ON COMPOSING WEB SERVICES FOR COALITION SCENARIOS: CONCEPTS AND OPERATIONS [1]

Chirine GHEDIRA, Zakaria MAAMAR, and Djamal BENSLIMANE

Abstract: The rapid development of information and communication technologies provides new opportunities for users to access up-to-date information anytime, anywhere. The adoption of these technologies is highly recommended in coalition operations of humanitarian-assistance type, which feature the commitment of several international partners. A humanitarian-assistance scenario needs the simultaneous participation of governmental and non-governmental organizations in order to relieve the consequences of a natural disaster. In this scenario, the participants have to agree on the information to share and act in a coordinated manner despite the different doctrines, cultures, and languages that exist among them. Moreover, the diversity and versatility of a humanitarian-assistance scenario constitute another set of obstacles that have to be overcome by the participants. This paper aims at promoting the appropriateness and relevancy of Web services in coalition operations since they can improve the inter-platform communication through well-defined standards.

Keywords: Web Services, Semantic Mediation, Coalition, Humanitarian Assistance.

Introduction

The latest development of information and communication technologies has enabled the emergence of an increasing number of various systems. At different time of day, users from different businesses and with different background work together towards achieving joint operations following common interests. However, these users are at different locations (a distribution constraint), rely on different systems (a heterogeneity constraint), and use different languages for communication (a semantic constraint). In addition, the increasing demand of users for high quality and timely information is putting businesses under pressure of adjusting their know-how and identifying new ways for collaboration with peers. Despite these constraints, a strategy that supports users' collaboration could be based on Web services.[2] Web services are nowadays emerging as a major technology for deploying automated interaction between distributed and heterogeneous applications. Web services are considered as self-contained, self-describing, modular applications that can be published, located, and invoked, respectively.

Web services-based Business-to-Business (B2B) scenarios yield insight into the capacity of Web services to be composed into high-level business processes usually known as composite services. Composition primarily addresses the situation where a user's request cannot be satisfied by any available Web service (called service in the rest of this paper), but a composite service obtained by combining available Web services could be used.[3] For the requirements of composition, a composite service is always associated with a specification that describes, among other attributes, the list of component Web services that contribute to the composite service, the execution order of these component Web services with respect to data and temporal dependencies, and the corrective strategies in case of exception handling. The Web services community uses different languages for specifying Web services composition (e.g., Business Process Execution Language, Web Services Flow Language). The primary objective of these specification languages is to provide a high-level description of the composition process; they do not specify any implementation details or concerns. The specification of composite services deals also with the semantics of information that the component Web services exchange.

In this article, Web services are used in the context of a humanitarian-assistance scenario in which different nations, the United Nations (UNs), and Non-Governmental Organizations (NGOs, e.g., Médecins sans Frontières), participate and work together with the objective to relieve the consequences of natural disasters. In any multinational scenario, collaboration represents common responsibilities and constitutes a major pillar for success. As a prerequisite to that collaboration, the participants have to agree on the information to share and act in a coordinated manner despite the different doctrines, cultures, and languages. Moreover, the diversity and versatility of a humanitarian-assistance scenario constitute another set of obstacles that participants have to overcome. In this article, the authors aim at discussing the value added to coalition operations by Web services and how they can boost the efficiency of these operations. It is agreed that the Web services improve the inter-platform communication through well-defined standards mainly based on XML. The salient features of the proposed in this article Web services-based approach to the support of coalition operations are as follows:

- The participants in a coalition contribute with different types of Web services. The Web services offer the same functionalities that generally exist. However, they differ in arguments such as execution cost, execution time, QoS, etc.

- Compositions of Web services are made according to pre-defined specification templates.
- Ontologies support the semantic mediation during Web services composition. It will be shown below that the lack of an explicit semantics hampers the possibilities of automating coalition operations.

The paper is organized as follows. The next section provides an overview of the running scenario, namely humanitarian assistance. The section after that defines Web services and the process of composing them. Then, the Web services-based approach to the support of operations of humanitarian assistance in a coalition scenario is presented. Finally, conclusions and future research directions are given.

Running Scenario: Humanitarian Assistance

Nations, the UN, and NGOs are the three major providers of humanitarian assistance in today's international community. Their methods of offering assistance and expected results may differ, but their general aim to provide relief to suffering is the same.[4] Unfortunately, the international humanitarian-assistance system is not a well-defined framework of laws, principles, or norms. Instead, the assistance system is based on a set of informal arrangements that emerge among the participants. There is no single framework that could be applied to every assistance scenario. Maamar and co-workers have identified and summarized the elements that characterize a coalition operation as follows[5]:

- People from different countries, at different locations, and at different moments of time contribute to the definition of the operations (e.g., deploying tents). However, these people usually do not agree on the semantics of the information they exchange and do not manage the same type of resources that range from low- to high-tech equipment.
- At diverse hierarchical levels, different people make decisions that influence the decisions of others either positively or negatively.
- At the theatre of operations, it is a complex task to provide and maintain a high-level assistance to the participants. Lack of reliable communication infrastructure could be one of the obstacles.

In coalitions, three types of interaction were identified;[6] they are highlighted in Figure 1. Interaction of type interconnectivity allows simple data transfer without semantics between the participants. Interaction of type composition enables the integration of the Web services that the participants put forward into common operations. As it has been discussed already, composition mainly deals with the increasing complexity of users' needs. Last but not least, interaction of type collaboration supports the decision-making process between the participants for efficiency reasons. In Figure 1,

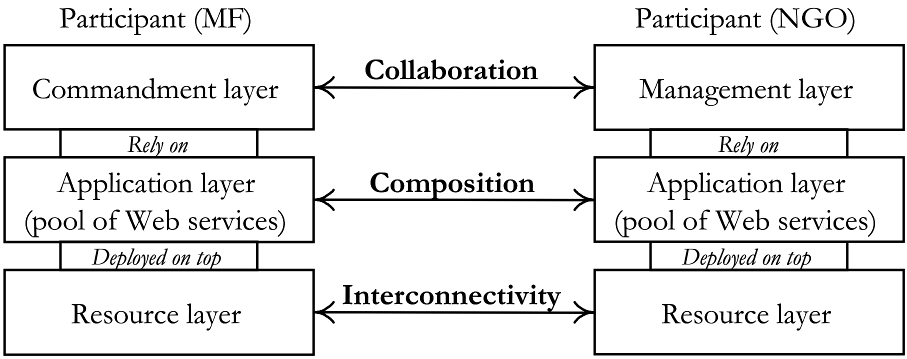

Figure 1: From Interconnectivity to Collaboration through Composition.

the commandment/management layer relies on the application layer to achieve the coalition's main mission (humanitarian assistance). Underneath this layer, the application layer offers different types of Web services that vary from data fusion and weather forecasts to logistics. It may happen that a composition of these Web services is required when a participant has some but not all of the information and abilities needed to perform an operation. To support the deployment of these Web services, a resource layer is considered.

Web Services

This section consists of two parts. The first part defines what a Web service is and the second part classifies the composition of Web services into two types.

Definitions

A Web service is an accessible application that other applications and humans can find and trigger to satisfy various needs. Benatallah, Shengand, and Dumas [7] associate the following properties with a Web service: independent as much as possible from specific platforms and computing paradigms; primarily developed for inter-organizational situations; and easily composable so that developing complex adapters for the needs of composition is not required.

Several standards support the development of Web services, such as SOAP (Simple Object Access Protocol), WSDL (Web Services Definition Language) and UDDI (Universal Description, Discovery and Integration).[8] SOAP is an XML-based lightweight messaging protocol intended for exchanging structured information between applications in a decentralized environment. WSDL provides description of connection and communication with a particular Web service. Finally, UDDI represents a set

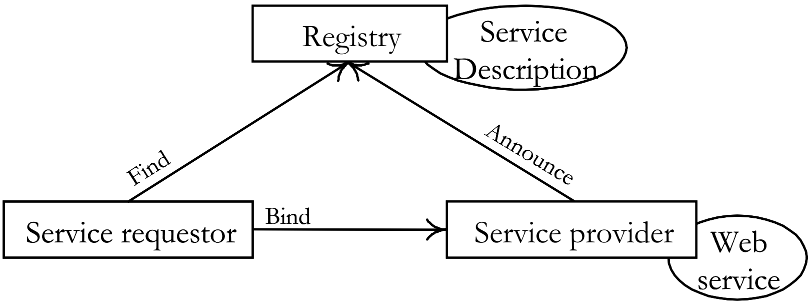

Figure 2: Typical Usage Scenario of Web Services.

of protocols and is directed towards providing public directory for the registration and real-time look-up of Web services and other business processes. The common usage scenario of Web services can be associated with three phases (publish, find, and bind) and three modules, namely, service requester, service provider, and registry (see Figure 2). The requester invokes services. The provider posts services for invocation purposes. Finally, the registry supports posting and announcing Web services to the potential community of requesters.

Composition of Web Services

A composition operation connects Web services together in composite services. The connection of Web services implements an underlying business logic, which depends on the application domain and control flow of the business case for which the composite service is devised. Examples of business cases are many, such as travel planning and journal-paper review. For the requirements of composition, a composite service is always associated with a specification that describes, among other attributes, the list of component Web services that participates in the composite service, the execution order of these component Web services, and the corrective strategies in case of exception handling. Figure 3 demonstrates the specification of a composition service for travel planning. The specification uses a combination of state-chart and service-chart diagrams.[9]

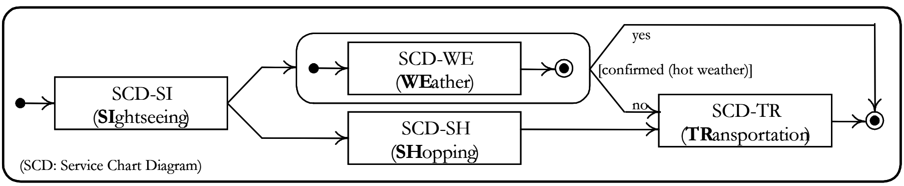

Figure 3: Sample of a Composite Service Specification.

It is accepted that the efficiency and reliability of a composite service strongly depend on the commitments, performance, and delivery capabilities of each component service. In what follows, an overview of the approaches for developing composite services is presented.[10]

- *Proactive composition vs. Reactive composition.* A proactive composition is an off-line process that gathers in-advance available component services to constitute a composite service. The composite service is pre-compiled and ready to be triggered on users' requests. In a proactive composition, the component services are usually stable and may possibly be running on resource-rich platforms. A reactive composition is the process of creating composite services on-the-fly. A composite service is devised on a request basis from users. Due to the on-the-fly property, a component manager is required to ensure the identification and collaboration of the component services. Despite a "certain" complexity of the reactive composition, it has several advantages compared to the proactive composition, for instance, the possibility of tracking the status of the composition process so that corrective actions can be promptly taken, and the possibility of optimizing runtime arguments such as bandwidth use, data transfer routes, and execution charges.
- *Mandatory composite service vs. Optional composite service.* A mandatory composite service corresponds to the compulsory participation of all the component services in the execution process. Because it is expected that the component services will be spread over the network, the reliability of the execution process of each component service affects the reliability of the whole composite service. An optional composite service does not necessarily involve all the component services. Some components can be skipped during execution due to various reasons such as possibility of substitution or non-availability.

Web Services in Coalition Scenarios

This section consists of three parts. The first part presents the proposed architecture on which the Web services-based approach for supporting coalition operations is deployed. The second part describes the operations in this architecture with an emphasis on the semantic inconsistencies that occur between Web services. The solution proposed to deal with these inconsistencies is given in the third part of the section.

Architecture

Figure 4 presents the Web services-based approach to support of coalition operations. The approach is based on three inter-related modules: composition, mediation, and execution. Deployed on top of a collaboration platform, the modules interact with several providers of Web services, which identify the participants in a coalition, respectively. The role of the platform is to ensure the flow of exchange between the modules: from composition to execution through mediation. In addition, the platform is associated with two repositories (represented with ovals in Figure 4), one for the specification of composite services and the other for ontologies to be used during data semantic mediation. One of the prerequisites of our approach to support of coalition operations is to agree on the meaning and structure of the information that the Web services request and provide. Therefore, there is a need for (i) an explicit semantic description of the Web services' capabilities and requirements, and (ii) a mediation that matches input and output parameters between Web services not just at structural but also at semantic level (Maamar, Benslimane, and Narendra also promote mediation at context level).[11]

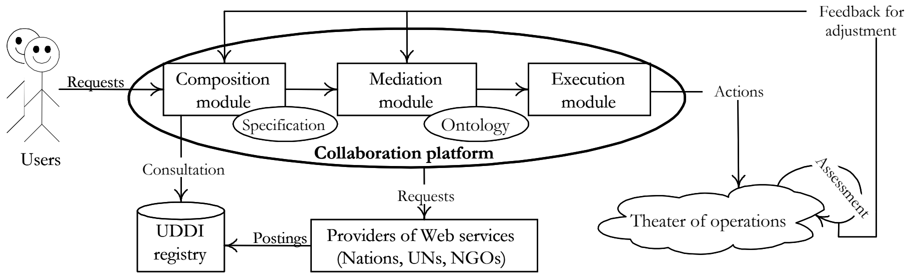

Figure 4: Web Services-based Approach to Coalition Operations.

In what follows, the role of each module is explained according to the interaction that the module performs with other peers. Initially, providers specify their Web services prior to posting them on the UDDI registry of the collaboration platform. By providers the authors mean nations, UNs, and NGOs. Examples of Web services are many, varying from "weather forecasts" of the operations theatre and "transportation planning" of resource distribution to "store tracking" of the distributed aids.

Composition Module

The role of the composition module is to satisfy requests that originate from users (e.g., the manager of a transportation division). The requests are associated with specification of composite services and can require, for their performance, the participation of multiple Web services contributed by multiple providers. For example, before planning "food distribution," it is deemed appropriate to check the weather forecast for cases of snow storm alert. Once the specification of the composite service is identified, the composition module searches for the relevant Web services by consulting the UDDI registry. Afterwards, this specification is passed on to the mediation module. At this stage of the composition process, the list and execution order of the component services are known. It is accepted that more than one service can offer the same functionality. Therefore, Web services are associated with such criteria as execution cost, reliability, and response time that determine their selection.

Mediation Module

The mediation module is responsible for identifying and fixing all the semantic inconsistencies that could occur during Web services composition. These inconsistencies are normal due to the fact that the services originate from different providers with different practices. In addition, it is known that current standards for Web services only achieve services composition at the level of message interactions. This is by far not sufficient, as composition needs also to be conducted at the level of message semantics. The semantic composition guarantees that the information exchanged between Web services is clearly understood. The need for a common semantics is intensified when Web services that originate from different providers have to take part in the same composition. In case the semantic heterogeneity is not dealt with properly, it poses a serious problem to Web services composition.[12] To tackle this problem, the mediation module of the collaboration platform is bound to the ontology that is adopted by the participants of the humanitarian-assistance scenario. Additional details on this challenging issue are given in the section devoted to semantic mediation. When these inconsistencies are resolved, the specification is passed on to the execution module.

Execution Module

The execution module receives a free-of-conflicts specification from the mediation module and its responsibility is to execute this specification. The execution consists of triggering the Web services, supporting the exchange of information between the Web services, and last but not least, communicating the latest details to the concerned parties. For instance, the status of setting up tents for refugees is submitted to the participants in charge of the mission at the commandment level. It is interesting to note that the actions taken by the execution module have an impact on the theatre of operations. This theatre of operations is under a continuous assessment so that appropriate feedbacks are given and adjustments are made. The composition and mediation modules are interested in the feedbacks. For instance, it might happen that a semantic inconsistency was not resolved properly because the location of a camp is distant from a road due to poor handling of measurement units (cm vs. inches).

Operations

Figure 5 illustrates the activity diagram of the proposed Web services-based approach to coalition operations support. In this figure, rounded rectangles highlight the performance of activities. Regular lines correspond to the chronology of interactions between activities. And finally, the dotted line boxes assign activities to one of the three modules of Figure 4, namely, composition, mediation, and execution.

The main steps in the activity diagram of Figure 5 are as follows: situation and request study, Web services identification for a given composition task, heterogeneity problem analysis in case the interfaces of the Web services have to bind to ontology (see the section on semantic mediation), composite service execution, outcome evaluation of actions, and adaptation of the composition to accommodate organizational changes. In addition, the activity diagram enables highlighting the relations that exist between the composition, mediation, and execution modules. In Figure 5, the "composite service scheduling" activity has the role of orchestrating the invocation of Web services and supporting the transfer of information to the appropriate Web services. The scheduling could, for example, be based on a time stamp that checks the temporal consistency of the Web services.[13] It should be noted that Web services orchestration could take two different forms: centralized and peer-to-peer. The centralized form assumes that the composite service triggers the appropriate component Web services when needed. This form is present in the eFlow system of Casati and Shan.[14] One of the drawbacks of the centralized form is the bottleneck that a composite service could be for the normal progress during the deployment of a specification. The peer-to-peer form, as adopted by Benatallah, Shengand, and Dumas,[15] assumes that the component Web services manage the appropriate information that allows triggering their peers.

For the reason that it would not be possible to predict all the situations that could happen in a coalition scenario, which means the non-existence of an appropriate specification that addresses the requirements of this situation, the composition module should have the possibility to find new Web services according to these requirements. Despite the ongoing research efforts that aim at automating the composition of Web services, some of the activities will still need human intervention. This represents one of the challenges of the authors' project on Web services for coalitions.

Semantic Mediation

Composition of Web services based on common agreement (a starting point to interpret the description of Web services in a particular domain/ context) assumes an initial step of mediation between the descriptions of the interfaces of these services. Indeed, data structures and contents received in a response to a message do not always

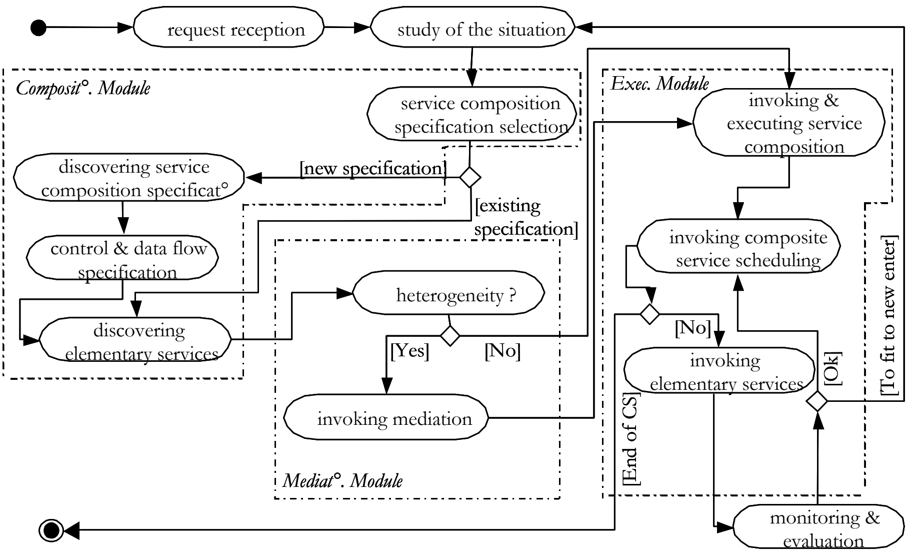

Figure 5: Activity Diagram of the Web Services Approach to Coalition Operations Support.

match the structures and contents required as input to a forthcoming component Webservice. In the proposed Web services-based approach to coalition support, the common agreement relies on the existence of ontology (a specification of the concepts of an application domain and the semantic proximity existing between these concepts). The use of ontology aims at solving the heterogeneities between the Web services. These heterogeneities are classified into two types: semantic and structural. The semantic heterogeneity concerns label conflicts of the vocabulary used for data description, unit and value conflicts that refer to different units used in the same description, and different values having the same meaning. The structural heterogeneity concerns primarily conflicts associated with parameters organized in different ways.

Ontologies give the right solution to the work on information structuring and modelling in a multi-participants scenario. Ontologies provide a formal conceptualization of a particular domain that is shared by a group of people in an organization.[16] However, centralized ontologies are featured by a complex development curve and are difficult to maintain due to time and efforts required for proposing and agreeing on the terms and their description. Bonifacio, Bouquet, and Traverso suggest a distributed approach to ontologies development.[17] This approach meets the requirements of disparate organizations and processes, as well as those of the considered coalition scenario. From a technological perspective, peer-to-peer solutions are well suited for distributed structures. It is possible for different participants to maintain their information structure while exchanging data with others. The peer-to-peer paradigm offers a relative independence regarding the architectural layer and physical constraints over the underlying network.[18] Since each element of the system acts as a client and server, this allows solving such problems as high load on a single server, replication and consistency between replicas, and lack of network resources in general. A coalition scenario can easily be mapped to a peer-to-peer configuration. Each participant acts as a peer from two perspectives. From a client perspective, a NGO-participant could ask for the support of military forces participants to supply food and medical equipment by air. From a server perspective, the same NGO participant could be asked to assess the population needs of a specific region so that military forces could secure the region prior to aid distribution. The interactions between the participants in a coalition are bi-directional and call for a continuous monitoring of the events in order to take actions. If no single Web service can satisfy a functionality required for accomplishing a mission, there should be a possibility for combining existing Web services in order to fulfil the mission.

In coalition operations, participants willing to join a peer group that already provides Web services first have to bind to the ontology of this group. To this end, the participants have to prepare a description, using for example OWL-S (Ontology Web Language-based Web Service Ontology, formerly DAML-S), of their Web services based on the ontology that describes the properties, semantics, and capabilities of the services (what the service does, how the service does it, and how the service is accessible). Afterwards, the WSDL-file of each Web service is mapped to an OWL-S description that can be interpreted by all the peers in the community (see Figure 6).

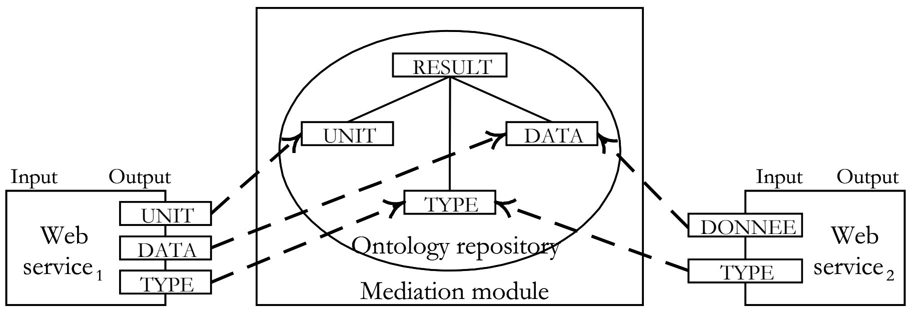

Figure 6: Interface Mappings to Ontology.

In Figure 6, the ontology repository is an integral part of the mediation module. We recall that this module returns a free-of-data conflict specification of a composite service to the execution module. The ontology repository includes all the ontologies that match the OWL-S description of the different Web services in a composition. Each ontology specifies the concepts of a domain and their association (represented by regular lines in Figure 6). The mapping of the Web services' interfaces (see the dashed lines in Figure 6) between the outputs and inputs of connected Web services refers to the association rules between each ontology that are stored in a mapping registry. In Figure 6, while the outputs of the first Web service (WS1) are "unit," "data," and "type," the second Web service (WS2) only needs two inputs, namely, "données" and "type". In WS1, "Data" output represents the coordinates that characterize the position of a security unit. WS2 needs these coordinates as inputs so that it can assign the task of securing the region identified with these coordinates to that unit. In WS1, the ontology that is used describes the location in English metric, whereas WS2 adopts a French metric. With the mapping rules between the ontologies corresponding to the different metrics, the mediation module translates the output of WS1 into French metric (e.g., "x coordinate" becomes "coordonnée x") and sends them as input to WS2.

Conclusion

This article demonstrated the importance of integrating Web services into operations of supporting coalitions. The importance comes from the challenges that coalitions face in terms of doctrine heterogeneity, complexity of decision-making processes, and lack of reliable communication infrastructure, to mention just a few. Another challenge that was subject to discussions in this paper was semantic mediation of the information that participants exchange. An approach-based on Web services provides a new alternative to the middleware-based approaches for system integration. Web services aim at improving the inter-platform communication through standards such as WSDL, UDDI, and SOAP.

The proposed Web services-based approach consists of three inter-related modules (composition, mediation, and execution) that were deployed on top of a collaboration platform. The composition module is responsible for satisfying user requests. The mediation module is responsible for identifying and fixing all the semantic inconsistencies that could arise during Web services composition. Finally, the execution module is responsible for executing the specifications of composite services. More work still exists around the proposed Web services-based approach for coalition support, for instance, Web services adaptability for exception handling reasons and ontology maintenance for efficiency reasons.

Notes:

[1] The views and opinions expressed in this paper are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements of Claude Bernard Lyon 1 University or Zayed University.

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