International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. #, No.# (Mon-20..)

CABPE: Context-Aware Business Process Execution

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Received ## Mon. 20##, Revised ## Mon. 20##, Accepted ## Mon. 20##, Published ## Mon. 20##

Abstract: In today's dynamic business environment, the need for adaptive and context-aware business process execution is paramount. This article introduces an innovative architecture designed to address this need by seamlessly integrating contextual information into business processes. As businesses increasingly rely on ubiquitous computing technologies, the ability to adapt processes in real-time based on contextual cues becomes a critical competitive advantage. Our architecture builds upon the foundational principles of Service-Oriented Architecture (SOA), providing a robust framework for optimizing the flow of business processes. By incorporating contextual awareness into the execution flow, we empower organizations to respond dynamically to changing circumstances and seize opportunities more effectively. Using a detailed case study focused on the transportation industry, we illustrate the practical application and benefits of our architecture. Through this case study, we showcase how our approach enhances operational efficiency, streamlines workflows, and improves resource utilization. The primary contribution of our work lies in the novel integration of context-awareness into business process execution. By blending contextual information seamlessly into the execution flow, we set a new benchmark for agility and intelligence in business operations. This integration enables businesses to not only adapt to current conditions but also anticipate future needs, thereby staying ahead in today's fast-paced market landscape.

Keywords: Business process execution, Context-aware Architecture, Business process modeling, Context-awareness, Service Oriented Architecture, ubiquitous computing

1. INTRODUCTION

The advent of Business Process Management (BPM) systems in the 1990s marked a turning point in optimizing business operations, driven by a relentless technological revolution. With the emergence of advanced artificial intelligence techniques, widespread deployment of cloud computing, and the acceleration of digital transformation, performance and efficiency standards have been redefined. Now, adjusting business processes based on real-time operational context represents a significant strategic challenge for organizations.

Business processes that demonstrate sensitivity to context and are capable of dynamically adjusting to economic fluctuations, consumer expectations, or legislative changes have become essential. This operational flexibility is of paramount importance in fields such as logistics, where streamlining live routes can generate significant savings, or in the healthcare sector, where the ability to respond promptly and appropriately can be crucial. However, despite the evident value of contextual adaptation, existing systems are often hindered by a lack of flexibility, slow responsiveness, and limited integration of updated data.

In response, this article proposes a revolutionary architecture that is sensitive to the evolving context within which businesses operate, leveraging the pervasive nature of ubiquitous computing to enhance operational efficiency.

Our novel Context-Aware Business Process Execution (CABPE) architecture incorporates a multi-faceted approach to Business process execution. It seamlessly integrates contextual information from various sources, thereby allowing organizations to adapt their processes in real-time. This dynamic approach to BUSINESS PROCESS execution represents a leap forward from the static models of old, providing a much-needed versatility in the face of technological advancements.

With the proliferation of devices and sensors, organizations can now capture a wealth of contextual

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information, from equipment performance to consumer behavior. The effective utilization of this data is what sets CABPE apart, offering a strategic advantage through improved responsiveness and a heightened understanding of the operational context. This article will delve into the intricate relationship between context-awareness and Business Process Management, elucidating how our architecture not only responds to contextual shifts but also proactively capitalizes on them to drive business.

In the forthcoming sections, we will explore the critical role of technology in Business Process Management, introduce the CABPE architecture, and present a case study from the transportation sector to illustrate the practical application of our approach. By the conclusion, we will have presented a holistic view of how integrating contextual information with Business Process Management can significantly elevate a company's efficiency and competitive edge.

2. Background and Related Work

A. Context and context-awareness

Context-awareness and context are important concepts within the domain of computer science and human-computer interaction. Context refers to the environmental, social, and task-related factors that can influence the behavior and perception of individuals. Context-awareness refers to the capacity of a system to align with the user's context by providing relevant information and services in a timely and personalized manner.

Numerous studies have investigated the impact of context and context-awareness on various aspects of human-computer interaction, including user behavior, system performance, and user experience. For example, a study by [1] explored the use of context-awareness in mobile computing applications, showing that context-aware systems can significantly improve user performance and satisfaction. Similarly, a study by [2] demonstrated the effectiveness of context-awareness in improving the usability of mobile devices.

Additional research has concentrated on developing and implementing context-aware systems. For instance, a study by [3] proposed a context-aware framework for smart homes, which can provide personalized services based on the user's context. Another study by [4] developed a context-aware recommendation system for e-commerce, which can provide personalized recommendations based on the user's context.

Furthermore, context and context-awareness have also been studied in the context of healthcare. For example, a study by [5] explored the use of context-awareness in healthcare applications, demonstrating the potential benefits of context-aware systems in improving patient outcomes and reducing healthcare costs. Similarly, a study by Srinivasan et al. [6] investigated the use of context-awareness in personalized healthcare, showing that context-aware systems can play a role in improving the accuracy and effectiveness of healthcare interventions.

Moreover, context and context-awareness have been studied in different domains, such as social networks and e-learning. In fact, a study by [7] investigated the use of context-awareness in e-learning applications, demonstrating that context-aware systems can improve learning outcomes and learner satisfaction. Another study by [8] explored the use of context-awareness in social networks, showing that context-aware systems can improve user engagement and user satisfaction.

Indeed, the literature on context and context-awareness has emphasized the importance of context in the design and development of ubiquitous computing applications. Researchers have proposed various frameworks and models for context modeling and reasoning and have explored various approaches to addressing privacy concerns in the context of context-aware computing.

B. Business process

In today's competitive business environment, optimizing organizational performance is crucial. One approach that has gained significant attention in recent years is Business Process Management (BPM), which is defined in [9] as "Business Process Management (BPM) is a systematic approach to improve organizational performance through the effective and efficient management of business processes. It involves the identification, analysis, modeling, design, implementation, monitoring, and continuous improvement of business processes to meet customer requirements, achieve strategic objectives, and comply with regulatory and legal requirements."

As previously mentioned, Business Process Management is a management approach that focuses on optimizing business processes to enhance organizational performance. The BPM cycle is a series of interrelated stages that organizations follow to achieve this goal.

Indeed, Business Process Execution is a systematic approach to optimizing business processes through multiple stages: model, execute, and optimize. This iterative process involves analyzing current processes, creating a blueprint of the desired process flow, modeling the process, executing it using appropriate tools and technologies, monitoring performance, and making improvements based on feedback. The goal of Business Process Management is to enhance organizational performance by improving productivity, efficiency, and customer satisfaction.

In fact, Business Process Execution refers to the implementation of a business process to achieve specific goals or objectives. Since the evolution of the BPE(Business Process Execution) concept, several tools and techniques have been proposed to address various issues.

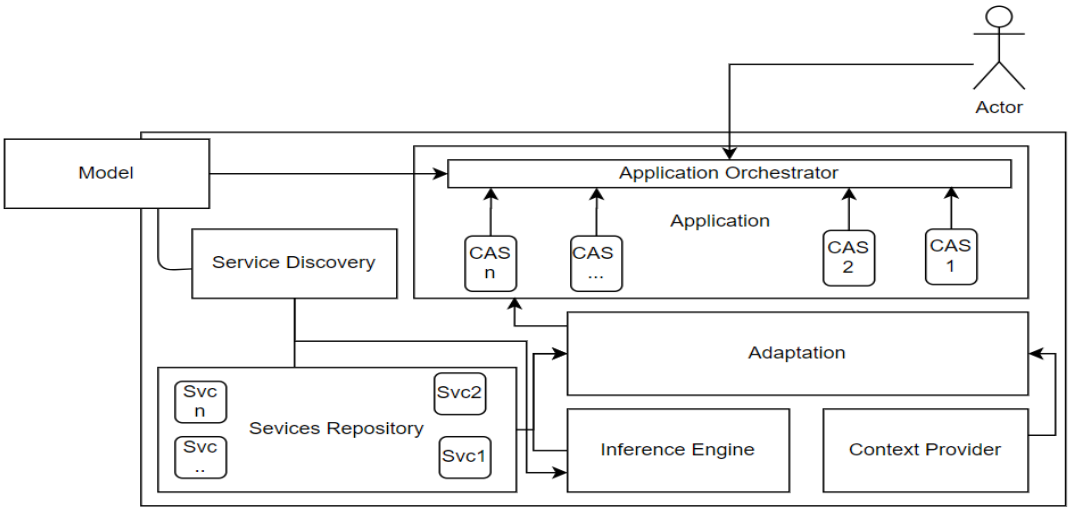

Figure 1 : CBPE Architecture: Contextual Business Process Execution

Literature suggests that workflow management systems [10], process mining techniques [11], and business process management systems [12] can help organizations improve their Business Process Execution. Business Process Execution Language (BPEL) is a widely used standard for executing business processes in service-oriented architecture environments [13]. The use of techniques such as compensation, transaction management, and error handling can help ensure that business processes are executed reliably and fault-tolerantly [14].

Indeed, various approaches have been proposed by researchers to overcome the challenges associated with BPE (Business process execution) . For example, some researchers have suggested leveraging IoT technology, while others have proposed a new approach to execute the BUSINESS PROCESS in the cloud. Moreover, some researchers have proposed integrating blockchain technology for securing BUSINESS PROCESS execution. These innovative approaches are helping organizations to streamline their business processes and enhance their operational efficiency.

3. CABPE Architecture

The CABPE (Context-aware Business Process Execution) architecture represents a paradigm shift in how business processes are executed. Rooted in SOA (Service-Oriented Architecture) principles, it is meticulously designed to embed contextual intelligence into business process execution. This architecture is not just a framework; it's a strategic tool enabling businesses to seamlessly integrate and leverage contextual data for enhanced process efficiency and adaptability.

Key components of the CABPE architecture include the Model, ServiceDiscovery, Service Repository, Inference Engine, Context Provider, Adaptation, and Application. Each component serves a distinct but interlinked function:

- The Model acts as the blueprint, outlining the business process framework.
- ServiceDiscovery is pivotal in selecting appropriate services from the extensive company's service repository, based on specific process requirements.
- The Service Repository is a comprehensive database of all available organizational services.
- InferenceEngine plays a critical role in understanding and utilizing the semantics of the services, ensuring that semantic queries are efficiently handled.
- Context Provider is the linchpin that gathers and formats contextual data from varied sources, making it usable for the system.
- The Adaptation component is where the magic happens – it tailors services according to the nuanced context provided, ensuring that the execution is always in line with the user's current environment.
- Finally, the Application component is the executor, orchestrating the flow and interaction of services within the business process.

This intricate interplay of components within CABPE is designed for two primary outcomes: streamlining the

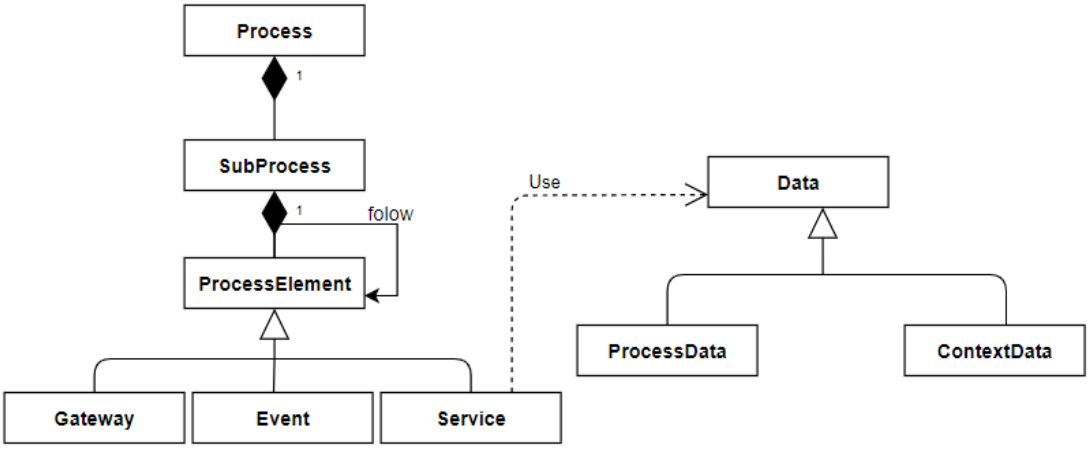

Figure 2 : Business Process Meta-Model

execution of business processes and significantly enhancing organizational efficiency.

A. Model

In the domain of business process modeling, various techniques like BPMN (Business Process Model and Notation), EPC (Event-driven Process Chain), and Petri nets have been widely employed, each offering distinct advantages and limitations. BPMN is renowned for its intuitive graphical notation, EPC for its event-centric approach, and Petri nets for their mathematical precision. The choice of a suitable modeling technique becomes complex, especially when addressing intricate and diverse business processes.

In our research, we have adopted the metamodel proposed in [24], which stands out due to its holistic approach to the intricacies of business process modeling. This metamodel uniquely addresses the typical challenges encountered in modeling, offering a comprehensive framework that encompasses both the operational aspects of business processes and the subtleties of contextual information. Its implementation aims to map the intricate web of interdependencies that exist between various facets of business processes and their surrounding contexts, thereby providing a more accurate and flexible tool for modeling these relationships.

Central to our metamodel is its detailed structure, as depicted in Figure 2. At its foundation lies the 'Process' element, which is the core representation of the business process. This element is subdivided into 'SubProcesses', consisting of a series of 'ProcessElements'. These elements represent the key components of a business process, including Gateways, Events, and Services. The Gateway element, in particular, plays a pivotal role in orchestrating the flow between Services and Events, ensuring seamless process execution.

Moreover, our metamodel includes a comprehensive depiction of the data integral to the business process, categorized into 'ProcessData' and 'ContextData'. This distinction allows for a nuanced representation of both the operational data and the contextual information that influences the process, enhancing the model's applicability and adaptability.

Overall, our metamodel offers a robust and adaptable framework for business process modeling, elevating the precision, flexibility, and scalability of these efforts. It represents a significant advancement in the field, aligning the detailed operational aspects of business processes with the broader contextual factors that influence them.

B. Service Discovery

Service discovery is a crucial component in service-oriented architectures (SOAs) as it enables the identification and utilization of services that are available. Numerous techniques and approaches have been proposed for service discovery, each with its own strengths and limitations.

In the existing literature, various approaches have been proposed to implement service discovery. Some approaches involve a simple keyword and category search on UDDI. Hatzi et al. [25] proposed a specialized framework for retrieving services in WSDL and OWL-S standards by adapting the TFIDF model. Another approach utilized identification with Woogle in WSDL (Web Services Description Language) artifacts that recommend similar services [26]. Other approaches are based on semantic languages such as OWLS-MX [27] and SAWSDL[28], With the capability to automatically discover service compositions.

Our approach to service discovery involves two methods. The first method is a simple search by name, which is straightforward since it only requires the name of the service to retrieve it. However, in cases where the desired service cannot be found by name, we employ a semantic search approach. This approach involves searching for services that are semantically like the name in question, to increase the chances of finding the required service. This technique provides a more sophisticated and efficient way of service discovery, ensuring that users can find the services they need even if they don't know the exact name of the service they're looking for.

C. *Service Repository*

Service repository is a central repository or database that contains a collection of services. These services are available for use by different applications or systems within an organization. The repository typically contains information such as the name, description, functionality, quality of service, and other relevant details about the services.

The importance of a service repository cannot be overstated in service-oriented architectures (SOAs). One of the primary benefits of a service repository is that it enables service reuse, which can lead to significant cost savings for organizations. By having a centralized location for services, organizations can avoid duplicating services and instead reuse existing ones, which can help to reduce development time and costs. Additionally, a service repository can help to improve the quality of services by

providing information about service functionality, quality of service, and other relevant

details. This information can help developers make informed decisions about which services to use and how to integrate them into their applications. Finally, a service repository can also help to improve the overall management and governance of services within an organization, as it provides a centralized location for managing and tracking services.

Service repository is a catalogue of services provided by the company. it contains all the services. Each service has an inputs/outputs.

Our service model is built on two fundamental components: services and parameters.

The service component represents the core functionality that is being provided to users, while the parameter component serves as the input and output of the services. Parameters play a crucial role in facilitating the flow of information between the different services that are part of the business process. They enable data to be shared and passed between services, allowing the overall process to function efficiently. By defining and managing services and their associated parameters, we can create a flexible and scalable SOA that can meet the changing needs of the business.

to use the service and make it available for service discovery, it must be registered in our service registry.

The service registry serves as a reference to store and retrieve data structures that facilitate communication between applications. It acts as a central repository for storing and accessing schemas that are useful in developing specific applications. In our case, we utilize the service registry to store and retrieve valuable information that enables us to optimize the utilization of our services

D. *Context Provider*

Context provider aim to extract contextual information from various sources, including databases, web services, sensors, and more. The gathering of contextual information relies on the type and sources of this information. For instance, transportation information is directly supplied by the transportation company, leading to frequent updates, The collection process involves engaging with diverse and distributed software or hardware components.

Fig. 3 shows the architecture of our context provider.

- Context Model: enables the representation of context in a structured format that can be utilized by other components. In the context of business processes, any information that enhances the modeling, execution, or improvement of the process is considered relevant. To ensure that this context can be formalized in a generic way and used in other applications, we have based our model on the meta-model proposed in [24].
- Context Information transformer: o ensure that the various information collected from diverse sources can be utilized by the other components of the architecture, the context information transformer.

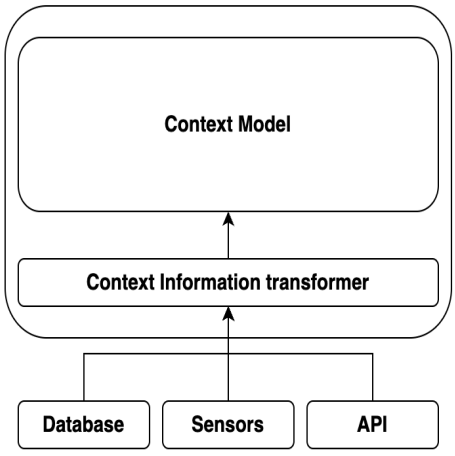

Figure 3 : Context Provider

E. Inference Engine

The Inference Engine in the CABPE architecture, based on ontologies, aims to process contextual data and generate relevant situations for the execution of business processes. Ontologies play a crucial role by providing a formal representation of domain knowledge, enabling the inference engine to reason logically and coherently.

Through ontologies, the Inference Engine can model concepts, relationships, and rules specific to the application domain. For example, in the transportation domain, ontologies can define concepts like stations, transport lines, schedules, and their relationships. These ontologies facilitate a precise understanding of the context in which business processes are executed.

The Inference Engine analyzes real-time contextual data and deduces specific situations. These situations represent the current context in which business processes need to be executed. For example, a situation may include information about the user's location, traffic conditions, user preferences, etc.

The Inference Engine generates situations that are then sent to various parts of the system, including the Adaptation component. This component utilizes these contextual situations to customize business processes according to the specific context. For instance, if the Inference Engine identifies a scenario where the user is rushed and traffic is heavy, the Adaptation component might suggest alternative routes or faster transportation modes.

In this way, the Inference Engine supplies the CABPE system with relevant contextual situations based on ontologies. These situations are employed by different system components, such as the Adaptation component, to optimize the efficiency and applicability of business processes in dynamic and changing environments.

F. Adaptation

Adapting a system to the user's context is the operation that involves making modifications to software or a computer system in order to ensure its functions and improve its performance in its usage environment. There are two types of adaptation: static and dynamic. The choice of adaptation type depends on the constraints and nature of the application. Static adaptation corresponds to the adaptation performed before the application's execution or the adaptation made during the initialization phase of the application.

To build context-aware services, we need to define mechanisms for adapting the behavior of the services based on the current context situation. The required mechanisms should allow for loose coupling between the core services and the adaptations. Thus, the services should be able, in our case, to dynamically adapt their behavior to different situations by leveraging only relevant contextual information.

Indeed, the service must be able to modify its behavior according to the current observed situation and operate in a runtime environment that is both dynamic and changing (current context). During its execution, the service should be able to detect changes, assess the need for adaptation to the current situation, reconfigure autonomously, and implement the required adaptation for each specific situation.

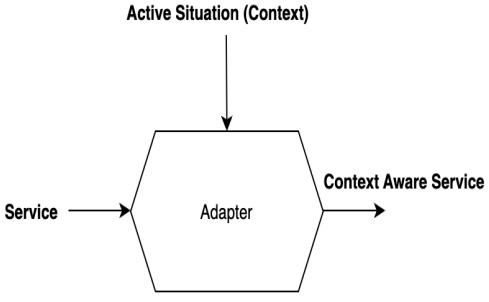

Figure 4 : CBPM Adapter

Our adapter operates by taking as input two essential elements: first, a service, and then relevant contextual information. It then operates to produce as output a service adapted to the context. In other words, this adapter's mission is to make the service sensitive and responsive to the provided contextual information, significantly enhancing its relevance and usefulness in various usage scenarios.

Our approach has been to implement a method based on

the aspect-oriented programming (AOP) paradigm. This means that we introduce specific behaviors, or aspects, cross-cutting into the service code so that it can adapt flexibly according to the context. The use of AOP allows us to insert these behaviors without significantly altering the service structure, making it extremely adaptable and scalable while addressing the various challenges that SOA architectures may face.

4. RESULT

A. *Case Study: TRANSPORT SYSTEM*

To validate our methodology, we have implemented it in a real-world scenario, specifically the transportation case study. This case study is known to present a significant challenge when it comes to utilizing contextual information in business processes.

The selected case study revolves around a transport company's process, which involves recommending optimal routes within the city of Rabat. This transportation service application is designed for both the city's residents and passengers. Essentially, anyone looking to gain insight into the various routes within Rabat can utilize this application.

In various situations, several challenges may arise when developing a transportation application, including:

- Capturing context from multiple sources: One of the significant challenges is collecting context information from various sources such as the user's environment and devices. This information can include location data, weather, traffic, and other relevant factors, which can be used to optimize the user's experience.
- Incorporating the user's environment and traffic context: The application needs to consider the user's environment and traffic context to provide effective services such as route search and display.
- Managing data privacy and security
- Ensuring compatibility with various devices and platforms

By addressing these challenges, transportation applications can provide more personalized and efficient services to users, enhancing the overall user experience and improving operational efficiency.

B. *Application*

Through this case study, we aim to demonstrate the effectiveness of the transportation company's approach in providing an intuitive and user-friendly solution for navigating the city's routes. The application targets a broad audience, encompassing anyone who needs information on the various transportation options available in Rabat.

We will showcase a few screenshots of our application, giving a glimpse into its design and user interface. Our application features a clean and intuitive user interface, making it easy for users to access the various services on offer.

The emphasis is on simplicity and ease of use. We've designed the application so that users can quickly find the information they need, whether it's planning a route, checking public transport schedules.

Our application aims to simplify the lives of users by providing a practical and efficient tool for getting around the city of Rabat. Its intuitive interface and useful features make it an ideal companion for anyone using public transportation in the region.

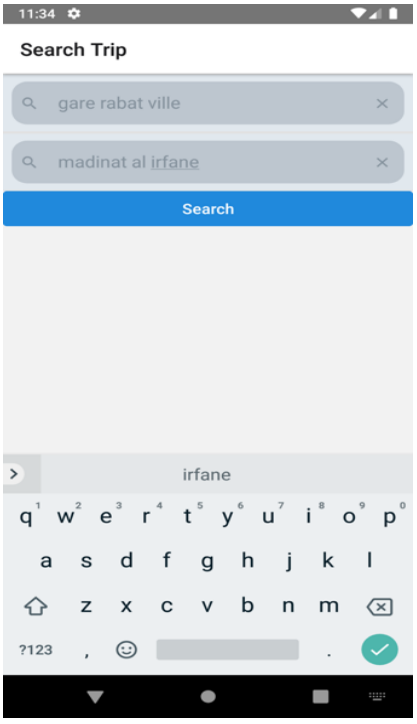

Figure 5 : SearchTrip

Figure 6 : Display Result

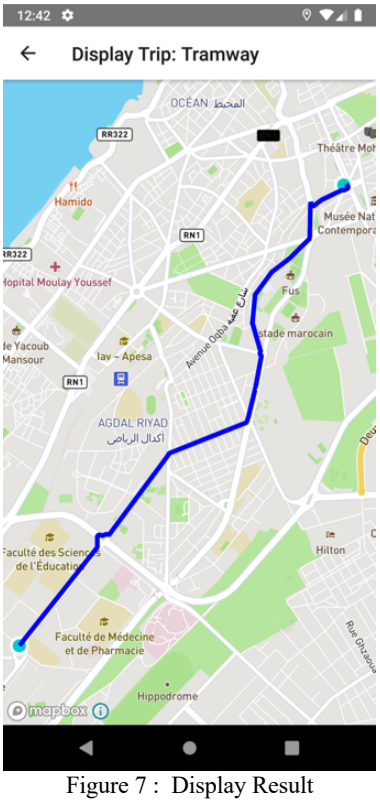

Figure 7 : Display Result

5. CONCLUSION

In summary, this article has introduced a groundbreaking approach to Business Process Management (BPM) that leverages contextual information to enhance the efficiency and competitiveness of companies. Our focus has been primarily on the BUSINESS PROCESS modeling phase, where we have introduced two key components: a business process meta-model (CBPM) and a context meta-model. These models lay the foundation for our proposed architecture for BUSINESS PROCESS Execution (CBPEA), which is based on a service-oriented architecture (SOA) and incorporates components for implementing contextual services tailored to the user's needs.

Moving forward, our current efforts are directed towards enhancing the BUSINESS PROCESS through the integration of machine learning algorithms into the service selection component of our CABPE architecture. This advancement aims to further personalize and optimize services for the end-user, ensuring that business processes are not only context-aware but also adaptive and responsive to changing conditions. By leveraging machine learning, we can improve the accuracy and effectiveness of service selection, leading to better outcomes and increased user satisfaction.

The implementation of our approach in a prototype within the transportation domain has yielded promising results, validating the effectiveness of integrating contextual information into Business Process Management. In this prototype, we demonstrated how our approach can optimize transportation processes by considering factors such as traffic conditions, weather forecasts, and user preferences. By dynamically adjusting transportation services based on real-time contextual information, we were able to improve efficiency, reduce costs, and enhance the overall user experience.

Looking ahead, we see vast potential for the application of our approach across various other domains. From healthcare to finance, manufacturing to retail, integrating contextual information into Business Process Management can lead to significant improvements in operational efficiency and user satisfaction. For example, in healthcare, our approach could optimize patient care by considering factors such as medical history, current symptoms, and resource availability. Similarly, in finance, it could streamline loan approval processes by analyzing market trends, customer profiles, and risk factors.

Overall, our approach to Context-Aware Business Process Execution (CABPE) represents a paradigm shift in Business Process Management (BPM), offering organizations a powerful tool to adapt and thrive in today's dynamic business environment. By combining advanced modeling techniques with innovative architectural designs, we have laid the groundwork for a new era of business

process management—one that is context-aware, adaptive, and poised for success in the digital age.

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