Designing a Service Composition Framework to Support Multi Actor Networks

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Abstract: *Mobile technologies provide opportunities to create innovative applications to improve public safety. New mobile services can be composed by reusing existing ones provided by various actors. The realization requires the cooperation between independent public organizations having their own and sometimes even opposing objectives. As a result decisions about composition requires negotiation and involvement of decision-makers from various organizations. A composition framework is necessary to support decisions regarding the selection of services within a multi-actor setting. In this paper we derive requirements and develop a composition framework based on a process-driven approach.*
Keywords: Service composition, location based services design, decision-making, case study, public safety.

1. Introduction

Improving the safety of citizens and reducing costs in the healthcare are on top of the political agenda . A major role is foreseen for the smart deployment of ICT (Dutch Ministry of the Interior and Kingdom Relations 2003). Context-aware mobile services are an important breakthrough innovation. Increasingly services consist of sub-services provided by various organizations. For example, if a police officer wants to check data of a car, this composed service consists of checking the license plate and owner information at the RDW (Rijksdienst voor het Wegverkeer, the Dutch road traffic department), checking if the taxes have been paid at the Inland Revenue and also checking if all fines have been paid in the police database. This seems a simple service consisting of three sub-services, however, in order to realize this composition, involved actors need to have at least a shared understanding of the capabilities of each sub-service, agree on service levels and costs and agree on authorizing and providing access to each others' systems. Especially the last element might be complicated as it can cause considerable risks and requires mechanisms to ensure a certain level of security and privacy. Even if a service is not directly visible or accessible to the user it is still important to know when it will be used, in order to predict the overall performance of the assembly of services. In our case study the actors involved had different priorities and where inclined to solve local problems first, which further complicates the realization of these compositions which have a more long-term focus.

The process of service assembly is referred to as service composition (Casati and Shan 2001). Service composition plays an important part in Service Oriented Architectures (SOAs). Applications are assembled using universal description and discovery mechanisms. Changes in requirements leads to the need for other services and to other sequences of services invoked. Services that provide some form of generic functionality can greatly optimize an application architecture and increase the overall productivity of application development projects (Erl 2004). Various service composition approaches exist, service composition is not standardized, nor does any of them include definitions of the key non-functional requirements that every composition approach must satisfy (such as scalability, dependability, and correctness) (Milanovic and Malek 2004).

Composition of services is necessary to master complexity (Alonso et al., 2003). Services can be grouped using common aspects, thus providing ways to browse different candidate services for a specific purpose. When deciding on a set of alternative compositions, the characteristics of the multi-actor network should be addressed. The actors involved are both autonomous as interdependent to a

certain degree. These opposite characteristics can complicate the decision making process. The *goal* of this paper is to derive a composition framework that is able to deal with the characteristics of a multi-actor network. The framework has to provide specific support for multi-actor decision making. This paper is structured as follows. In the following section we discuss the research approach, thereafter we present the literature background. In section four we present a case study and derive requirement on a multi-actor composition framework. In section five we derive our composition framework and finally we draw conclusions.

2. Research approach

Two main research steps are taken, we first derive requirements on a composition framework using an exploratory case study. Second, we develop a composition framework meeting these requirements based on insights from literature and practice. The composition framework is developed by taking a process view on compositions. We derived first the main phases and further detailed these phase using the insight from the case study and literature findings. The case study was conducted at the ISC, a part of the Dutch police and security services. ISC (ICT-Service Cooperation Police, Justice departments and Safety Services) is the ICT agency for the entire law enforcement and security (OOV) chain. ISC has its origins in the police sector and many of its employees are former police officers. The organization focuses on effective, reliable and fitting ICT solutions for the police, the justice departments and their partner organizations in the law enforcement and security sector in the Netherlands.

To derive the requirements of the composition framework we worked closely with the department of research and innovation of the ISC. During the case study scenarios for new mobile police services were developed. General requirements and constraints for new mobile police services were obtained using a group support system (GSS). A GSS is an electronic meeting environment that supports meeting participants in brainstorming, commenting idea's and voting processes (DeSanctis and Gallupe 1987). Important advantages of using a GSS are the anonymity of contributions, parallel communication and the fact that every contribution to a meeting is recorded instantly. Using the results of the GSS session, a series of four interviews with designers and an E-mail discussion, a number of designs of possible future services was evaluated.

3. Literature background

In order to design a framework to support the multi actor service composition process we first describe the technical and organizational context of the composition process.

3.1 Technical aspects

The SOA paradigm focuses on building information systems by discovering, matching and integrating pre-developed services (Linthicum 2004). The basic idea of SOAs is to decompose a system into parts that are made accessible by services, to design these services individually and to construct new systems using these single services (Freemantle, Weerawarana et al. 2002).

By offering a more flexible, interoperable and standardized model for hosting application functionality, the concept of a Service Oriented Architecture (SOA) provide an opportunity to rethink and improve business processes (Erl 2004). The services concept can be used to access data and/or functionality in components, applications or legacy information systems. As such SOAs can be used to extend existing architectures and leverage investments in legacy systems (Janssen and Wagenaar 2003). SOAs are often implemented using web service technology. The most common and valuable use of web services is to enable inter-application and inter-organization communication, by abstracting proprietary technology and establishing an universal integration framework. Web services introduce new opportunities for application reuse (Erl 2004).

The number of possible services will rapidly increase, as web service technologies makes it possible for each department and organization to create, offer and consume services. SOAs implemented by means of the web service technology stack have reduced the technological hurdles; service interfaces can be rapidly created and published by software tools with very limited need for human involvement.

Consequently the process of deploying the set of services provided by private and public parties becomes increasingly difficult. The number of services that is available and that can be (re)used in business processes is gigantic and grows continually (Janssen and Feenstra 2006). Organizations lack sufficient insight into how to identify web services and align them with both their existing, as well as their potential business processes.

Several composition approaches exist (BPEL, OWL-S, Web components, pi-calculus, Petri-nets, model checking and finite-state-machines) (Milanovic and Malek 2004) all focus on automated decision making. None provides support for human decision makers. Next to this most composition approaches neglect specification of nonfunctional Quality of Service (QoS) properties such as security, dependability, or performance. Only OWL-S lets users define some nonfunctional properties (namely, quality of service), but that capability has yet to be fully specified. Compositions can also be derived from purely semantic reasoning regarding service offerings and service demands. This leaves the human decision makers 'out of the equation' and neglects the characteristics of the actor network.

3.2 Organizational aspects

Due to reduced budgets and requests for increased performance levels, independent public organizations will have to cooperate increasingly in the near future to create new services. These organizations already have their own set of services and will also need to connect to each other services in order to provide meaningful combinations of services.

The decisions regarding the composition of a service are taken within a network of different actors. All stakeholders (commercial or non-commercial, single department or large organization) have a certain unique view to the service composition problem. The actors have mostly different interests and are dependent on each other. Due to these dependencies no single actor is able to solve the problem autonomously. None of the actors can impose a particular solution to the others. Often a solution has to combine several contradictory goals and interests.

The actors in the network will need to cooperate to a certain extent in order to realize a solution that at the same time helps realizing the common goal and pays enough attention to their specific interests. The decision-making process is effective only if it leads to commonly taken decisions (Bruin, Heuvelhof et al. 2002). All parties should be committed to implementing the decisions. The decision-making process that leads to a service composition will therefore also need to deliver a set of rules to which every actor involved will comply.

Often no single or 'best solution' exists. (Bruin and Heuvelhof 2000) The problem addressed cannot be seen as a 'hard science' multidimensional optimization process that can be solved using mathematic algorithms. The different stakeholders will use different terms (syntax and semantics) to describe services. Next to this they also will differ in their view on the required service levels.

Networks of actors are characterized by dependency between actors, differences between actors that interferes with cooperation, resistance of actors that don't see their interests met by choosing a particular solution and dynamics regarding the group of actors involved in the decision-making process (Bruin and Heuvelhof 2000). The process of service composition was already complicated due to a lack of structured evaluation methods for service components with comparable functionality. This problem is further complicated due to the multi-actor context. This means it is even more important to have a framework to support the service composition process in some structured way. The framework will have to deal with the views of different actors involved.

4. Case Study: Requirement from practice

At this moment, Dutch police officers working on the streets can be supported in their daily tasks by means of the P-Info system. Using a mobile phone and a PDA, the officers can request various types of information, for example stolen goods, missing persons and the insurance status of cars. These services are realized by large compositions of smaller services each providing access to a specific police register. As an illustration we take an existing P-info service and describe a possible extension of it. This example concerns the situation of a traffic check where police officers construct a road block and check all passing cars. These checks are mostly carried out during weekends to check for unsafe driving and alcohol abuse.

4.1 Existing situation

In the first part of this example the police officers make use of existing state of the art mobile computer equipment to check persons and vehicles. The second part of the example describes what can happen after a person is arrested for drunk driving. Transport has to be arranged for the person involved and for his car. Currently these tasks are all performed by police officers, in the future this may change however.

The current P-Info system consists of a number of regional, national and international data sources provided by different organizations. These sources can be queried in a unified way. The results of the queries is made visible on a mobile terminal (PDA) using a regular cell phone and a Bluetooth connection. This system is currently available to all 26 Dutch police regions, on subscription basis.

A web server coordinates the request to the separate data stores. The web server compiles the results in a single page overview. Using this overview, officers can zoom in on the information found in the connected registers. All pages are formatted in default HTML. A protected GPRS channel is used to transport the data from the web server to a mobile phone. The mobile phone is linked by means of a Bluetooth connection to a regular PDA. The officer interacts with the system using the web browser of the PDA. For navigation the stylus is used. If desired, the regional police force can decide to use a ruggedized PDA.

4.2 Composition scenario

A possible future extension of the system relates to the improvement of police care and the inclusion of third parties. After arresting a person for drunk driving the officer has to manage the task of transporting a car to the police station or to the home address of the owner and transporting the arrested person to his home after settlement of the legal matters related to the processing of the fines.
In order to improve the quality level of police work, the work is extended to checking the appointments of local police officers. In this case it appears that the arrested person has a history of incidents related to alcohol abuse. The officer now decides not only to arrange necessary transports but also to schedule a meeting for one of his colleague to see the arrested person at a later date in order to discuss the past events and the possibilities to reduce further troubles. The details of these colleagues are found by searching through a database that contains data regarding which group of officers is responsible for which area of the involved city. Browsing a group of local responsible officers requires connections to all police regions, making appointments requires connections that not only can query or read information, but also are capable of storing or writing to remote systems. In order to select taxi and transport companies, multiple possible alternatives have to be considered and evaluated.

4.3 Composition objectives

The police management has a number of objectives that need to be addressed during the realization of the extensions to the current P-info service. The first objective concerns the reuse of existing assets. It desired to reuse as much existing components as possible. The second objective concerns the performance reliability of the composed service. The services need to be up and running with as little interruptions as possible while providing an acceptable user experience. The third and last objective relates to the planning of the realization of a composition. It is important to be able to estimate what

tasks are executed by whom, at what moment in time, what the requirements are to start the task, what other tasks this task depend on and what the expected results of this task are. Next to these issues, 'what if' questions need to be addressed. What if a provider changes the implementation of a service, decides not to offer the service anymore or suppose a new provider suddenly offers a cheaper service.

4.4 Composition hurdles

In this case the needs are expressed poorly. The functional aspects of the new service are more or less clear, the non-functional (Quality of Service) aspects are completely missing. What is for example a good performance level of the services provided by a scheduling service? How is this level expressed and measured? In order to specify the needs sufficiently many additional service attributes will need to be described. This concerns both the existing services as the desired situation. What for example is the maximum value for the response time of the composition?

As part of the design process, a set of alternative compositions needs to be proposed and evaluated. In order to decide on the alternatives, evaluation criteria need to be agreed on. The proposed compositions can for example be ranked according to the expected performance values. The overall performance in case of partial composition failure also will have to be addressed. When realizing the composition sourcing issues and planning need to be addressed, it needs to be clear for example from what moment on a transport company is legally obliged to respond to requests. Next to this it may be convenient to have test services operational that have exactly the same interface as the original services, but are only used to verify the integration of different services in the composition.

This can be summarized in the following hurdles:

1. It is unclear how to express the requirements for a service composition
2. It is unclear how to evaluate a service composition
3. It is unclear what the alternative compositions are if part of the service composition fails
4. Participating actors do not have a shared view on the service composition

The four hurdles can easily occur during the realization of the composition for the extended license plate check service. It may very well be possible future users can provide very little input on the requirements. They for example ask for a 'user friendly and fast service'.

For the existing service, the integration of services into the composition was realized by a small number of developers. The danger exists that for the new scenario, these developers will implicitly make the service selection decisions (evaluate the compositions) just by delivering a single script or source file that performs the requested tasks. The motivation for selecting services then is known by the developers only and remains unclear to others. What happens in case of failure will only be discovered when a failure occurs. Service compositions may contain weak points, that are waiting like 'unknown time bombs' to disrupt the execution of the composition. If this happens at an inconvenient moment the consequences can be very severe.

Due to this the need for a structured approach to the service composition tasks exists. Objectives need to be stated in a structured way, existing services need to be described. A structured way to express the desired composition, to design possible alternative compositions and to evaluate these compositions is required. The structured approach needs to identify the need for services not available at this moment and provide the decision-makers with a planning of the realization process of the composition.

5. Composition framework

The composition framework should guide the decisions regarding the selection of services to include in a composition. It should provide solutions to the problems listed in the previous section. Therefore it should enable the decision-makers to express and evaluate the service characteristics, to evaluate several alternative compositions and to design a representation of the service-to-be for communication and planning purposes.

The service composition process can be viewed as a design process, Maffin (Maffin 1998) argues that many design process can be broken down to set of common basic features, such as specification, function, layout, documentation and evaluation.

According to (Dym, Agogino et al. 2005), a design process is characterized as a systematic, intelligent process in which designers generate, evaluate and specify concepts for devices, systems or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints. The element of a constraint is an important requirement for the composition framework. It should be possible to check whether the proposed design (composition) falls within the required bandwidth of constraints.

In a multi actor environment there has to be room for multiple views or interpretations. An important aspect of a process that facilitates the construction of a design (in this example the construction of the composed service) is to tolerate ambiguity and to handle uncertainty while maintaining sight of the big picture (Dym, Agogino et al. 2005). Due to this the composition framework will have to allow the actors to evaluate different alternative compositions and to negotiate the question which composition is most suitable for all actors together.

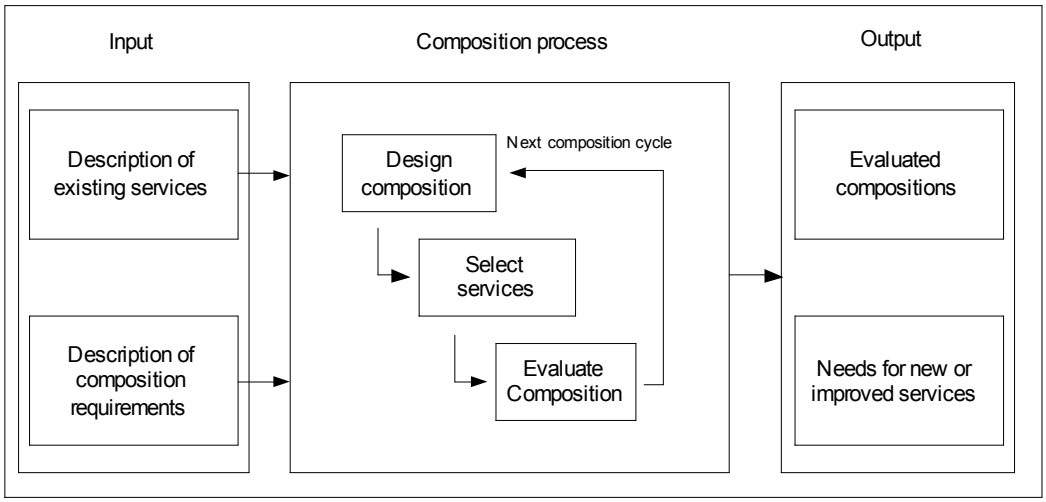

Figure 1. – Stages of the composition process.

Figure one shows a schematic representation of the design framework, the framework consists of three main parts, an input part where descriptions of existing services and requirements are stated, the actual composition cycle and the output part where evaluated compositions and the need for new or improved services are specified. These three parts will be discussed in more detail in the remainder of this section.

5.1 Framework input

For the realization of context dependent and group supporting police services, a solid design has to be offered, a system architecture is required. An architecture is the blueprint of the system, it contains the result of the decisions concerning selection and configuration of the components used. During the formulation of this architecture, various decisions need to be taken regarding the selection and configuration of the components (services) that will be used.

The usage of existing services (for example for location determination, authentication etc.) has advantages like: less maintenance effort is required, the realization of a new services possible in a shorter period of time, easier iteration (shorter design cycles) during the realization of a service.

This leads to the need for methods to evaluate different alternative service compositions (the central theme in this research project). It is also foreseeable the police services will connect to other (private) organizations in order to realize a business service. Multi attribute utility theory (Keeny and Raiffa 1976) can provide a suitable method to evaluate alternative service compositions.

The usage of components leads to a number of questions for the police: which components already exist? How are these components made available? How and where are these components described (functional and non-functional)? How are these descriptions used in the process of business service assembly?

5.1.1 Existing services repository

In the input step, information regarding existing services is stored in a register. This information consists of a combination of information from service suppliers, evaluation derived from past service usage and reviews of services performed by others.

The service information consists of a functional and a non-functional part. The functional part describe the tasks a service performs. The non-functional part describes the Quality of Service attributes (for example the service execution time, reliability and availability).

In order to record the properties of an existing service, a set of categories has to be designed to describe its functionality. This set of categories can be viewed as a tree-like structure; each category may have a number of sub-categories. In turn the sub-categories themselves may also have sub-categories. Each service is assigned to a specific node (place) in this functional tree. In this way the function of a service is recorded.

Next to the functional description of a service, the non-functional attributes also need to be stored. Comparable services (for example GPS position providers) have the same set of quality attributes. These sets of attribute may be stored in an 'attribute template' for convenience. After specifying the type of service, the list of attributes that to be specified is clear immediately.

In order to design an attribute template, a set of quality attributes, dimensions and units has to be available. When a service is characterized, a specific value is assigned to a specific quality attribute. This value represents a certain dimension and is expressed using a specific unit.

During this first step the functional categories need to be decided, the quality attributes, units and dimensions need to be assembled to attribute templates and the services need to be described using these templates.

The output of this step is a shared register (database) containing the descriptions of the existing services. Note that his is much more than an UDDI directory, which only stores a fraction of the information needed. This database should be accessible to all stakeholders. The information in this database has to be checked and descriptions of new services have to be added regularly. This register should exist before the composition process is executed. Stakeholders should organize this updating process and indicate who is responsible for the updates and at which interval these updates need to occur.

5.1.2 Service requirements

When designing a service composition, it is essential to know the purpose or objective/goal of the composition. Mostly some real world problem needs to be solved, in solving this problem a business service plays an important part. Humans interact with the composed service in order to execute some specific task. The usage of the composed service enables this task or improves some aspect of the task execution. The description of the purpose of the system has to be provided by the stakeholders. The process of writing down the specifications can for example be assisted by different forms of brainstorming sessions, by conjoint analysis of user preferences, by observing the current practice and by different kinds of interviews with stakeholders.

The output of this step should identify a set of UML storylines and UML use cases identifying the usage scenario's of the business services. Next to the storylines and use cases representing the functional requirements of the system, also the non-functional attributes need to be expressed. The output of this step should be documented as structured sets of requirements for every single composed service. Each business service should have its own service requirements document.

5.2 Service composition process

A service composition is assembled by making several decisions regarding the most suitable components on multiple levels of abstraction. At one abstraction level the set of possible services is ranked using a predefined set of aspects and previously determined values for the characteristics described by the aspects. A service quality repository is required in order to be able to execute the ranking process.

5.2.1 Design composition, composition task

The design of the composition template is the first step of the matchmaking process between service offerings (existing services) described in step one and the demands or requirements described in step two. The requirements should be met by the service composition that has to be designed.
In this step a template for the composed service is made, the types of services that are needed to realize a composition for a specific storyline are selected. For example, in a specific scenario needs exist for a credit card payment service, a license plate checker and an appointment making service might be required. The end result of this step then will be only a list of required services. This list is realized by looking at the category classification used to describe the functional properties of the existing services.

The input of this step exists of the service offerings and composition requirements made in the first two steps. The result is a list of service types needed to realize a composition for a specific storyline. Only the types of services are specified, no actual service offerings are selected in this stage.
The selection of services to fulfill the tasks for a specific storyline has to be agreed on by all actors, it might however be possible to design a set of composition templates in advance and to discuss these templates during a meeting with all stakeholders. It is very important to get the consent of all actors because the set of needed service types to realize the composition for a specific storyline is an important element of the shared vision regarding the services to be developed.

5.2.2 Selection of available services

Services are realized by means of filling out a template. The template indicates the types of services needed (payment, registration, authentication, product search, credit check, etc.). The template specifies which services are needed; the template however does not specify the supplier of these services. Using the previously made descriptions of available services, the templates can be filled out by using different service descriptions.

The selection of suitable services is carried out using the composition template (set of service types needed, or 'service shopping list') created and agreed on in step three.
During this step for each service in the composition template, a set of candidates is made. If a candidate offering contradicts with the required constraints, this alternative is directly skipped.
By combining the sets of candidates, a relatively large number of possible compositions can be generated. The composition template is transformed in a number of compositions by selecting services out of the sets of candidates. A simple template with four service types, which all have three different candidates leads to a total of $3^4 = 81$ compositions to be evaluated.

The output of this step consists of all possible service compositions for a specific storyline. In the case of the small example of the previous paragraph, this would lead to 81 small lists of selected services.

5.2.3 Evaluation of alternative compositions

The composition related step contains the evaluation of the proposed service compositions. The evaluation is carried out partly by means of performance indicators (as overall speed, reliability or costs of a composition) and partly by means of voting where each participant can input non-rational elements to express his preference for a certain composition.

The choice of performance indicators is based on the requirements and the service descriptions. After indicators have been chosen, their values need to be calculated for each alternative composition. The alternatives can then be ranked on different (combinations of) indicators. Each actor can indicate his preferred compositions by means of voting. The voting results can be discussed and multiple rounds of voting can be necessary in order to arrive at an agreement.

The outputs of this step are ranked list of compositions including the data of the votes and possibly include important comments/remarks of the voting session.

5.3 Output

The output part describes the products generated by the composition framework. Using these products the actors involved should be able to maintain an overview of the compositions made.

5.3.1 Reporting on evaluated compositions and planning

During this step reports are made of the compositions agreed on in step five, a planning for the realization of the compositions is made. The planning includes a list of services to be delivered by the stakeholders, for each service a date is listed. In this way the critical path can be determined and smaller parts of the business services can be tested before the last service it depends on becomes available. The composition reports including the planning are then distributed to all actors involved or stored in a shared document system. Using this document actors should also organize the responsibility for the new service.

5.3.2 Reporting on needs for new and improved services

In step four (selection of services) the situation may occur a certain service is not available and also not easily to assemble by means of another service composition. The composition process then comes to a halt. To prevent this, in this case a ‘dummy’ service has to be used. The dummy services’ functional and non-functional attributes have to be specified as accurately as possible because they are the starting points of the search for the service. It may also be decided one of the stakeholders develops the service or issues an order to a third party for development.

6. Conclusions and further research

Services are more and more composed out-of-existing ones. In a multi-actor network service composition requires negotiation processes and decisions made by managers representing independent organizations having their own objectives and requirements. None of the current approaches take the characteristics of a multi-actor network into account. Using a case study we derived requirements on a composition framework and we found that a framework should meet the following, generic requirements: it should enable the decision-makers to express and evaluate the service characteristics, to evaluate several alternative compositions and to design a representation of the service-to-be for communication and planning purposes. The composition framework should guide the decisions regarding the selection of services to include in a composition.

Next we derived a composition framework by taking a process-based view on the multi-actor decision-making process. The main phase we derived are 1.) the input stage aimed at defining objectives and requirement specifications, 2.) the composition process itself and 3.) the output stage. The framework offers a structured way of service composition. During each phase representatives from multiple organizations are involved in order to create a composite service that is acceptable for all parties. The framework is prescriptive in the sense that each phase is needed to derive a composition based on

multi-actor involvement. However, it is not prescriptive in the sense that a certain phase should be supported in a particular way. It is aimed at supporting decision-makers acting within the complexities of a multi-actors environment by providing insight in alternatives, dependencies and implications.

Our further research focuses on developing a tool supporting the composition framework and testing the framework and tool in practice. The tool should support multiple ways to deal with each phase, for example it should be possible to execute the evaluation of alternative proposed compositions.

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