletion of resources, rise in pollution levels, increasing carbon footprint etc. One such effect of the growing population is inflating rates of waste generation [2]. The waste generation of the world is growing at an alarming rate and poor waste management is further adding to this rate. Due to the rising urbanization, the material consumption is also rising and as a consequence of this waste generation is also increasing and has now become a matter of serious concern. The waste generated from households in general terms is referred to as Municipal Solid Waste (MSW) and it contains different types of waste both bio-degradable as well as non-bio-degradable. The biodegradable waste includes food waste, garden waste etc., while the non-biodegradable waste includes plastics, wood, rubber, paper, glass etc. [3]. These wastes are generally in accumulated form and are often characterized as garbage. Each type of waste has its own characteristics and qualities. However, when this garbage is collected from households, it is a single mixture and includes almost all types of waste in it. In developed countries, this waste is generally source segregated and it becomes easy to handle, manage, transport and process these wastes.

However, in developing countries like India, the waste segregation at source is not a common practice, and it becomes difficult to process the waste as per its characteristics [4]**.** In some places, this waste is segregated after collection and then it is processed accordingly depending on its characteristics and then is recycled or recovered. The segregation is done manually on the collection site by rag pickers which is not only time-consuming but also an unhygienic practice. The left waste which can't be recycled is sent directly to the landfill site and is dumped within the land which increases the burden on the land. In smaller cities where proper waste management is not available, the waste is directly collected and dumped in the landfill sites [5]**.** The problem with landfills is that it requires space, it pollutes the overall water as well as air quality of the area within the radius of the landfill site which imparts significant effect on the health of the people working on the landfill site as well as to the people residing in the adjoining area.

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India is the house of three out of fifty biggest landfill sites in the world. The capital of India New Delhi has the seventh biggest landfill site in the world and from this the seriousness regarding waste management issues can be understood. Improper implementation of government policies, lack of infrastructure and lack of awareness has only catalyzed this problem of waste management [6]. The solution to this problem lies within the source of generation itself. Improperly segregated waste affects the overall process of waste management. If the waste is properly segregated into various categories at the source, it becomes easier to further process the waste, and hence the burden on landfilling can be reduced significantly and also the recovery and utilization of the waste can be increased [7]

Automation based or automatic sorting of waste is a newer technique in which the waste gets sorted automatically by the means of machines known as waste segregators. Waste segregators eliminates the need for appointing labors at site for segregation, also they overcome the problem of poor awareness of citizens when it comes to the correct selection of bin for a specific type of waste, hence, these systems can deal with two major flaws in the solid waste management system in one go. Many automatic waste segregator systems have been designed which can sort the waste into many categories by the means of robotics and sensor-based techniques. Automatic sorting of the waste can be a gamechanger in waste segregation and consequently in the overall solid waste management system. [8]

If the process of source segregation can be mechanized, then it becomes a lot simpler and quicker to process this waste. Also, the overall cost involved in the waste management for segregation of waste and the waste processing time can be reduced to a huge extent. Moreover, if the source segregation is done effectively, it can also generate revenue for the stakeholders. Thus, in the light of this issue, the present study is undertaken to design and develop a mechanized waste segregation system and to further scale up to the community level.

II. LITERATURE SURVEY

A. Waste Sorting and Techniques for Waste Sorting

The sorting of the waste is practiced generally either at source of waste generation i.e. households or at the processing site like landfills etc. Segregation has certain advantages like easy management of waste, increase in efficiency of SWM process, high resource recovery etc. Nowadays, sensor-based sorting of waste has gained focus and many technologies have been devised for effective sorting of waste. The technologies pertaining to waste sorting have been summarized in the Table I.

Table I
Overview Of Waste Sorting Technologies

Techniques	Types of materials recovered	Types of sensors	Main process features	Classification success & recovery rate (in %)	Limitations	References
X-ray based sorting techniques						
XRT/ DEXRT and EMS method	Cast and wrought aluminum, Cu, Mg	Line scan camera, DE- XRT detector, EMS	Specific atomic density of material irrespective of size, moisture or dust is detected	90-97	-Issue in categorizing between wrought and cast aluminum (can be overcome by hybrid techniques) -DEXRT inefficient for smaller particles	[9], [10], [11]
XRF based	PVC	X-ray source, XRF detector	Detects elemental composition of material in the form of tracers based upon atomic density	92-96	-XRF cannot differentiate plastic types (except PVC)	[12]
XRF based	As, Cr, Cu treated wood	X- ray tube, solid state detector	Detect reflectance of particle signature of the material	91-98	-Identification of tracers are limited to periodic table	[13], [14], [15]
Optical based sorting techniques						
Optical sorting method	Cu, Al, Mg, Zn, SS, Ni, Br	3D imaging camera, Optical	Material color (red, green, and blue), shape	86-95	-Inductive sensors are sensitive to distance changes	[16], [17], [18]

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		CCD, Linear laser	and size properties detected		-Complex shapes of material can cause variation in measurement	
Co-occurrence feature sorting	WP, ONP, OCC	Web camera	Classification is done through rule- based classifiers and by energy for the co-occurrence matrices	90.67	-Unsuitable for real- time implementation -High computational time	[19], [20]
Template matching/ DNA computing algorithm	WP, ONP, OCC	Web camera	RGB string is applied over entire pixels and template matching is done.	90-96	-Varied illumination can cause error in detection -High computational time	[21], [22]
Dominant color	WP, ONP, OCC	Web camera	Features taken. Histogram scale length on the dark side, histogram scale length on the light side, energy, mode using KNN classifier and by absolute distance metric	93	-Performance is influenced by lighting conditions -Consistent illumination is required	[23]
Windows feature method with RGB color space	WP, ONP, OCC	Web camera	RGB component mode and energy taken by CBR approach. case base reasoning	95.17	-	[24]
Windows feature with HSI color space	WP, ONP, OCC	Web camera	Mean of hue and mean of saturation are calculated by chromaticity. with window-based subdivision, distance, and voting	91.07	-Weight of the throughput depends upon the grade and size of the paper	[25]
Optical sorting	Colored glass (red, green, blue)	Line scan camera	Properties based upon their color intensities	-	-Possibility of misreading of colors due to film buildup -Cullet furrowing can cause non uniformities	[26], [27], [28]
Ultraviolet based sorting	Ceramic glass, lead glass, borosilicate glass	Ultraviolet sensor	Material is identified based on monochromatic properties	-	-Detection of non- transparent or low- transparent impurities are not possible	[29], [30]
Spectral based sorting techniques						
Hyperspectral based sorting	Cu, Al, Pb, SS, Brass	Spectral CCD camera	Detects spectral signature and color properties of material	95-98	-HSI fails to discriminate stainless steel if it has the same spectral information with other non-ferrous metals	[31], [32]
Spectroscope analysis method	PE, PET, PP, PS, PLA, LDPE, HDPE	NIR, MIR, VIS spectrometers	Material color (red, green and blue) and spectral signature are detected	96-98	-	[33], [34], [35]
Spectral sorting approach	Ceramic glass	CMOS spectrometer camera (NIR, VIS, HSI)	Detects spectral signature of the material	-	-VIS signal ignores material with label and surface contaminants	[36], [37]

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B. Recent studies in waste segregation system

[38] designed a waste sorting system which is first of its kind as it uses optical sensors, machine learning and multi-feature recognition method to accurately sort the waste. The system is based on 3-dimensional image processing. It has the potential to sort the waste on the basis of color, texture and shape which makes the sorting of the system more accurate than the conventional sensor-based sorting systems. The waste moves on the conveyor belt and the scanning camera senses the waste and by image recognition identifies the waste type and the corresponding assembly moves the waste detected into the corresponding bin.

[39] designed an Automated Waste Sorter with Mobile Robot Delivery Waste System which can be used to sort the wastes like aluminium cans, glass bottles, and plastic bottles. The system consists of a magnetic motor and neodymium magnets. A tunable capacitive sensor has been used which through the change of capacitance can identify the glass bottles. The system is a conveyor-based system which has been attached with a mobile robot delivery waste system which automatically feeds the waste into the segregator system. The system utilizes microchip PIC 16 F877A to handle the operations of the system. The sorting accuracy of the system has been found to be 93.75 %.

[40] proposed a technique called Automatic Sorting of Solid Wastes Using Sensor Fusion which uses sensor fusion technique in which the outputs of the various sensors have been combined and calibrated for detection of the desired type of waste. The use of such a technique makes the sorting process more reliable and accurate. The system has been equipped with programmable logic controller, an inductive proximity sensor, a capacitive proximity sensor, and a photoelectric sensor. The system has the capability to sort the waste into four categories. As soon as the waste is detected the stepper motor tends to rotate at a particular angle to collected the waste into a particular type of bin.

[41] designed a segregator system which can sort the waste into metal waste, wet waste and dry waste. The ARM micro-controller acts as the central controller of the system. Conveyor belt has been used to move the waste through various set of sensors. The metal waste is detected using inductive sensor, the dry and wet waste gets sorted by the help of moisture sensor. The system is also equipped with an infra-red sensor which turns the system on when waste is fed into the system.

[42] proposed Automation of Waste Segregation System using PLC which is a conveyor-based waste segregation system. It uses a moisture sensor to differentiate between wet and dry waste fed into the system. The segregator system is controlled by Programming Logical Controller (PLC). An infrared sensor has been used to detect if a waste is fed in the segregator system. The PLC is a BOSCH Rexroth manufactured by BOSCH. For the detection of plastic waste, the system uses a photoelectric sensor with built in amplifier which can detect clear plastic bottles. Proximity sensor has been used to detect paper and glass waste in the segregator system. A hydraulic cylinder has been equipped into the waste segregator system to push the waste detected into the corresponding bin type.

[43] suggested a design of a sensor-based waste segregator system. The system is capable of sorting the waste into three basic categories of waste namely glass, metal and plastic. The design of the system is quite similar to the ones discussed in the previous literature. Like other systems, this system is also a conveyor-based system where the waste is moved through the detection points of various sensors. The system uses a Programming Logical Controller to control and co-ordinate the input and output of the signals as well as the movement of the conveyor belt.

[44] illustrated a waste segregator system which sorts the waste fed in the segregator system into metal, wood and plastic. The segregator system utilizes a set of sensors to distinguish between types of waste. It relies on inductive proximity sensor to detect the metal objects in the waste. Capacitive sensor will be used to differentiate between metallic and non-metallic materials. The waste segregator system segregates the fed waste by the means of a moving conveyor belt through which the waste moves through varies sensor assembly and gets sorted upon detection of particular type of waste. The entire working of the system is controlled by a Programming Logical Controller which has been calibrated with the various sensor combinations for waste detection and conveyor movement.

[45] proposed a waste segregator design which like previous designs discussed in the literature review doesn't rely on the conveyor belt for the movement of the waste in the system. Instead it uses a flap design and a rotor type arrangement which is used to rotate the three bins about a central axis. The system is capable of sorting the waste into wet waste, dry waste and metallic waste depending on the type of waste fed into the system. An infrared proximity sensor module has been set up to detect the presence of waste into the system. The inductive sensor has been used for detecting the presence of metal in the system. Capacitive sensing module has been used to detect between the wet and dry form of waste by assessing the relative permittivity of the material. The central brain of the system is micro-controller MSP430G2553 which is used to control the outputs of the sensor and the movement of the flaps.

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[46] IoT Based Automated Waste Segregator for Efficient Recycling. The system segregates the waste into metal waste, dry waste and wet waste. The system uses Arduino mega controller for handling the sensor operations and the movement of the conveyor belt. A metal detector-based sensor has been used to identify the metals in the waste. The moisture sensor has been used for distinguishing between the wet and dry type of waste. The system has been equipped with a digital LCD display which shows the status of the system.

III. RESULTS and DISCUSSION

A. *Design of the Waste Segregator System*

The proposed waste segregator consists of four sensors for the detection of the waste fed into the system. The inductive sensor is used for the detection of metal waste. Three capacitive sensors will be used for the detection of glass waste, paper waste, plastic waste respectively on the basis of dielectric values of the waste. The actuator is used to push the waste into the corresponding bin upon successful waste detection. The waste segregator system will be operated and controlled through the help of Programming Logical Controller (PLC). The waste movement will be controlled by flaps which will be operated by the means of a D.C. motor.

B. *Working of the Waste Segregator System*

The waste will be fed into the waste segregator system one by one. The waste will enter directly into the first chamber where the inductive sensor is placed. If the waste is metal, then the actuator placed with sensor will start working and will push the waste into the bin for metal waste. If the waste is not detected by the sensor, then the flap will open by the means of D.C. motor and the waste will fall into the second chamber where first capacitive sensor is placed for the detection of glass waste. If the waste is glass waste, the actuator will push the waste into the glass waste bin. If the waste is not detected by the sensor, the corresponding flap will open and the waste will fall into the third chamber where capacitive sensor is placed for detection of paper waste. If the waste is paper waste, the senor will detect it and the actuator will push the waste into the paper waste bin. If the waste goes undetected, the flap will open and the waste will fall into the final chamber where capacitive sensor for detecting plastic waste is placed. If the waste is detected by the sensor as plastic waste, the actuator will push the waste into the plastic waste bin. Any waste that goes undetected through all the four sensors will reach to the last bin which is placed for undetected waste.

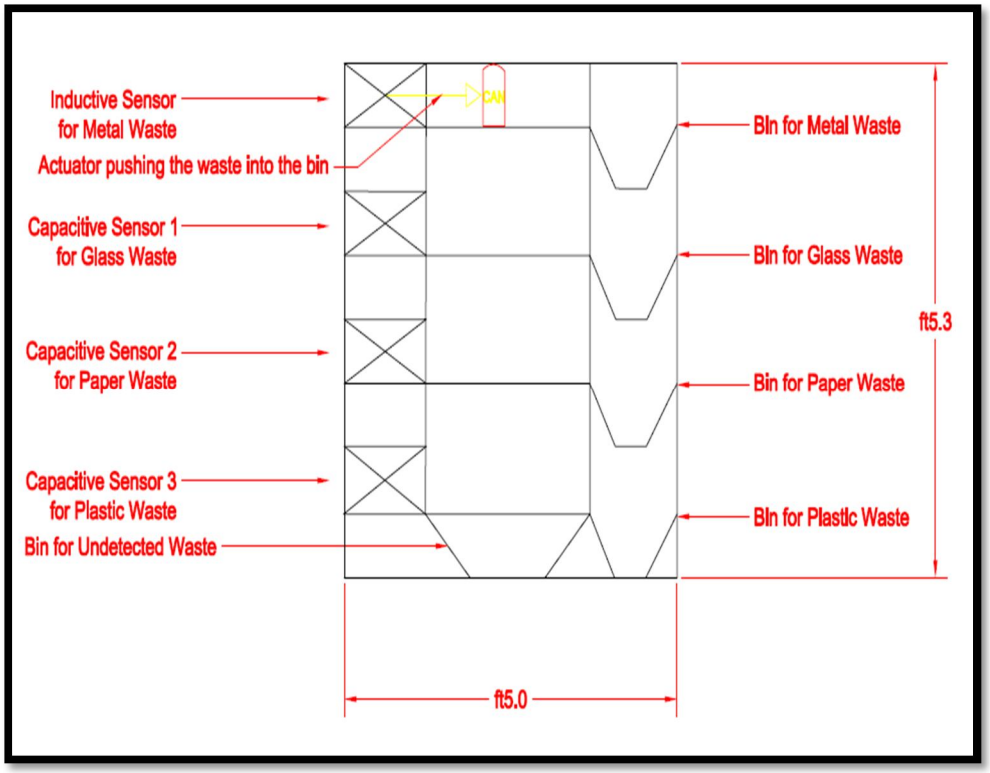

Fig. 1 Waste segregator system

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Fig. 2 Programming logical controller

Fig. 3 Inductive sensor

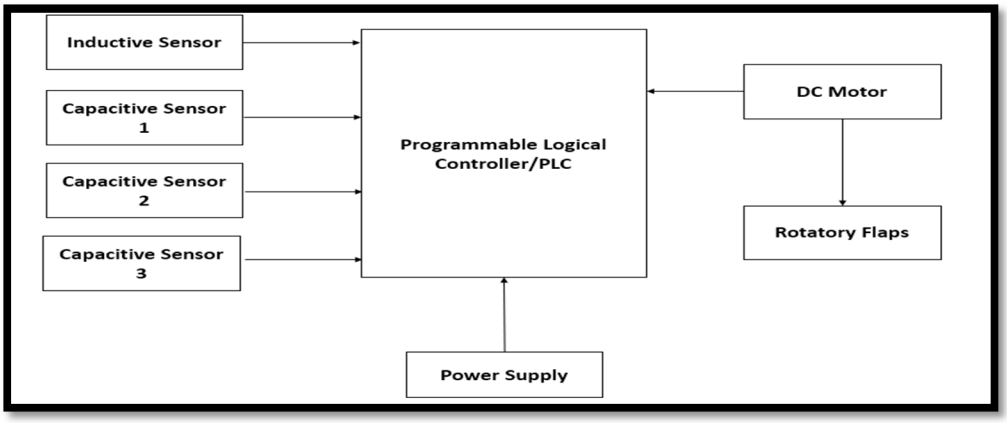

Fig. 4 Block diagram of waste segregator system

IV. CONCLUSIONS

Effective management of waste is the need of the hour and a wake-up call for the waste generators. Waste segregation can play a pivotal role in the improving the overall process of waste management. A well segregated waste into its primary categories can readily improve the material recovery process of waste, energy generation potential of the waste, recycling rates of the waste. Segregation of waste can lead to cost savings as there will be no need to employ manual sorters for waste sorting, lower carbon footprint, greenhouse gases emissions, reduction in land, air and water pollution are the colossal benefits of waste segregation. The proposed design of waste segregator system is unique in the sense that it doesn't involve the use of conveyor belt which consequently saves on the space requirements and also makes the design less complex. Taking the world towards automatic segregation of the waste rig at the source of waste generation in a sustainable, user friendly, environment friendly and economical manner can be a breakthrough in the solid waste management system.

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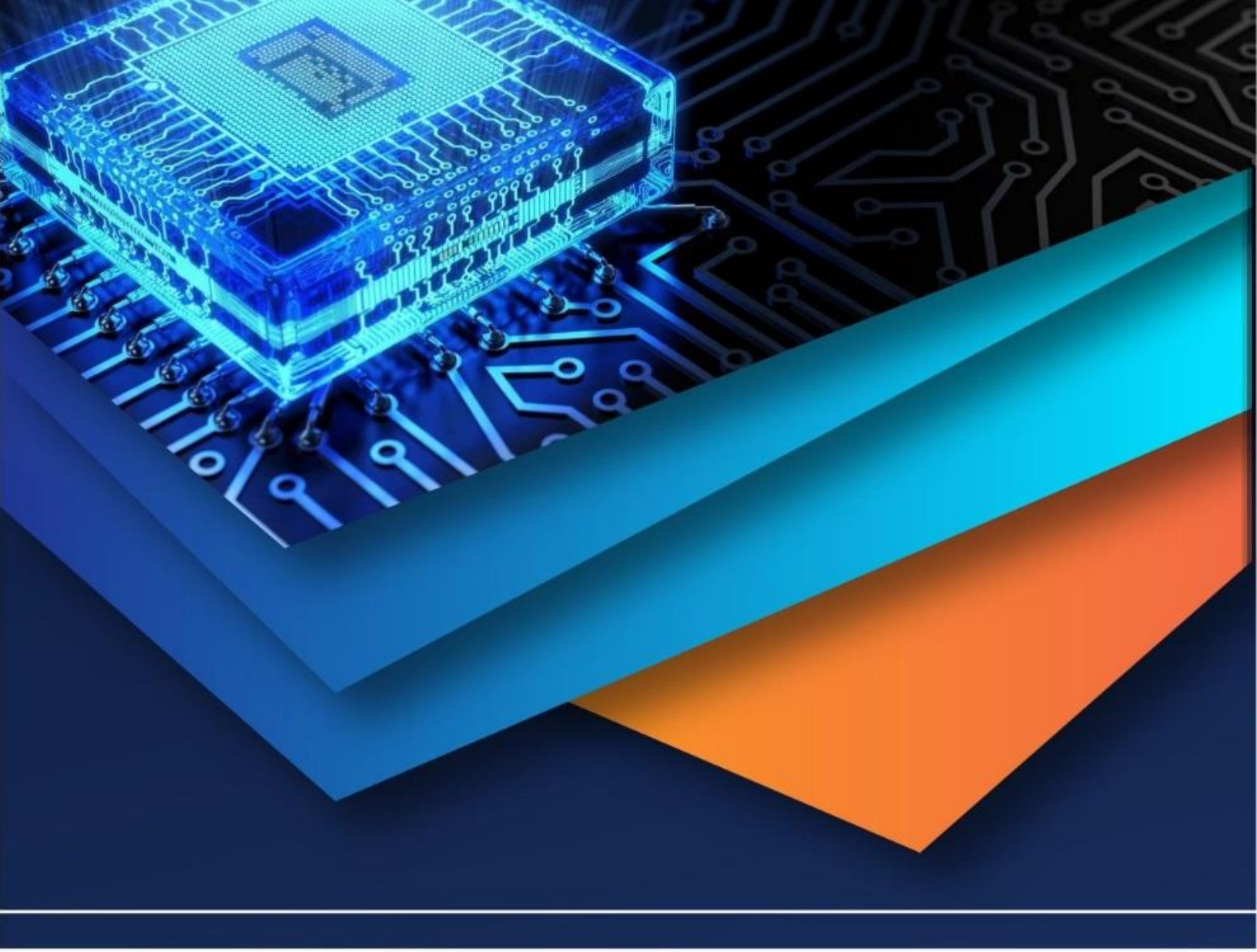

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