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Contents

Emergence of Smart City: Challenges and Opportunities

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ABSTRACT

With the progression of time, the world population is expanding. Appropriate usage of resources and different devices in the smart city, is extremely crucial to be able to quickly evaluate, monitor, and regulate the Internet of Things (IoT) resources. As a result, technology and equipment facilitate to make us smarter and more accessible and usable. Creating smart linked systems for our cities has several advantages for residents all over the globe, not only in terms of improving quality of life, but also in terms of ensuring sustainability and the most efficient use of resources. These solutions rely on a coordinated effort by the government, the private sector, and local citizens. Smart cities, on the other hand, may leverage technologies like the Internet of Things to improve the lives of people and develop connected living solutions for the expanding global urban populace with the right support and infrastructure. This chapter discusses the role of smart cities and also highlights its features, Technologyused, benefits, limitations and challenges.

Keywords: Smart city, IoT, AI, block chain, ICT, digital city, smart healthcare, smart technology.

INTRODUCTION

Smart cities collect and analyze data using connected sensors, lighting, and meters that are examples of IoT devices. Cities then use this data to improve infrastructure, public utilities, and services, among other things. This ICT architecture includes aconnected object network with intelligence and gadgets (also referred to as a "digital city") that sends data through wireless technologies and the cloud. Cloud-based IoT apps collect, analyse, and manage real-time data to help municipalities, organizations, and individuals improve their quality of life by making better decisions (Thalesgroup). In the smart city, the uses of IoT are used without human association. Different IoT devices are associated for distinct activities and communicate with each other. IoT connects billions of devices, generating massive amounts of data that must be processed, managed, and stored on the cloud. IoT is often characterized as a real object that is widely scattered and has limited storage and processing capabilities, with the goal of improving the performance, reliability, security and their infrastructure (Talari, S). Smart energy, smart buildings, smart citizens, smart transportation, smart healthcare, smart infrastructure, smart technology, smart governance and education, and last but not least, smart security are all areas where smart technology may help. The features of a smart city are shown in Figure 1.1.

Figure 1.1 features of a smart city

• Smart Economy: It helps local firms contend on a universal basis whereas in addition creating high-quality, well-paying jobs.

• Smart People: They are competent personnel to facilitate that utilize of information and technology, values creativity and innovation, and is keen to try new things. They have the assistance of community leaders and mentors, and they meet the demands of today's and tomorrow's employers.

• Smart Governance: It guarantees that the resources available in the city are efficiently utilised to improve living conditions.

• Smart Environment: It aids in the attainment of good growth while preserving resources. It unifies the living and working environments. It maintains a balance between energy supply and consumption.

• Smart Living: It ensures that all residents have access to a healthy way of living healthcare, education, and securities are all important factors to consider.

• Smart Technology: It makes use of cutting-edge wireless technologies like as zigbee, zwave, bluetooth, and LoRaWAN. It aids in the automation of domestic gadgets, among other things.

• Smart Energy: It makes use of a smart grid to offer continuous electricity while also allowing for power/energy conservation.

• Smart Healthcare: To provide better healthcare, it makes use of the most up-to-date amenities for patients, such as remote monitoring.

• Smart Mobility: It makes use of current transportation infrastructure and cuttingedge technology to provide smart mobility solutions for people.

2. LITERATURE REVIEW

The notion of the smart city may be traced back to the 1960s and 1970s, when the Community Analysis Bureau began collecting data, issuing reports, and directing resources to the regions that needed them most in order to combat impending calamities and reduce poverty. There have been three generations of smart cities since then. Technology suppliers were the driving force behind Smart City 1.0. Despite the municipality's incapacity to completely comprehend the technology's potential consequences or the effects it may have on daily life, this generation concentrated on adopting technology in cities. Smart City 2.0, on the other hand, was driven by cities. In the second generation, forward-thinking municipal officials assisted in determining the city's future and how smart technology and other innovations may be used to achieve that goal. In the third generation, Smart City 3.0, neither technology suppliers nor city officials are in charge; instead, a citizen co-creation model is promoted. This most recent modification appears to be motivated by concerns about equality and a desire to build a smart community that is socially inclusive (Ahad,20). Vienna, Austria is one of the first cities to use this third-generation concept. Wien Energy, a local energy provider, has formed a cooperation with the city of Vienna. Vienna included residents as investors in local solar facilities as part of this cooperation. Citizen participation in topics such as gender equality and affordable housing has also been emphasised in Vienna. Vancouver, Canada, followed the Smart City 3.0 approach by including 30,000 residents in the development of the VancouverGreenest City 2020 Action Plan (Ahad,20)

Another precursor to the smart city is the digital city, a technologically-defined city that uses widespread broadband infrastructure to support e-Governance and "a global environment for public transactions" (Mitchell, 2000) [12].The notion of smart city is established from the combination of the knowledge society and digital city. It is defined as a "multi-layer territorial system of innovation" made up of digital networks, individual intellectual capital, and the social capital of the city, which together constitute collective intelligence (Komninos, 2008) [13].

3. SMART CITY ARCHITECTURE

The Internet of Things consists of three levels including the perception layer, the network layer, and the application layer, as shown in Figure 1.1. The perception layer encompasses a collection of Internet-enabled devices capable of perceiving, detecting, gathering, and exchanging information with other devices over Internet communication networks. Perception layer consists of radio frequency identification devices, cameras, sensors, and global positioning systems . The network layer's job is to data from the perception layer is forwarded to the application layer within the constraints of device capabilities, network limitations, and application constraints. IoT systems make use of a variety of technologies like Bluetooth and ZigBee to send data from perception devices to a nearby gateway based on the communication parties' capabilities. (Huang) 2G, WiFi, 3G, 4G, and Power Line Communication (PLC) are examples of internet technologies Because apps intend to develop smart cities, smart homes, demand-side energy management, power system monitoring, , distributed power storage coordination, and renewable energy generator integration, the information is received and processed at the application layer. As a result, we may develop more effective electricity distribution and management systems.

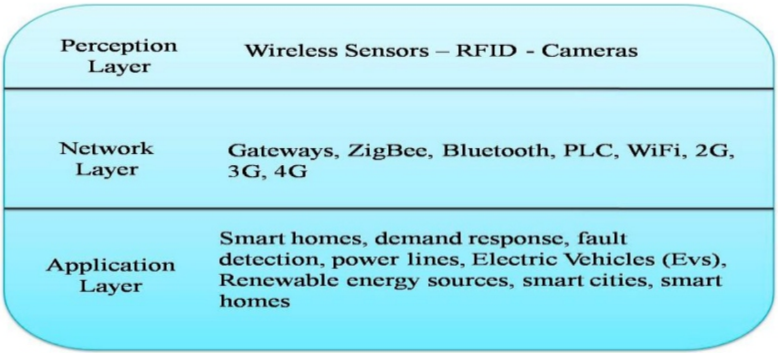

Figure 3.1 IoT layers.

4. Smart City Technologies

Technologies crucial for smart cities are as follows:

4.1 Information and Communication Technology

Figure: 4.1 ICT

For a city to be smart, establishing a two-way communication connection is crucial.. And here is where information and communication technology (ICT) comes in. ICT creates a link between citizens and government. The government can use ICT to study demand patterns.

4.2 Internet of Things

4.2 Internet of Things

Figure: 4.2 IOT

Every device in a smart city must be coupled to one another so that it can communicate through one another and build decisions for itself, allow for the management of the resources of a megacity.

4.3 Sensors

Figure 4.3 Sensors

Sensors are unnoticed but pervasive in the metropolitan environment. Sensors are an important component of any intelligent control system..

4.4 Geospatial Technology

Figure 4.4 Geospatial Technology

whatsoever is build in a smart city must be right, and in order to build right, a right plan is required, which requires accurate, concise, as well as detailed data. It provides a location that enables for better pinpointing of the need.

4.5 Artificial Intelligence

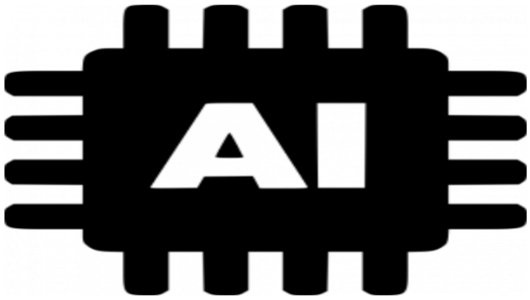

Figure 4.5 AI

AI enables machine-to-machine contact by digesting and making sense of data. AI may be able to figure out where they occur. most frequently and under what circumstances, and this information can be utilized to improve power management.

4.6 Blockchain

Figure 4.6 Block Chain

The block chain is a relatively latest application to the smart city notion. It is used to protect data transmission. (Syed,21)

5. Characteristics and Limitations of a Smart City

5.1 Characteristics of a Smart City

Dense environment, like that of cities and capitals, requires its subsystems to work as one system with intelligence being infused into each subsystem. Researchers who support this integrated view stress the importance of the organic integration of a city's various subsystems (transportation, energy, education, healthcare, buildings, physical infrastructure, and public safety) into one unified system to create a smart city

Figure 5.1 Characteristics of a Smart City [18]

5.2 Limitations of a Smart City

• Very limited Privacy:

Maintaining anonymity has become increasingly difficult with the emergence of surveillance cameras and sophisticated systems that are networked across multiple places. Face recognition technology, for example, has changed the way we think about personal privacy.

• Social control:

The ability to track and centralize data grants a great deal of power to the person in control of it. Anyone with access to people' data, whether it's a government or a corporation, may influence, control, and intimidate the public.

• Excess network trust:

Cities that rely nearly entirely on technologies and networks lose control over their decision-making and in the event that these tools are unavailable, you may be unable to react or act.

5.3 Smart Cities Mission

The Smart Communities Mission's goal is to promote cities that provide basic infrastructure and provide a fair quality of life for their residents, as well as a clean and sustainable environment and the use of "Smart" solutions. The emphasis is on sustainable and equitable development, with the goal of creating a repeatable model that will serve as a beacon for other aspiring communities. The government's Smart Cities Mission is a bold new effort. Its purpose is to establish examples that may be repeated both within and outside of the Smart City, thereby catalysing the creation of similar Smart Cities across the country.

As a result, the Smart Cities Mission's goal is to spur economic growth and improve people's quality of life by facilitating local area development and utilising technology, particularly technology that leads to Smart results. Existing areas (retrofit and redevelop), including slums, will be transformed into better planned areas through area-based development, thereby improving the overall liveability of the city. To accommodate the growing population in metropolitan areas, new spaces (greenfield) will be constructed around cities. Smart Solutions will allow communities to improve infrastructure and services by combining technology, information, and data. This type of comprehensive development would improve people's quality of life, create jobs, and raise incomes for everyone, including the poor and disadvantaged, resulting in inclusive cities.

The ability of a city to produce well-being for its residents is described as “smart."However, it is not just about how citizens benefit from the government's services. Citizen participation is a critical component of a smart city. It is based on the notion that citizens, rather than the city, construct it. This instrument is used by cities to collect data in real time on a variety of topics, such as traffic, air and water quality, and solar radiation. The government can respond quickly with this information to fix almost any situation. Installing sensors in the streets to detect things like empty parking places and traffic congestion, estimating how long it will take the next bus to arrive, and measuring air and water quality are just a few of the most well-known uses of this instrument. Others, such as sensors that detect the quantity of pedestrians, address environmental challenges. When there aren't any people nearby, the sensors can limit the amount of street lights, saving energy.

To make use of this data, governments must first figure out how to arrange it all in a way that is both meaningful and actionable. That's why Bismart invented bigov Better City Indicators, a tool that allows you to monitor and analyse data in graphical form so you can see trends and patterns clearly and fast. Governments aren't the only ones who have access to this kind of data. People may use data to better manage their days thanks to apps like ApparkB, Bicing, and others. Barcelona, for example, built a new intelligent bus network based on information on how passengers really used public transportation. This new network is more efficient, and it provides high-quality bus service to 95 percent of the city's people. Better and more frequent bus service is now available thanks to the upgraded bus network. Bus stations are very well connected to other modes of transportation.

GPS sensors are being used by the city to improve emergency medical services. Ambulances are detected by traffic lights, which adjust their output to allow emergency services to move through the city as rapidly as possible while avoiding dangerous circumstances. Bstia Ciutadana is another app that allows Barcelona people to better their life through technology. They may use the app to report problems such as malfunctioning stoplights or overflowing trash. As a result, the authorities will be able to dispatch a team to address the issue as quickly as feasible.(Ahad, 20)

5.4 What makes a smart city tick?

Smart cities use a web of linked IoT devices and other technology to fulfil their aims of bettering people's lives and growing their economies. Smart towns that succeed follow a four-step process:

1. Collection - Data is collected in real time by smart sensors placed around the city.
2. Analysis - The information gathered by the smart sensors is analysed in order to derive useful conclusions.
3. Communication - Through robust communication networks, the insights discovered during the analytical process are disseminated to decision makers.
4. Action - Cities utilise data-driven insights to develop solutions, enhance operations and asset management, and improve people' quality of life.

5.5 Why do we require Smart Cities?

A smart city's main objective is to develop an urban environment that provides inhabitants with a high quality of life while simultaneously producing overall economic growth. As a result, one of the most significant advantages of smart cities is their potential to allow improved service delivery to people with less infrastructure and expense. As the population of cities grows, it becomes important for these cities to make better use of existing infrastructure and assets in order to handle the growing population. Smart city apps can help to make these changes, as well as improve city operations and people' quality of life. Cities may use smart city apps to discover and develop new value from their current infrastructure. The enhancements help governments and citizens save money by facilitating new income sources and operational efficiency. (Ahad, 20)

5.6 Are Smart Cities Sustainable?

As smart cities strive to enhance efficiency in urban areas and promote citizen wellbeing, sustainability is an essential consideration. Cities have a number of environmental benefits, such as smaller geographic footprints, but they also have certain drawbacks, such as the usage of fossil fuels to power them. Smart solutions, such as the deployment of an electric transportation system to decrease emissions, might help mitigate these detrimental consequences. While not in use, electric cars may serve to control the frequency of the electric grid. Such sustainable transport options should also see a reduction in the number of cars in urban areas as autonomous vehicles are expected to reduce the need for car ownership amongst the population.

Developing such long-term solutions might have both environmental and socioeconomic advantages.

5.7 Challenges in Smart Cities

Smart cities come with a lot of advantages, but they also come with a lot of problems.

These include government officials who allow citizens to participate in large numbers.The private and public sectors must also work together with residents so that everyone may contribute positively to the community. Smart city initiatives must be open to the public and accessible through an open data site or mobile app. This allows individuals to interact with the data and accomplish personal activities such as paying bills, locating efficient transportation alternatives, and evaluating home energy consumption. To avoid hacking or misuse, all of this need a strong and secure data gathering and storage infrastructure. Data from smart cities must also be anonymized to avoid privacy concerns. With hundreds, if not millions, of IoT devices needing to connect and operate together, connectivity is likely to be the most difficult problem. As demand grows, this will allow services to be connected and continual improvements to be made.(samih, 19)

Aside from technology, smart cities must also include social aspects that contribute to a cultural fabric that is appealing to inhabitants and provides a feeling of place. This is especially crucial in cities that are being built from the bottom up and must attract citizens.(Sharon)

CONCLUSION

We offered a survey of several initiatives in the field of smart cities in this chapter. Europe, Paris, New York City, and London are at the forefront of smart city development around the world. In this chapter, we will look at the notion of smart cities, the perception layer, the network layer, and the application layer, as well as smart city technologies, their benefits, limitations and challenges. Creating smart linked systems for our cities has several advantages for residents all over the globe, not only in terms of improving quality of life, but also in terms of ensuring sustainability and the most efficient use of resources. These solutions rely on a coordinated effort by the government, the private sector, and local citizens. Smart cities, on the other hand, may leverage technologies like the Internet of Things to improve the lives of people and develop connected living solutions for the expanding global urban populace with the right support and infrastructure.

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Tasks optimization and knowledge reuse during product design process

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A B S T R A C T

The work presented in this paper provides an approach for minimizing the time during the design project of mechanical products. This approach focuses on a process of knowledge capitalization and knowledge reuse, which encourages to take advantage of knowledge stored in the project memory to minimize design time and exploit knowledge commensurate with project design that travels the shortest minimum.

This work is based on two aspects. The first aspect is developing an ontology devoted to define and specify the knowledge domain of users; the second is the integration of an organizational model in the ontology in order to specify the collaboration between the actors and the knowledge sharing process. Through this paper, we focus on providing assistance to businesses involved in design projects.

Keywords_ Project memory, organizational model, ontology, knowledge reuse, knowledge capitalization, minimizing the time.

INTRODUCTION

During the last two decades, the competitiveness and competitive between companies has been altered. Competitive companies are those that have the ability to quickly transform new ideas precisely new knowledge into new products or develop their products through their control of the design process.

Therefore, industrial companies are facing competition from increasingly strict. In this regard, we note that the major advantage for any business is concentrated on the design activity; the latter consists in the elaboration of the definition (technical, functional and geometric) of a product based on specifications. In fact, design is a process that does not stop when we arrive at a product, but it takes every look how we can offer the market quickly and cheaply. This is why the design is becoming increasingly complex. On the one hand, the requirements of clients experienced a remarkable transformation, and on the other hand, knowledge related to the design process are constantly increasing, while improving the techniques and available solutions in order to achieve quality products that conform to our needs.

Knowledge scattered encourages companies to seek a way to store, analyze, share, and apply where the discipline of knowledge management (KM) which is interested in improving the use of the knowledge portfolio.

Knowledge management is a strategic multidisciplinary to achieve the aimed objective to exploit optimally the knowledge of the company.

Owing to this perspective, knowledge management is considered such as a major economic challenge for any organization that seeks the performance.

This work will be designed to minimize the duration of a design project. We are also interested in the knowledge reuse process in order to offer to business actors the most relevant knowledge of the process minimum duration, and also the knowledge capitalization process that is used to store and preserve knowledge from each new design project.

This paper is organized as follows: section 2 introduces the background used in this work. Section 3 describes our minimizing duration of design process approach. In section 4, we give an overview of related work and we conclude by stating the main research ideas.

BACKGROUND

a. The design process

The design process used by the company is based on the retroactive and cooperative model [Ben Miled, 2020].

This design process is mainly composed of four phases, each one containing a set of activities, which can themselves be divided into sub-activities. Each activity ends with the completion of a deliverable. Indeed, an activity involves several actors or trades. A business actor may play one or more roles. Activity takes place in a very specific time, described with a start date and an end date.

Phases of the design process are the same for all projects in product development. The first phase called phase of "feasibility study", a second phase called "preliminary", a third phase represented by "detailed study" and finally the phase of "industrialization".

These four phases are responsible for the birth of a mechanical product.

The following figure shows the first phase of the design process used by the company

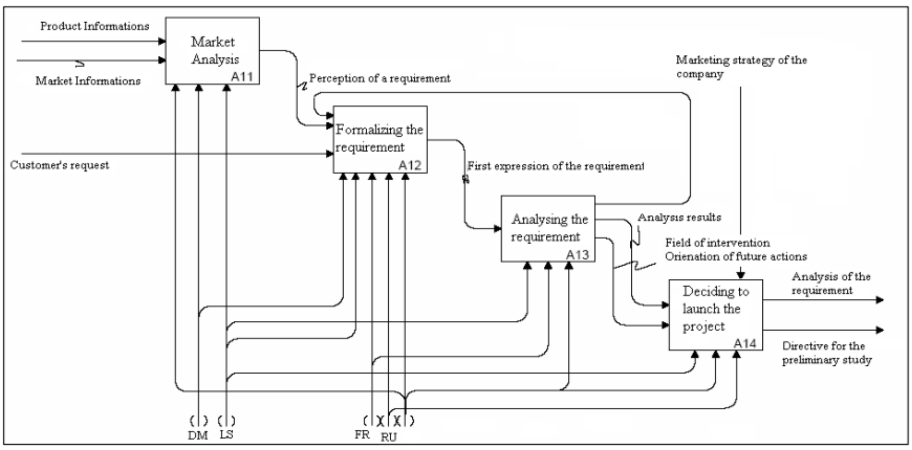

Figure 1. The first phase of the design process used by the company

b. Meta-Model RIOCK

We [Ben Miled, 2014] have resorted to the use of organizational model in engineering design projects. Indeed, the organizational model reflects the inclusion of social and cooperative aspects of the design process that encourages business actors to work together by creating, using and sharing their knowledge in order to achieve a common goal.

Organizational modeling is based on the meta-model RIO [Hilaire, 2000], which is essentially based on three main concepts namely: organization, interaction and role. This model is intended to represent an activity by an organization. Within this organization we describe the roles of business interact. With relation to this, an interaction means collaboration and exchange (sharing) of knowledge between business actors' trades.

The Meta model RIO allows us to represent a phase of an organization divided into activities, including those activities are themselves described by organizations.Moreover, the meta-model RIOCK [Ben Miled, 2020] adds to the model RIO competences and knowledge. It highlights the knowledge and skills that actors have jobs and are necessary for the performance of a design project.

Each activity at each phase is represented by an organization (Figure 2) describing the roles and interactions on the one hand and the knowledge associated with competences on the other hand.

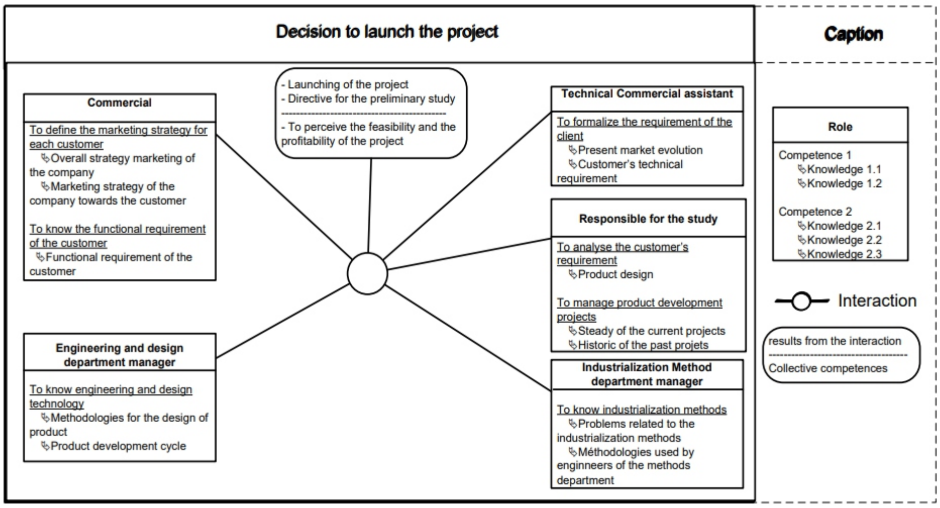

Figure2. An organization in RIOCK Model

Competence can be expressed as the ability of an individual to demonstrate his knowledge and expertise in a professional [Le Bortef, 2000].

Knowledge is defined as an interpretation of information in a specific context.

For this reason, our knowledge cartography is based on Monticolo's research work [Monticolo, 2007], so that we can properly lead the process of capitalization and reuse of knowledge in design projects.

c. Project memory model

A project memory is defined as: “a model with the organization of information and knowledge created, shared and used in a project, for reuse by business actors” [Matta, 2000].
It is used to store and index the knowledge used in projects, in order to facilitate their access, their shares and their reuses by business actors. It defines the structure and the explicit representation of knowledge on organization.
Monticolo [Monticolo, 2007] proposed a memory project model called "Memodesign", this model describes a collection of knowledge related to the business context of the project and will be subsequently classified according to its typology and taxonomy.
This project memory is built round six groups of knowledge, namely: Project Background, Project Evolution, Project Vocabulary, Project Experience, Project Process and Project Expertise.

III. Minimization approach proposed

The idea of our work is to develop a knowledge management system which ensures minimization of the duration of a project design, promoting reuse and capitalization of knowledge.
Our system proposes the design process that follows the minimum duration, as well as knowledge. It can assist the business actor in the process of mechanical product design. Moreover, it contributes to the construction of the project memory, because we store the knowledge of each new design project.

a. Building the ontology

The construction of ontology is based on the model of the life cycle of an ontology proposed by [Fernandez-Lopez, 1999]. This life cycle can be summarized in three main activities that are: management, construction, and support. Whose construction involves four steps: specification, conceptualization, formalization and implementation.
Obviously, we will rely on the methodology proposed by Ben Miled [Ben Miled, 2020] to prepare the tables presenting the concepts, attributes and relationships between concepts.
Figure 3 below shows a sample of our ontology developed. This excerpt highlights the organizational structure generated in organizational modeling in the design process. We find the design process part, related to different phases via logical constraints, where each phase can also distinguish its own activities. Each organization at the organizational model represents an activity identified by a concept in the ontology.

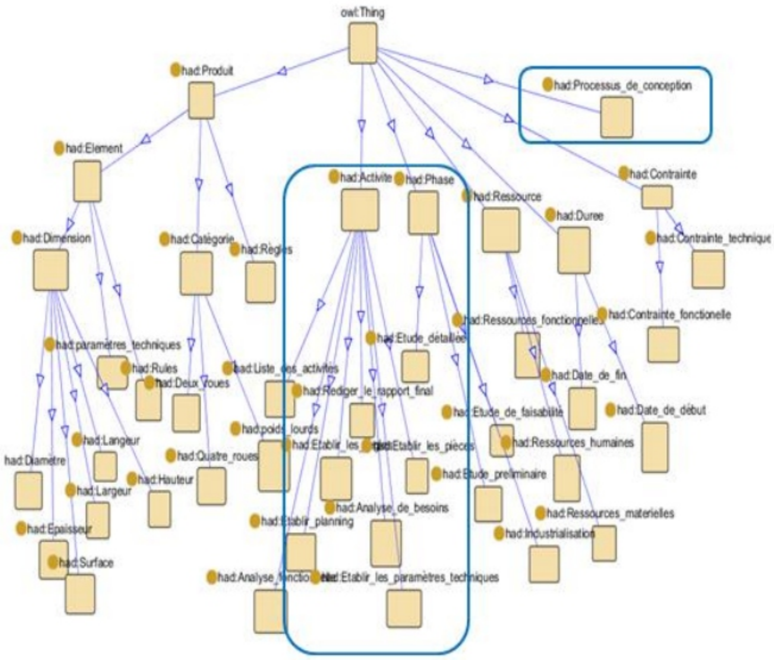

Figure 3. Excerpt of the proposed ontology.

Table 1below shows some concepts of our ontology.

Term	Concept ID	Parent ID	Definition in natural language
Design process	Design_process	__________	The process in question.
Phases	Phases	__________	All phases forming a design process
Preliminary study	Preliminary_study	Phase	The preliminary study is a phase that fits in the concept phase.
Activities	Activities	________	The activities forming each phase.
Needs analysis	Needs_analysis	Activities	*Analyse de besoins* is a type of activity.

Tab 1. Some concepts from our proposed ontology.

The ontology concepts are formalized through OWL and RDF. The following example (fig.4) reflects the concepts (Needs_Analysis, Activities).

```
<owl:Class rdf:ID="Needs_Analysis">
<rdfs:subClassOf>
<owl:Class rdf:ID="Activities"/>
</rdfs:subClassOf>
</owl:Class>
```

Figure 4. Definition of class « Needs_Analysis »

Table.2 below shows some attributes of our ontology.

Attribute	Id relation	concept associated	Attribute type	Description
Start date	Startdate		Date time	The start date for determining on each type of activity: This is to say when the actor began his task.
End date	Enddate		Date time	The end date of an activity, that is to say, when we finished this task.
Human resources	Human_resources		String	Roles available to complete each activity.

Tab 2. Some attributes from our proposed ontology.

The figure (fig. 5) below shows the definition of an example of an attribute on the concept of "activity". The example "Startdate" is a property DataProperty, which is of type "& xsd; dateTime".

```
<owl:DatatypeProperty rdf:ID="Startdate">
<rdfs:domain rdf:resource="#Activities"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#dateTime"/>
</owl:DatatypeProperty>
```

Figure 5. Attribute Defintion « Startdate »

Table 3 below shows some relations of our ontology.

Relation	ID relation	Original concept	Target concept	Definition in natural language
Has activities	Has_activities	Phase	Activity	Activities that make up each phase.
Has phases	Has_phases	Processus_de_conception	Phase	Phases that determine each design process.
Has date	Has_date	Activities	Date de début Date de fin	An activity consists of two dates: a start date and an end date.

Tab 3. Some relations from our proposed ontology.

b. Exploitation of project memory

Knowledge conceptualized in our ontology can be used in different ways. Therefore, we note SPARQL [Seaborne, 2008] which is considered both as a language and as a query protocol. SPARQL allows querying RDF descriptions using clauses.

We want to especially address the following question: Determine the start date of all activities (fig. 6). And in the same way we also determine all end dates of activities.

```
SELECT ?x
WHERE {
?activite had : numero “Numero 1“.} UNION
?activite had : numero “Numero 2“.} UNION
?activite had : numero “Numero 3“.} UNION
?activite had : numero “Numero 4“.} UNION
?activite had : numero “Numero 5“.} UNION
?activite had : numero “Numero 6“.} UNION
?activite had : numero “Numero 7“.} UNION
?activite had : numero “Numero 8“.} UNION
?activite had : Startdate ?x.}
```

Figure 6. Sparql Query

The figure (fig. 7) f below shows the result.

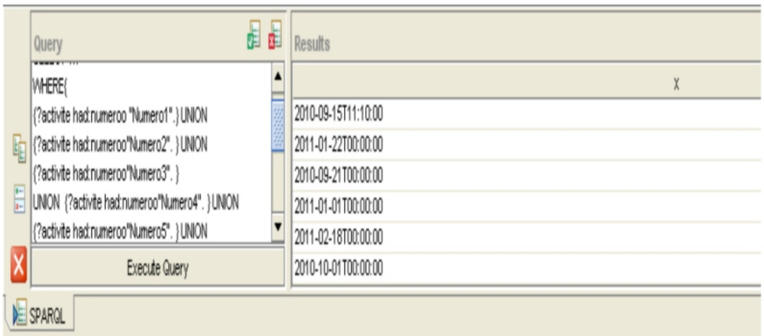

Figure 7. The result of the query

The results given by the queries: determine start date and end date, will help us to highlight our devoted approach to minimizing the duration of a project design.

c. Proposed system

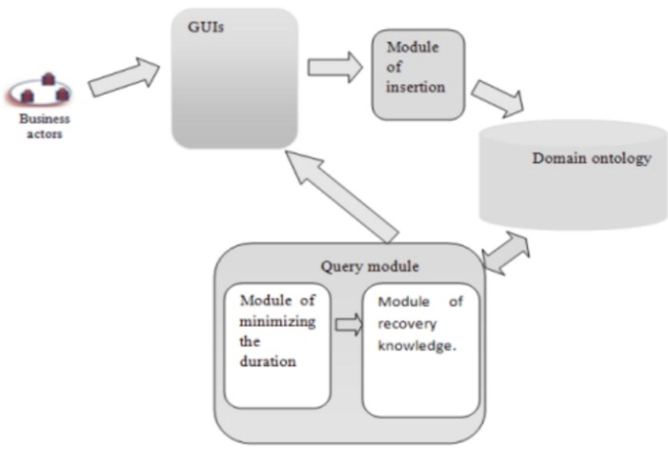

Figure 8. System components

The figure above (fig. 8) shows our system to minimize the duration of a project design. This system is divided into two modules namely the inserter and the interrogation module which, in turn, consists of two inseparable modules, which are the module of minimizing the duration and the retrieval module knowledge.

We also disclose information to two passages, one painted path capitalization saying the path through which we store our knowledge, the other draws the path of knowledge reuse by business actors.

The first path is then essential and unavoidable step in the development of the project memory can be re-usable and help to maximize the design of future products. Thus, we aim to work through this to keep track of all projects carried out within the organization.

The second path leads the organization to reuse the knowledge and the past solutions to meet the new demand proportional to our new product.

The interrogation module of ontology is used to query the ontology, based on the query language SPARQL. Indeed, it has two modules that are heavily dependent: after searching for the minimum process, we try to retrieve knowledge. This passage is important because it guarantees us to reuse again the most relevant knowledge.

Module minimizing the duration facilitates the determination of process with the shortest minimum. It also allows us to see tracking scheduling to perform all activities involved in this process.

The retrieval module knowledge provides the knowledge we need every time. It gives us a knowledge reuse of the design process that runs the minimum time.

Figure 9 shows the retrieval module interface which presents activities of process with the shortest minimum

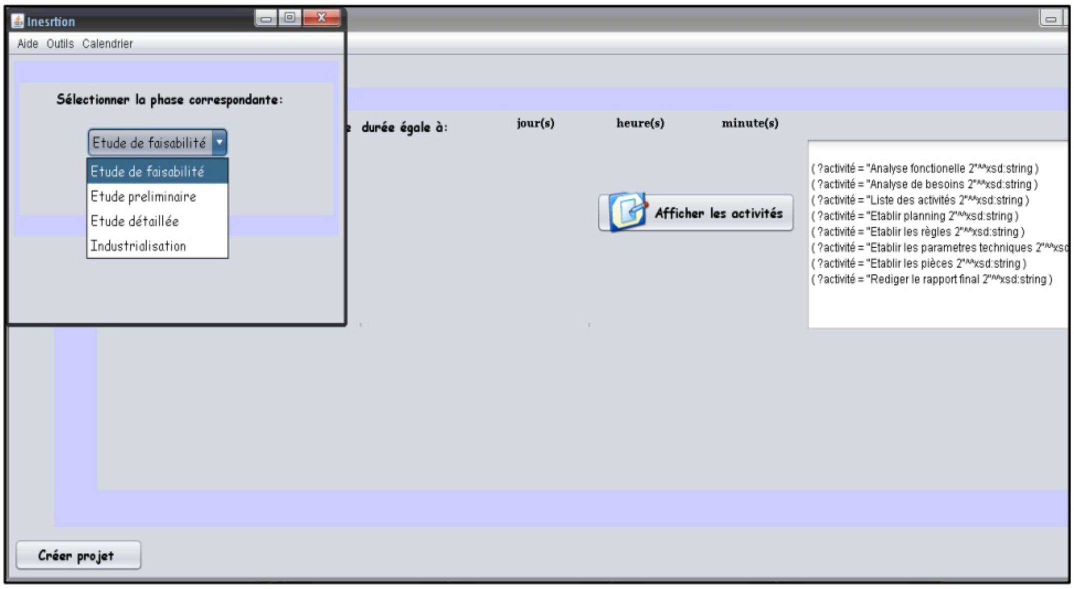

Figure 9. The retrieval module interface

d. The features of the proposed system

The first feature is summarized in minimizing the duration of a project design. Activity has a start date and an end date. We will calculate the duration of each activity and summing for the total duration of the design process. Subsequently, we determine which has the shortest minimum (Fig. 10).

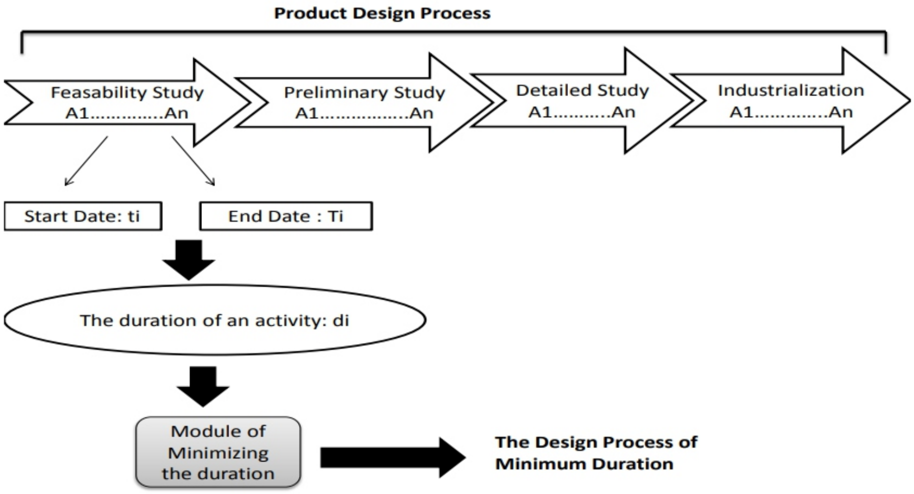

Figure 10. Minimizing the duration

With A1 An: All activities which form a phase.

A second feature is expressed through the reuse of knowledge. Reuse is defined as a major contribution in this paper, but it is represented in a different context compared to the works cited in the literature since the latter is proportional to the concept of time. It serves to make knowledge stored in memory accessible project in a timely manner.

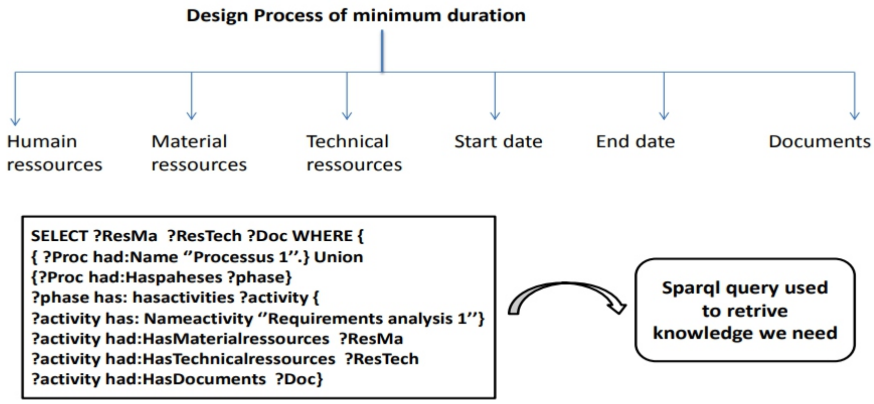

Figure 11. Knowledge reuse

As a result of the Sparql query (figure 11) the user receives a help window which provides him with knowledge in need. Figure 12 shows a portion of the push interface that presents an example of how the knowledge is proposed. The user can take into account this help and can also ignore it.

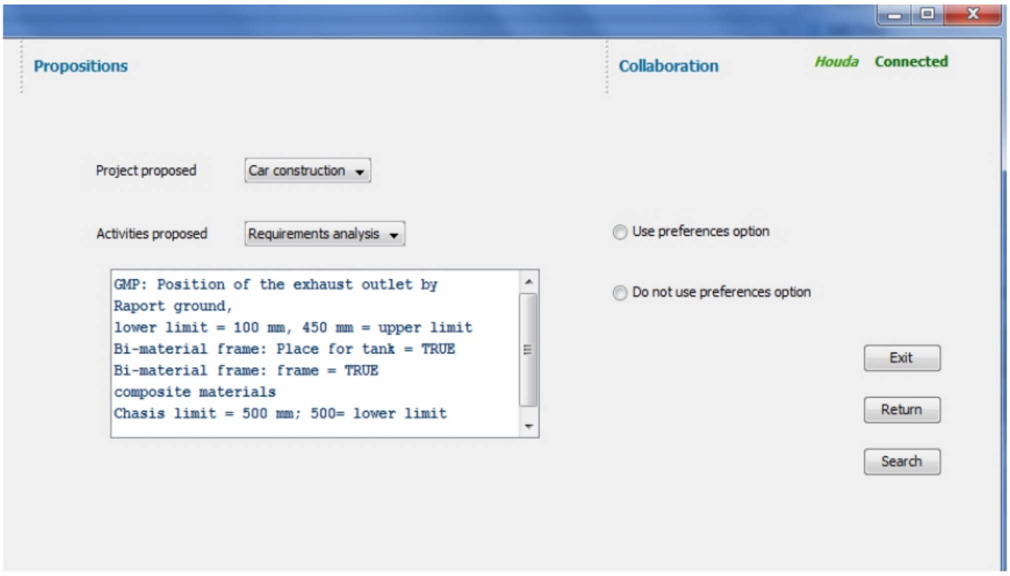

Figure 12: The push Interface

The third feature after our work focuses on the capitalization of knowledge. The aim is to retain the knowledge relating to each design process within the project memory (fig. 13).

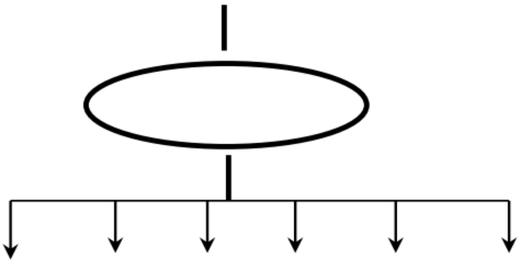

Figure 13. Knowledge capitalization process

Each project established at the organization must be registered at the memory, to ensure that we can turn back to the knowledge of past projects via module reuse. It is therefore to determine the start dates, end dates, material resources, human, technical, input and output parameters (Fig. 13).

IV Experiments

We have tested the tool by the help of groups of students collaborating on the conception of different products. We provided students with questionnaires to show in which phase knowledge proposed by the tool are relevant and have been reused. The students attributed a note between 0 and 5 for each phase (No benefit, Small benefit, Moderate benefit, large benefit, Very large benefit, extraordinary benefit). The more the note is raised, the more the proposed knowledge is relevant and was reused. The results extracted from the questionnaires are presented in

Fig. 14. This figure shows that the proposed knowledge are mostly reused during the first two phases. This can be explained by the lack of information about product to be developed.

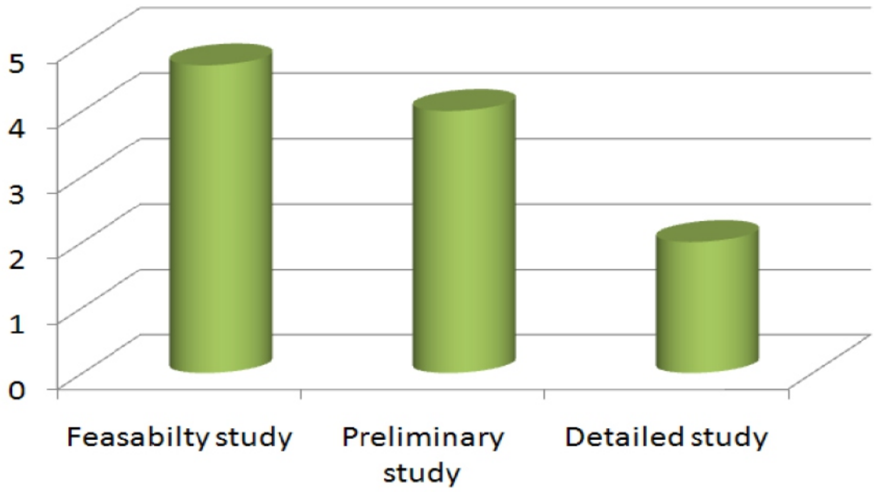

Figure 14. Knowledge reuse per phase

We study also the time factor and Fig. 15 shows the same project duration for two groups from the same category (beginner). Group 1 uses the tool to realize the project and group 2 doesn't. Group 1 takes less time than group 2 to finish each phase of the design process. For example, for feasibility study, group 1 takes 22 days to finish it and group 1 takes about 13 days. These preliminary results show that this software tool provides relevant knowledge that help in reducing project realization time.

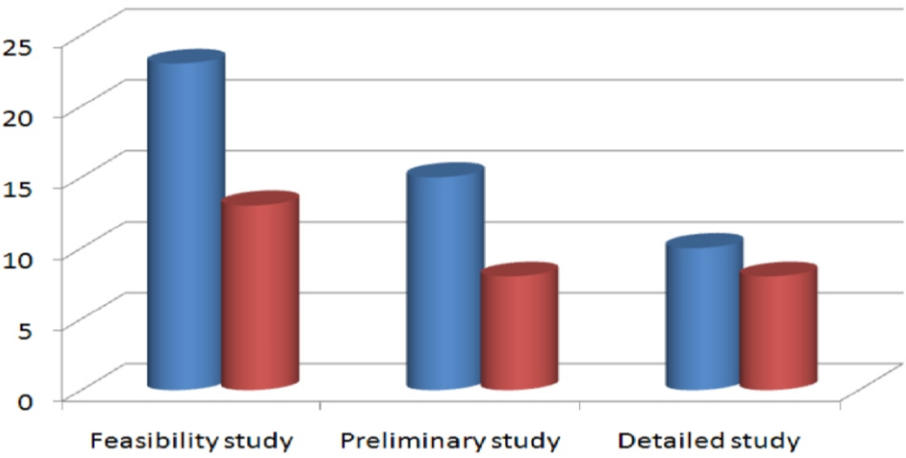

Figure 15. Tasks Optimization

V. Related work

A knowledge management system has an effective solution in order to focus on the process of capitalization and reuse knowledge. This system is defined as follows: "knowledge management systems (KMS) are computer systems developed to support and to improve the processes of creating, storing, research, transfer and application of knowledge" [Alavi, 2001].

Knowledge Engineering aims to collect, analyze, structure, represent and reuse Knowledge.

Much research has been done in this domain; Gandon [Gandon, 2002] adopts an approach for the management of an organizational memory [Matta, 2000] [Foghouli, 2020], combining ontology engineering, semantic Web and Multi agent system in an integrated solution. He tackled the problem of knowledge reuse based on the user profile which is a description of their interests, activity, etc. However, he did this without taking into account the role of the user in the design process. Tacla [Tacla, 2003] developed a model for the cooperative construction of project reports. In this model, after an initial modeling of the domain, the acquisition of the knowledge is made in an ascending and integrated way, from the daily activities of the individuals. Tacla's research provides a path for the re-use of the knowledge by explaining how to capitalise upon it, but it did not tackle the automatic assistance of users to help them by reusing knowledge. Some works focused on the user task to put such assistance [Revilla, 2000]

[Melo, 2020] into context [Prie, 2000], while others tried to capture general web navigation episodes on static signatures [Corvaisier, 1997] [Jaczinski, 1998], or, as in Takano, Yurugi and Kaenaegami [Takano, 2000], used past procedure cases to develop their use in specific applications. Champin [Champin, 2000] suggests exploiting the tracking of use of tacit knowledge by the designer by means of the mechanisms of reasoning from case.

These last works rely on the Case-Based Reasoning paradigm [Jaczinski, 1998], [Pretschner, 1999] [Khan, 2019]. These works aim at tracking and reusing experience but for our case we want to reuse knowledge contained in the ontology via concepts, attributes and relationships. Other research works focused on information research by the source's description [Callan, 2000], [Champin, 2004] [Li Yang, 2021] or by selection of minimum number of sources for a given request [Aksoy, 2005]. These works don't take into account the user profile in the search process and the context of the design process. Several approaches were developed to define the user profile; we can quote the adaptive approaches [Pruski, 2011] [jun yan, 2021], the semantic approaches [Billsus, 1999], [Xu, 1998][Chenliang, 2021] and the multidimensional approach [Kostadinov, 2003][Feddaoui, 2018][Lanza-Cruz, 2023]. All these works try to adapt to the user's preferences and interests by searching for information. In our research we try to search for knowledge which is the interpretation of information by a human in a given context according to the user's role in the product design project which consists of the main criterion of developing a framework to allow knowledge reuse during development process. The framework handles knowledge, which should be structured and organized in ontology using organizational approach.

VI Summary and Discussion

In this article, we introduced a framework based on ontology and mechanisms for knowledge reuse during product development. The objective is to facilitate the reuse of knowledge and minimize the duration of projects. . The framework exploits the capitalized knowledge in the best way and provides most relevant for users in order to facilitate their tasks. It offers the relevant knowledge to the right person on the right time. The framework is supported by a tool that brings an automatic help to the actors to facilitate their tasks and a personalized search for the knowledge.

Experiments are performed and preliminary results are presented to show the effectiveness of reusing knowledge during product development lifecycle.

Potentials and advantages of this tool has been reported by students. For example, based on questionnaires provided to students, the tool allows to consult the knowledge of the current project, namely the project memory as well as the knowledge of all projects. They found that this tool proposes a personalized consultation what avoids, according to them, the secondary knowledge. The students mentioned also that this software tool is very useful for the beginners by guiding them in every stage of the design process and proposing them a useful help via the automatic assistance and personalized search. The knowledge transfer allowed the students to have an idea on the work to be realized, to collaborate between them in a formal way and to adopt certain knowledge of which they share together.

They found this help very useful for the innovative projects. However, they highlighted that the tool does not allow managing knowledge for the activities which are not described in OntoDesign. Indeed, certain students do not want to limit themselves to the usual activities of the product design process. This establishes one of the major limits of the tool. These limitations constitute our ongoing work.

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BORDER SECURITY SYSTEM FOR ALIVE HUMAN BEING DETECTION ROBOT IN WAR FIELD USING IOT

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A B S T R A C T

The wireless communication technologies are rapidly spreading to new areas, including automation, data acquisition, building control, monitoring systems and many more. Autonomous robotic system is an outstanding innovation of a modern technology. It has been able to provide significant support to mankind by accomplishing arduous tasks that are apparently infeasible for human beings to perform. The existing system suffered many problems like high cost to set up communication between robot and rescue control unit, noisy wireless communication link between robot and control unit which ultimately stopped robot to function etc. The proposed system is able to solve all these problems. The proposed embedded robotic system detects alive human body in the catastrophic environments which is very helpful for rescue operations. Disasters can be of two kinds- natural and human-induced. Natural disasters are not under the control of human beings. The main aim of the paper is to implement a Wireless multipurpose Robot which can be controlled through PC using RF interface and navigates around the disaster areas and tries to find the humans who need help and tries to identify the forest fire.

INTRODUCTION

Disasters can disrupt economic and social balance of the society. Natural disasters occur frequently now a days. Many human beings are victims of such occurrences. Because of high rise buildings and other manmade structures urban and industrial areas can be considered to be more susceptible to disasters. These disasters can be categorized into natural and human induced disasters. Natural disasters include floods, storms, cyclones, bushfires and earthquakes where as besides natural disasters, the urban environment is prone to human induced disasters such as transportation accidents, industrial accidents and major fires. During such calamities, especially disasters, in order to prevent loss of life and property various essential services (like fire brigades, medical and paramedical personnel, police) are deployed. Some lose their lives because of not being treated at time. According to the field of Urban Search and Rescue (USAR), the probability of saving a victim is high within the first 48 hours of the rescue operation, after that, the probability becomes nearly zero. Generally, Rescue People cannot enter into some parts / places of the war field or in the earth quake affected areas. All of these tasks are performed mostly by human and trained dogs, often in very dangerous and risky situations. To avoid such losses, a robotic system can perform well for providing alert (detection) of human being.

The main purpose of the robot is to detect alive human beings after the occurrence of natural calamities with the help of IR sensor. The robot based system will sense the radiation of human being and condition the sensed signal to communicate to the control section of this robot. Based on the responded commands the robot will react upon. The rescuer may become a victim who needs to be rescued. The proposed system uses an IR sensor in order to detect the existence of living humans and a lowcost camera in order to capture video of the scene as needed

HISTORY OF FIELD OF INTEREST

The existing project was developed as a motion sensor alarm based on PIR sensor module. The presence of the any objects it creates a sudden change in the infrared radiations. In this project microcontroller monitors the output continuously from the sensor module and turns a buzzer on when it goes active. The sensor is in retriggered mode, the buzzer stays on as long as the motion is continuously sensed. It detects only the motion. It will detect all objects when it sense near to system. It only detects but does not send any alert message to the rescue team. It does not use wireless Technology.

That is why in in our proposed system developed based on Rasperry Pi based robotic automation rescue process.

PROBLEM DEFINITION

The border security suffer from intense human involvement any single technique encounters inextricable problems, such as high false alarm rate. Its very difficult to monitor with many soldiers in border areas because cost it effect so much the military

An embedded system is a computer system with a dedicated function, often with realtime computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. Modern embedded systems are often based on microcontrollers, but ordinary microprocessors are also common, especially in more-complex systems.

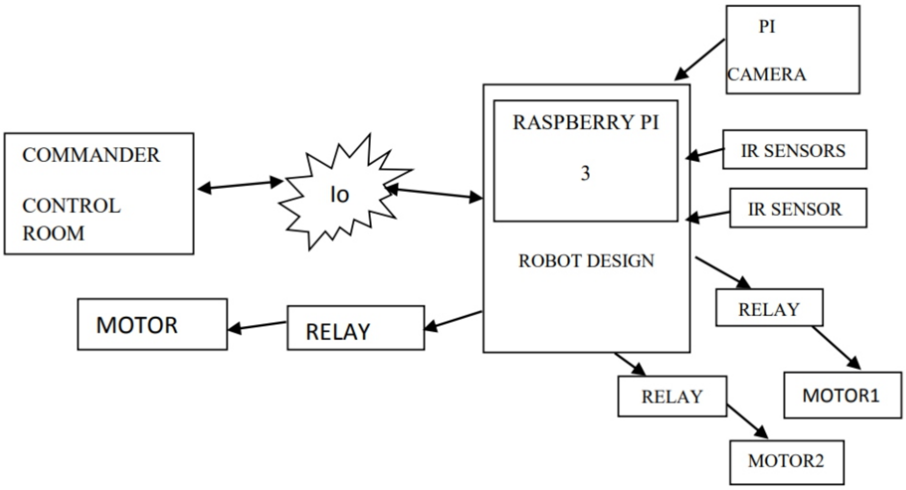
MOTIVATION OF THE PROJECT

This autonomous system is an innovation of modern technology. It has been able to provide significant support to mankind by accomplishing task that is impossible for human beings. The proposed embedded system detects alive human body in the catastrophic environment which is very helpful for rescue operations .In areas like war fields personnel rescue is difficult. In such circumstances the proposed system helps to perform tasks that cannot be performed by rescue team or modern tools and techniques. The proposed system detects alive humans by using a special type of sensor called IR sensor.IR sensor detects infrared radiations that are emitted by the human body. When the infrared radiations are detected from the human body.

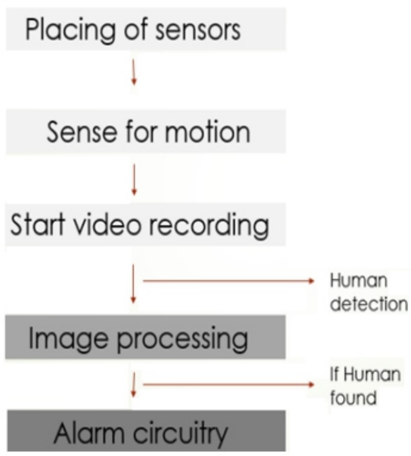
PROPOSED WORK

The border security system employs high-tech devices, such as IR sensors and camera which is capable of monitoring the border day and night. Raising an alarm on detection of human intruders across the borders, Image processing is processing of images using mathematical operations by using any form of signal processing for which the input is an image, a series of images, or a video, the output of image processing may be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a twodimensional signal and applying standard signal-processing techniques to it. Send Response image to server so that commander pass specific command to war robot, Based on commands Robot perform the specific operation

BLOCK DIAGRAM



METHODOLOGY



PHASE-1 Placing the sensors (ground and underground) across the border and testing for required detections (vibrations and motion).

PHASE-2 Transmitting the detected signals from the sensors to the controller placed in the remote host.

PHASE-3 The camera points to the detected area and the video is processed for detection of human intruders avoiding false alarms using image processing.

PHASE-4 Turning ON the alarm circuitry on detection of human intruders

PHASE-5 Testing of the product with software application to perform commander operations

SOFTWARE AND HARDWARE REQUIREMENT

HARDWARE

Raspberry -Pi

Raspberry Pi is a credit-card sized computer manufactured and designed in the united kingdom by the raspberry pi foundation with the intension of teaching basic computer science to school students and every other person interested in computer, programming and DIY-DO-IT yourself projects.

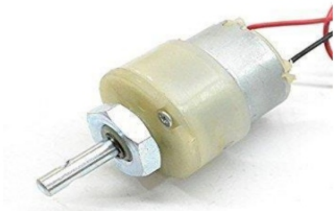
Pi Camera

In order to meet the increasing need of Raspberry Pi compatible camera modules. The ArduCAM team now released a revision C add-on camera module for Raspberry Pi which is fully compatible with official one. It optimizes the optical performance than the previous Pi cameras, and give user a much clear and sharp image

Infrared Sensors

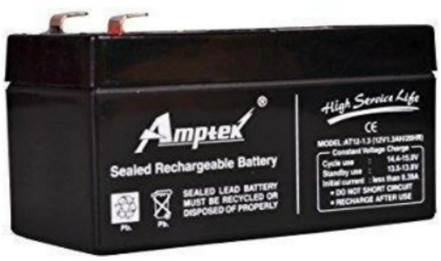
This device emits and/or detects infrared radiation to sense a particular phase in the environment. Thermal radiation is emitted by all the objects in the infrared spectrum and the sensor detects this type of radiation which is not visible to human eye.

Gear Motors



A small motor (ac induction, permanent magnet dc, or brushless dc) designed specifically with an integral (not separable) gear reducer (gear head). The end shield on the drive end of the motor is designed to provide a dual function. The side facing the motor provides the armature/rotor bearing support and a sealing provision through which the integral rotor or armature shaft pinion passes.

Power supply



12v 1. 3Ah Rechargeable Battery for Robotics. Used in Communication Equipments, Fire & Security Systems, Medical Equipments, Electronic Test Equipments, Electronic Weighing Scales etc.

SOFTWARE

Python 2.7

Python is an interpreted, high-level, general-purpose programming language. Created by Guido van Rossum and first released in 1991, Python has a design philosophy that emphasizes code readability, tably using significant whitespace. It provides constructs that enable clear programming on both small and large scales. Van Rossum led the language community until July 2018.

Python is dynamically typed and garbage-collected. It supports multiple programming paradigms, including procedural, object-oriented, and functional programming. Python features a comprehensive standard library, and is referred to as "batteries included".

OpenCV 3.2

OpenCV (Open source computer vision) is a library of programming functions mainly aimed at real-time computer vision. Originally developed by Intel, it was later supported by Willow Garage then Itseez (which was later acquired by Intel). The library is cross-platform and free for use under the open-source BSD license. OpenCV supports the deep learning frameworks Tensor Flow, Torch/PyTorch and Caffe.

Web application

In computing, a web application or web app is a client–server computer program which the client (including the user interface and client-side logic) runs in a web browser. We use a GUI application to enable the user to control the robot manually as well as automatically and to receive data and images of any intruder.

Cloud Server

A cloud server is a logical server that is built, hosted and delivered through a cloud computing platform over the Internet. Cloud servers possess and exhibit similar capabilities and functionality to a typical server but are accessed remotely from a cloud service provider.A cloud server may also be called a virtual server or virtual private sever.

SUMMARY

This system consist of a robot control section and video coverage section. This system consists of a Robot control section and video coverage section. Furthermore Robot section consists of a movable unit, The robot can be manually controlled using PC, with the help of Visual Basics. The user interface has options to control the robot motion and also displays the sensor details Visual analysis of the affected area is made possible by a wireless camera placed on the robot which captures live video of the scene. The live video enables the operator to control the robotic movement by observing the scene and avoiding obstacles.

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Generative Ai: A New Paradigm for Antibody Design and Development

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ABSTRACT

Antibodies are microscopic defenders in our body's immune system, protecting us against foreign pathogens. These specialized protein molecules, shaped like the letter Y are produced by plasma cells and possess the ability to precisely locate and bind to specific antigens, inactivating harmful substances like toxins and facilitating the destruction or neutralization of pathogens. The remarkable diversity of antibodies, generated by immune systems' adaptability often referred to as immune repertoire or a condition of genetic variations, allows the immune system to respond to a vast array of potential threats.

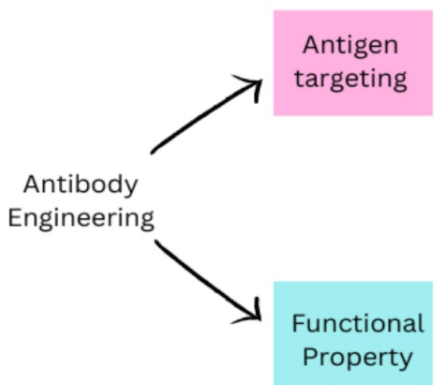
Recent advancements in artificial intelligence have opened new doors in many fields including medicine. By harnessing machine learning algorithms, generative AI models can be trained to design ground-breaking antibody structures with selected traits from existing data and knowledge. This approach can significantly accelerate the antibody discovery process, leading to the ushering era of smart medicine.

This paper aims to explore how generative AI is being utilized to design new antibodies. We explore how this technology could potentially streamline the traditionally lengthy process of developing new antibodies through physical enumeration. We aim to shed light on a promising frontier in drug discovery and synthesis. Our discussion encompasses both the potential benefits and the challenges of this emerging approach

Keywords- *Generative AI; Antibody design; De novo antibody design; Antigen; Epitope; Paratope; Affinity; Specificity; Immunoglobulin; Complementaritydetermining regions (CDRs); Therapeutic antibodies; Generative adversarial networks (GANs); Transformers; Antibody engineering*

Introduction

Diseases like cancer, autoimmune disorders, and infectious diseases continue to pose significant global health challenges, highlighting the pressing necessity for enhanced and efficacious therapeutic interventions. At the heart of the human immune system lie antibodies-remarkable proteins that act as the body's first line of defence against any unwanted or harmful foreign material medically referred to as pathogens [1] [2]



Antibodies play a crucial role in the immune response, binding to specific antigens present on pathogens and triggering a cascade of events that can neutralize or destroy the threats [1][2]. Developing new and improved antibody-based therapies is thereforecrucial for addressing a wide range of illnesses and improving patient recovery outcomes.

Background

Antibody Engineering: Shaping the immune response

Antibodies are Y-shaped plasma cell-derived proteins that are capable of recognizing and neutralizing specific invaders like viruses and bacteria. Through a process called gene rearrangement, the immune system can respond to a vast array of potential threats. Traditionally, researchers have employed various methods to discover and engineer antibodies with derider properties.

Library-Based Antibody research

This method forms the cornerstone of traditional antibody discovery. Scientists construct extensive repositories encompassing millions of different antibody sequences often derived from the immune systems of animals exposed to a specific pathogen. These libraries are then screened against the target antigen, identifying antibodies that bond with high affinity. Identified capabilities can then be optimized further through techniques like mutagenesis or antibody fragment engineering.

Context

Conventional methods for discovering new antibodies have often relied on tedious and labour-intensive approaches, such as immunizing animals and waiting for their immune systems to generate antibodies, or painstakingly screening vast libraries containing millions of potential antibody sequences [3][4]. These are excruciatingly slow, and often take years for scientists to identify viable antibody candidates. Researchers must meticulously test each antibody one by one, discarding countless failures before finding a rare success. This process can only become more complicated especially when dealing with targets that are unrecognizable by the immune system.

Research Objectives

The traditional approaches to antibody discovery have long been plagued by significant limitations. However, the emergence of generative AI has the potential to revolutionize the landscape of antibody development. Generative artificial intelligence models can be trained on extensive datasets to craft novel antibody structures with desired properties, such as enhanced binding affinity or specificity [1, 7, 8].

The objective of this paper is to provide insights into the future of this field and the role of cutting-edge technology in advancing the development of new and improved antibody-based therapies. We will delve into case studies that demonstrate the power of this technology and ongoing efforts to address the challenges associated with validating and optimizing these AI-generated candidates [4, 9]

Literature Review

The Interplay of Antigens and Antibodies

Antigens and antibodies play a crucial role in the immune system, working together to defend the body against foreign pathogens and other harmful substances. Antigens are substances that can stimulate an immune response, while antibodies are proteins synthesized by the immune system as a response to the detection of foreign substances known as antigens.

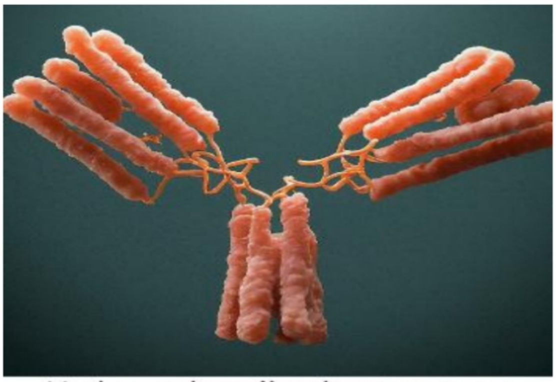
Antigen Structure

Antigens are typically proteins or sugars found on the outside of the cell or viruses.

Each antigen has a unique shape that is identified by the immune system as non-native. Antigens can be classified into two main categories: foreign antigens and autoantigens. Foreign antigens are derived from outside the body, such as viruses or bacteria, while autoantigens are derived from the body itself, such as tissues or cells [11].

Antibody Structure

Antibodies, also known as immunoglobulins are Y-shaped proteins produced by plasma cells in response to the presence of antigens. Each antibody has a unique shape that is complementary to the shape of the antigen it recognizes. Antigens are designed to bind to those antigens that have triggered their production and therefore, identify them for elimination by the immune system. [10].

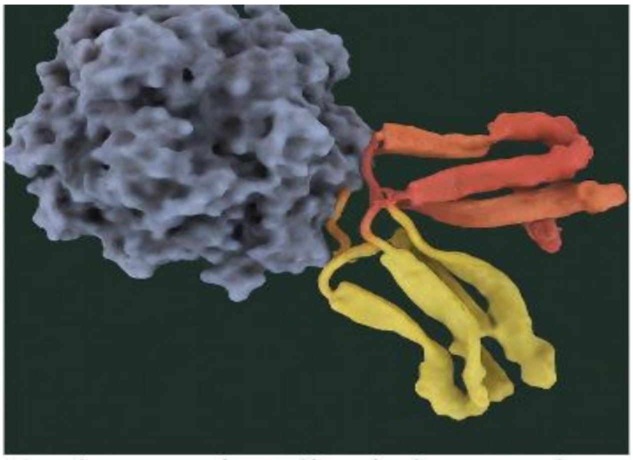


Y-shaped antibody structure

Antigen-Antibody Interaction

When a strange substance, like a virus or bacteria, gets into your body, your immune system, which is like a complex web of cells and molecules, kicks into action. Antibodies produced by B cells have unique binding sites that can recognize the specific shape and chemical features of the antigen's surface. This process is known as antigen recognition [1,2].

The binding between an antibody and its target antigen is highly specific and reversible. The antibody's binding site, called the paratope, fits complementarity with a particular region on the antigen's surface, known as epitope. This lock-and-key style binding is facilitated by a variety of non-covalent forces including electrostatic, hydrophobic and van der Waals forces [3,4]. The strength of the antigen-antibody interaction is known as affinity, determined how tightly the antibody can latch onto the target. Antibodies with higher affinity are more effective at recognizing and binding to their cognate antigens.



Antigen and antibody interaction

The Immune Response

Once an antibody has bound to an antigen, it can trigger a cascade of immune responses to normalize or eliminate the threat:

Generative AI: Revolutionizing Antibody Design

Sequence Generation and Optimization

At the heart of generative AI's impact in antibody design is its ability to generate novel antibody sequences optimized for desired properties like binding affinity and specificity. Researchers have developed advanced generative models such as variational autoencoders (VAEs) and generative adversarial networks (GANs), that can learn the complex patterns and rules governing antibody sequences from large datasets of natural antibodies [4,7]

These models can then generate millions of unique antibody sequences, exploring vast sequence spaces that would be impossible to cover through traditional experimental methods. By conditioning the models on specific target antigens, researchers can direct the sequence generation process to focus on bonders against a particular epitope of interest [2,6]

Structural Prediction

In addition to generating novel sequences, generative AI models can also predict the 3-D structures of generated antibodies. This is achieved by leveraging powerful protein structure prediction algorithms, such as AlphaFold, that have made significant breakthroughs in accurately modelling the folding of complex proteins [14,15].

By combining sequence generation and structural prediction, researchers can assess the binding properties of AI-designed antibodies in silico, identifying most promising candidates for further optimization and experimental validation [16,17].

Experimental Validation and High-Throughput Screening

While generative AI models can accelerate the antibody design process, experimental validation remains a crucial step to ensure the efficacy and safety of generated candidates. Platforms sux as phage display and yeast display facilitate the screening of millions of antibody candidates, identifying the most promising binders that can then be further characterized and optimized hence significantly reducing time and resources required to synthesize therapeutic antibodies [19,20].

From In Silico Blueprints to Potent Antibodies: The Gen-AI Workflow

Unlike traditional methods that rely on trial-and-error or brute force approaches, GenAI leverages a sophisticated workflow to design antibodies in silico, essentially creating blueprints for these powerful molecules in a virtual world

1. Data Acquisition: The key to successful Gen-AI antibody design lies in highquality data.

Antibody Sequences: Extensive datasets containing sequences of existing antibodies with known binding properties to various antigens. This information acts as a training ground for the AI to learn the intricate relationship between sequence and function.

Antigen Structure: 3D structures of the target antigen obtained from techniques like X-ray crystallography microscopy, allow AI to visualize the binding site and design antibodies that perfectly complement it.

Binding Affinity: This experimental data on how tightly existing antibodies bind to the target antigen helps the AI model refine its predictions and prioritize sequences with high predicted affinity

2. AI- Powered Sequence Generation: Beyond Trial and Error: Gen-AI employs a diverse technique to generate novel antibody sequences

Deep Learning for Structure Prediction: Frameworks like AlphaFold or Rosetta antibody design utilize known antibody structure datasets of significant size are employed to train deep learning algorithms. These algorithms can predict the 3D structure of a newly generated antibody sequence, allowing researchers to assess its potential fit with the target antigen in silico

Sequence-Based Antibody Design: Frameworks like A2Binder or Abinitio antibody focus on directly generating antibody sequences with desired functionalities. These frameworks often leverage techniques like Generative Adversarial Networks (GAN)

3. Virtual Screening: Once the AI model generates a vast library of potential antibody sequences it is time for virtual screening

Predict Affinity and Specificity: Using computational tools, the AI model analyses the generated sequences, predicting their binding affinity and specificity. With this approach, researchers can zero in on the candidates that have the best chance of success, making their work more efficient and productive. By identifying the sequences with the highest predicted affinity and specificity, researcher's ca focusses their efforts on the most likely candidate for success

4. Experimental Validation: From Virtual Design to Real-World Impact: While Gen-AI excels at prioritizing candidates, in vitro and potentially in vivo studies are still essential for validation.

Antibody Production and Testing: The shortlisted sequences are translated from their virtual blueprints into reality. Researchers synthesize these sequences in the lab to create functional antibodies. The synthesized antibodies are tested against target antigen using techniques like surface plasmon resonance or biolayer interferometry.

5. Antibody Optimization and Refinement: A Continuous Process: After synthesis comes the tiring process of refinement

Directed Evolution: By analysing the 3D structure and binding properties of the antibody, the AI can pinpoint specific areas for improvement, guiding researchers towards even more potent antibody designs. Imagine taking the most promising antibody candidate and introducing slight variations, then selecting the ones with improved properties.

Computational Frameworks for Antibody Design

De Novo Antibody Design

One of the most exciting applications of generative AI in antibody engineering is the ability to design antibodies from scratch, a process known as de novo antibody design.

By training generative models on larger datasets of natural antibody sequences and structures, researchers can learn the underlying principles that govern antibody diversity and binding properties [4].

These models can then be used to generate entirely novel antibody sequences that are optimized for specific targets or desired characteristics. For example, researchers at MIT have developed a generative AI model called AbDesign that can design antibodies from scratch, taking into account the desired binding properties and generating antibody sequences that are then folded into 3D structures using computational methods [4].

De novo antibody design possesses the possibility to expand the diversity of antibodybased therapeutics, allowing researchers to explore regions of sequence space that are inaccessible through traditional methods. By combining de novo design with structural prediction and optimization, researchers can rapidly generate and refine novel antibody candidates, accelerating the discovery of potent and specific binders [4].

Transformers and GAN-based Deep Learning AI

Transformers and generative adversarial networks (GANs) are two powerful deep learning frameworks that have been applied to antibody design.

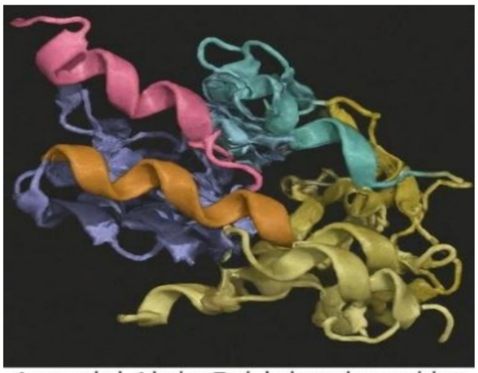
Transformers excel at understanding complex relationships within sequences, even when elements are far apart, such as protein sequences, using an attention mechanism. Researchers have developed antibody-specific transformer models, such as AntiBERTy, that are trained on large datasets of antibody sequences to learn semantic representations of immune repertoires [4,23].

GANs leverage a unique training paradigm where two neural networks work simultaneously. One network, the generator, continuously creates antibody sequences. The other network, the discriminator, plays the role of a discerning critic, striving to differentiate between real and generated sequences. Through this adversarial training process, the generator continuously hones its techniques to synthesize antibody sequences that mimic natural antibodies with remarkable accuracy [4,23].

AlphaFold and RoseTTAFold

AlphaFold and RoseTTAFold are two of the two of the most advanced protein structure prediction algorithms that have been adapted for antibody design.

AlphaFold, developed by DeepMind, uses a deep learning approach to predict the 3D structure of proteins from their amino acid sequence. The model has been trained on an available dataset solely composed of proteins with their respective structuring, including the challenging complementarity-determining regions (CDRs) [23].



A model AlphaFold developed by DeepMind

RoseTTAFold, developed by the University of Washington, is another powerful protein structure prediction algorithm that has been used for antibody design. The framework combines deep learning with computational modelling to predict the structure of antibodies and assess their binding properties in silico [23].

A model RoseTTAFold developed by University of Washington

RF-Diffusion [30]

RF-Diffusion is a novel deep learning framework for protein design that combines those strengths of transformer models and diffusion models. Diffusion models are a type of generative model that learn to generate data by gradually adding noise to input and then learning to reverse the process to generate new samples [30].

RF-Diffusion models have been applied to antibody design, where they learn to generate novel antibody sequences by gradually adding noise to natural antibody sequences and then learning to reverse the processes [30].

The ability to generate diverse antibody sequences while maintaining the structural and functional properties makes them well-suited for antibody library generation and optimization

Deep Sequencing-driven Computational Methods

Deep sequencing technologies have revolutionized the field of antibody research by allowing researchers to sequence millions of antibody sequences from a single sample.

These large datasets of antibody sequences have enabled the development of computational methods for antibody design and optimization [31] .

One example of a deep sequencing-driven computational method is the use of machine learning models trained on antibody sequences data to predict antibody properties, such as binding affinity and specificity. These models can be used to screen large libraries of antibody sequences and identify promising candidates for further optimization and experimental validation [31].

Another application of deep sequencing data is use of antibody repertoire analysis to identify common structural features and sequences associated with high-affinity [31].

AB-Gen Antibody Library Generation

AB-Gen is a computational framework for generating high-quality antibody libraries using deep learning and generative models. The framework consists of several key components:

1. CDRH3 Generation: The framework uses a deep learning model to generate novel CDRH3 sequences that are optimized for bonding to a specific target antigen [4,32]

2. HER2 Binding Prediction: The framework includes a model for predicting the binding affinity of antibodies to the HER2 antigen, which is a common target for cancer therapeutics [32]

3. Rosetta-based Optimization: The framework uses the Rosetta computational modelling suite to optimize the structure and binding properties of the generated antibody sequences [23]

4. GPT-based Generator: The framework includes a generative pre-trained transformer (GPT) model that can generate entire antibody sequences, including the heavy and light chains, based on the target antigen and desired properties [32].

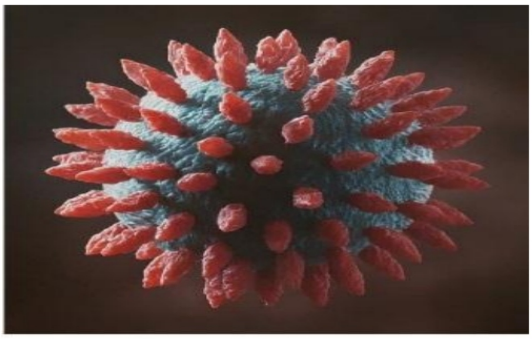
By combining these components, AB-Gen can generate large libraries of antibody sequences that are optimized for binding to specific targets and have a high probability of being functional and developable.

Use Cases: Generative AI to Revolutionize Antibody Discovery and Design

New Paradigm for Antibody Discovery for Infectious Diseases

The emergence of novel pathogens, such as SARS-CoV-2 has highlighted the urgent need for rapid antibody discovery to develop effective treatments. Traditional methods for identifying therapeutic antibodies, which often rely on animal immunization or screening large libraries, can be time consuming and resource intensive [32,33].

Generative AI models have demonstrated the ability to accelerate this process by designing novel antibody sequences optimized for binding to specific viral targets. For example, researchers have used deep learning-based frameworks to generate antibody candidates against SARS-CoV-2 spike protein, identifying potent binders that could be further developed into therapeutic interventions [4, 34].



Spike proteins
on the surface of SARS-CoV-2

Designing Bispecific Antibodies

Bispecific antibodies, which can bind to two different targets simultaneously, have emerged as a promising class of therapeutics with applications in cancer, autoimmune disorders, and infectious diseases [35,37]. However, the design of bispecific antibodies is inherently complex, as it requires optimizing the binding of two distinct antigenbinding sites.

Generative AI can accelerate this process by incorporating desired structural and physicochemical features into the generation process. For example, researchers have used these models to engineer antibodies with improved thermal stability, increased affinity or enhanced effector functioning and hence expanding the horizon of medical engineering [38,39].

Designing Antibodies for Autoimmune Disorders

Autoimmune disorders, such as rheumatoid arthritis, multiple sclerosis, and systemic lupus erythematosus, are characterized by the immune system's attack on the body's own tissues. Developing effective antibody-based therapies for these conditions is crucial and it can be challenging due to the need to target self-antigens and avoid unwanted cross-reactivity [40,41].

Generative AI models have shown promise in designing antibodies that can selectively bind to disease-associated autoantigens while minimizing the risk of off-target effects. By training these models on large datasets of autoantibodies and their target epitopes, researchers can generate novel antibody sequences that are optimized for specificity and safety [41,42].

Optimizing Antibody Developability

Bringing an antibody-based therapeutic to market requires not only potent binding and functional properties but also favourable developability characteristics, such as stability, solubility and immunogenicity [43,44].

Generative AI models possess the capability to be utilized in various domains such as design antibodies with enhanced developability features by incorporating these criteria into the generation of optimization process. For example, using these models, researchers have successfully engineered antibodies that exhibit enhanced thermal stability, reduced aggregation propensity, and reduced immunogenicity, all of which can improve the chances of successful clinical development [38,39].

Designing Antibodies for difficulty-to-Target Antigens

Certain antigens, such as those with complex structures or that are poorly immunogenic, can be challenging targets for traditional antibody discovery methods. Generative AI models, however, have the potential to overcome these limitations by exploring vast sequence and structural spaces to identify novel antibody candidates [42,45]

For example, researchers have used generative AI to design antibodies targeting the receptor-binding domain of SARS-CoV-2 spike protein, its complex and highly glycosylated structure has made it challenging for the immune system to recognize and effectively respond to [46,47]. By generating and evaluating millions of potential antibody sequences, these models were able to identify potent binders that could be further developed into therapeutic candidates.

Case Studies: Generative AI in Effective Antibody Design

Case Study 1: Absci-Pioneering De Novo Antibody Design with Gen-AI Challenge

Traditionally, antibody discovery relies on immunizing animals or screening large libraries which can be time-consuming and inefficient. Absci aimed to overcome these limitations by developing a Gen-AI platform for de novo antibody design

Gen-AI Approach

Absci's platform utilizes deep learning models trained on vast datasets of antibody sequences and structures. These models can be:

Generate novel antibody sequences: The models can design antibodies "from scratch" based on the desired target antigen and binding properties.

Optimize antibody properties: The platform can refine antibody sequences to enhance their affinity, specificity, manufacturability, and other desired traits.

Results

Absci has achieved significant milestones with their ground-breaking wet labs and GenAI platform, including

First de novo designed therapeutic antibodies: They successfully designed and developed the first-ever antibodies created entirely through Gen-AI targeting different therapeutic areas.

Rapid antibody discovery: Their platform allows for the identification of potent antibody candidates against various targets in a fraction of the time compared to traditional methods.

Impact

Absci's Gen-AI approach is transforming antibody discovery by enabling

Faster development of novel therapeutics: By accelerating the identification of lead antibody candidates, Gen-AI can significantly reduce the time required to bring new antibody-based drugs to the market

Exploration of new target spaces: The ability to design de novo antibodies opens up possibilities for targeting previously inaccessible antigens.

Case Study 2: MIT and the AbDesign Model

Challenge

Designing antibodies from scratch, known as de novo antibody design, is a challenging task. MIT aimed to overcome these limitations by developing generative AI models called AbDesign.

Gen-AI Approach

AbDesign is a deep learning model that can design antibodies from scratch, taking into account the desired binding properties and generating antibody sequences that are then folded into 3D structures using computational methods.

Results

AbDesign has demonstrated:

Novel antibody design: The model can generate entirely new antibody sequences that are optimized for specific targets or desired characteristics.

Improved binding properties: The designed antibodies exhibit enhanced bonding affinity and specificity to their target antigens.

Impact

AbDesign is transforming antibody design by enabling:

De novo antibody design: The model can design antibodies for scratch, opening up new possibilities for targeting previously inaccessible antigens.

Accelerated discovery: By rapidly generating and optimizing antibody candidates, Gen-AI can significantly reduce the time required to develop effective antibody-based therapeutics.

Case Study 3: University of Washington and the RAbD Framework

Challenge

Computational antibody design is a complex task that requires advanced algorithms and computational power. The University of Washington aimed to overcome these limitations by developing the RosettaAntibodyDesign (RAbD) framework

Gen-AI Approach

RAbD is a customizable suite for computational antibody design that employs a "Monte Carlo plus minimization" approach to sample and optimize antibody sequences and structural diversity.

Results

RAbD has demonstrated:

Improved antibody design: The framework can optimize antibody sequences to enhance their affinity, specificity, and manufacturability.

Rapid design: The framework can generate and optimize antibody candidates in no time compared to traditional methods.

Impact

RAbD is transforming computational antibody design by enabling:

Advanced antibody optimization: The framework can optimize antibody sequences to enhance their binding properties and manufacturability.

Accelerated discovery: By rapidly generating and optimizing antibody candidates, Gen-AI can significantly reduce the time required to develop effective antibody-based therapeutics.

Case Study 4: Regeneron and Gen-AI

Challenge

Regeneron aimed to overcome the limitations of traditional antibody discovery methods, which can be time-consuming and inefficient. They developed a suite of technologies, including VelociMab and VelociImmune, to efficiently produce and optimize fully human antibodies.

Gen-AI Approach

Regeneron uses genetically humanized mice to make the best human antibodies that are fully human and bispecific antibodies. These mice have been genetically modified to have a human immune system, making antibodies that resemble those found in nature [48,49].

Regeneron has achieved significant milestones with their Gen-AI platform, including:

Efficient antibody production: VelociMab and VelociImmune have enabled the rapid production of a multitude of optimized fully human antibody medicine candidates.

Improved antibody properties: The platform can optimize antibody sequences to enhance their affinity, specificity, manufacturability, and other desired characteristics [49]

Impact

Regeneron's Gen-AI approach is transforming antibody discovery by enabling:

Faster development: By accelerating the identification of lead antibody candidates, Gen-AI can significantly reduce the time required to bring new antibody-based drugs to market.

Improved therapeutic potential: The designed antibodies have the potential to become effective treatments for a broad range of serious medical conditions, including cancer, rheumatoid arthritis, and infectious diseases [48,49]

These case studies go to prove just how facepainting and creative the world of medicine has become ever since the advent of AI.

Methodologies

In this paper, we took a closer look at how generative Artificial Intelligence (Gen-AI) on antibody design. The methodology employed a comprehensive literature review process to gather and analyse relevant information.

Extensive Search Engines

A thorough search was conducted using various academic databases and search engines like Google Scholar, ScienceDirect, PubMed, and Web of Science. Keywords such as “generative AI”, “de novo antibody design” were used to identify relevant research papers, articles, and conference proceedings.

Snowballing Technique:

The initial search results were used to identify key authors and publications in the field. The reference lists of these sources were then reviewed. Peer-reviewed academic journals, reputable scientific websites, and publications from established research institutions were prioritized to ensure the quality and credibility of the information.

Each source was critically evaluated for its relevance, methodological soundness, and contribution to the understanding of Gen-AI in antibody design.

Copyright and Citation

Strict adherence to copyright guidelines was maintained throughout the research process. All sources were properly cited using a consistent style guide to avoid plagiarism and acknowledge the original authors and their contributions appropriately.The information presented in this paper is based on collected data and reflects a balanced and objective perspective on the current state of Gen-AI in antibody design.

Results and Discussions

The world of medicine has long relied on human ingenuity to combat disease. But a new player has entered the field, and it’s not a white coat-clad doctor. Generative Artificial Intelligence has popped up as a powerful tool, transforming the once-arduous process of antibody design. This journey wasn’t an overnight success story. It’s been a tale of overcoming challenges, integrating cutting-edge technology, pushing the limits of what can be done. The following case studies delve into how companies are wielding Gen-AI, not just to compete, but to redefine the landscape of antibody development and potentially rule the future of medicine.

Case Study	Challenge	Gen AI Approach	Results	Impact
Absci	Slow and inefficient traditional methods	Deep learning models for antibody sequence generation & optimization	• First de novo antibodies • Rapid antibody discovery	Faster development of therapeutics and exploration of new target spaces
MIT (AbDesign)	De novo antibody design	Deep learning models for antibody design & 3D structure prediction	• Novel antibody design • Improved binding properties	De novo antibody design and accelerated discovery
University of Washington (RAbD)	Complexities of computational antibody design	Customizable framework for antibody sequence & structure optimization	• Improved antibody design • Rapid design	Advanced antibody optimization and accelerated discovery
Regeneron (VelociMab/Immune)	Time-consuming traditional methods	Genetically humanized mice for optimized fully human antibodies	• Efficient antibody production • Improved antibody properties	Faster development and improved therapeutic potential

Conclusion: Ushering in a New Era of Therapeutic Discovery

The advent of Generative AI is poised to revolutionize the landscape of antibody design. By harnessing the power of AI, researchers can now explore vast source and structural spaces with unprecedented efficiency, accelerating the discovery of novel and potent therapeutic candidates. The case studies presented in this paper underscore the transformative potential of Gen-AI in overcoming traditional limitations and driving innovation in the field.

The implications of this technological advancement extend beyond the laboratory. As Gen-AI continues to mature, we can anticipate a future where tailored antibody-based therapies are more accessible, effective, and rapidly developed. This holds immense promise for addressing lots of different illnesses, from infectious to cancer and autoimmune disorders.

However, the full realization of Gen-AI's potential requires sustained investment in research and development. By fostering collaboration between academia, industry and regulatory bodies, we can create an environment where innovation thrives. Furthermore, addressing ethical considerations and ensuring responsible AI development will be crucial as we navigate this exciting new frontier.

Ultimately, the integration of Gen-AI into antibody design marks a turning point in the history of medicine. It stands as a testament to the ingenuity of humanity and our unwavering commitment to the pursuit of better healthcare solutions. By embracing this technology and exploring its full potential, we can usher in a new era of therapeutic discovery and improve the lives of countless individuals.

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