Interactive 2D – 3D Digital Maps for the support of emergency teams during rescue operations

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ABSTRACT

SHARE, a EU-funded 6th Framework Program project, addresses the need of emergency teams for multimodal communication and for decision support with a prototype advanced mobile service based on Push-to-Share technology. The SHARE system provides emergency workers with on-site, on-line details of operational history and current operational status as well as access to pertinent supporting information, in particular information concerning the environment of the incident. The SHARE system will incorporate an enhanced Tele Atlas 2D-3D digital map, including details on buildings and roads above and beyond those represented in basic digital road maps. The SHARE system will log communications and other multimedia data generated during the operation and store it in an ontology-based Knowledge Base, which makes possible the integration of the spatial information of digital maps with multimedia and operational information from external databases. In the final phase of the SHARE project, the system will implement a 2D-3D digital map enhanced with voice, image, text and video information. The map will be fully interactive, permitting emergency workers with mobile end devices such as PDAs and tablet PCs to query the system using a multimodal interface and retrieve information as well as to enter new information as the operation unfolds.

KEYWORDS

digital maps, 2D maps, 3D maps, rescue operations, mobile communication, spatial ontologies

INTRODUCTION

Currently, communication during rescue operations is largely limited to voice transmitted over walkie-talkie systems and visualization of operation development is centralized. As a rule, information represented by hand on a conventional map located in the operation control center as the incident unfolds. Rescue workers stand to benefit enormously from a system that exploits recent advances in mobile communication, multimedia processing, knowledge representation and in visualization of location information in the form of digital maps. The SHARE project, funded by the EU within the 6th Framework Program, will provide emergency rescue teams with an advanced mobile service that supports multimodal communication and information management. Rescue operations, in particular those involving large incidents or disaster management, stand to benefit enormously from the sophisticated interaction made possible by the SHARE system, which will supplement conventional voice communication with text messaging, video transmission and the exchange of geo-referenced information in the form of digital maps.

The SHARE system will log voice and text-message communication and video transmissions over a Push-to-Share server, creating a record of operation development. Logged information will be integrated with pre-existing data sources, in particular with the location information that makes possible representation in a digital map. This integration is accomplished using the Knowledge Base, an ontology-based system the integrated representation and management of the diverse information sources (spatial - maps, multimedia - communications, operational - rescue teams) involved in a rescue operation. Information is entered into the Knowledge Base by creating instances of concepts in the SHARE ontology, a process which is known as population. Figure 1 is a simple representation of the SHARE architecture.

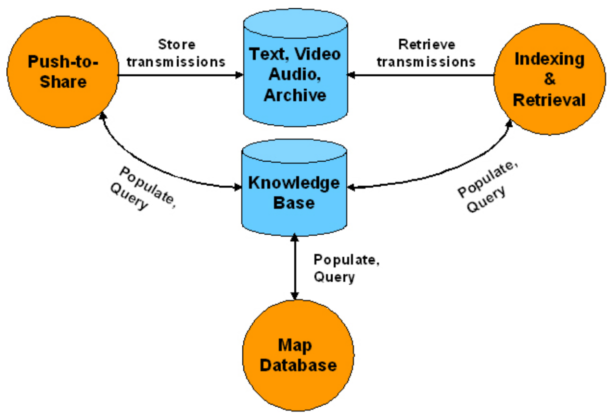


Figure 1- Simple representation of the SHARE system architecture

The SHARE system will provide emergency workers with on-line, on-site access to a structured record of operation development as well as to current status information, enriched with supporting information concerning the environment of the emergency and data on buildings and surrounding streets. The SHARE system aims to enhance operation efficiency and to support decision making by the rescue officers in charge of the operation.

The SHARE project is being carried out by a consortium of 9 partners from 6 European countries, who make a range of complementary contributions. Fraunhofer IMK (Germany) acts as project coordinator and technology provider for multimedia analysis and retrieval solutions. Siemens (Austria) provides the Push-to-Share technology from which the project SHARE gets its name. Push-to-Share is extension of Push-to-Talk, a communications protocol that provides an always-open communication channel for voice communication that can be accessed at the push of a button. Push-to-Share implements a channel for the exchange of multimedia data, which in the case of the SHARE project will include, in addition to voice, text messages, video, and map data. The National Center of Scientific Research “Demokritos” (Greece) is developing an ontology-based knowledge base, which is a connects all SHARE data services on a semantic level, and is, as such, a central component of the SHARE system. Additional partners include Telisma (France), who provides the automatic speech recognition technology used to implement speech input for mobile end devices and Loquendo (Italy), who provides speech the synthesis technology for speech output. These technologies allow PDAs and other end devices not convenient for conventional in-/output to provide the user with the possibility of multimodal input and output, for data entry and for information retrieval used to implement the multimodal interface necessary for mobile end devices such as PDAs which are not convenient for conventional input/output allowing multimodal input. University of Paderborn (Germany) and Fire Department Dortmund (Germany) act as domain experts and knowledge providers, playing an essential role in design and testing. The AIIA Lab at the Aristotle University of Thessaloniki (Greece) analyzes video sequences, concentrating on those recorded with thermal cameras, and extracting information important to firefighters in rescue situations. Finally, Tele Atlas (Belgium) provides expertise in the area of digital maps and is the main content provider, making available standard and enhanced digital maps which are used to offer advanced 2D-3D map services to rescue operation teams. Digital maps (both 2D and 3D) enhanced with multimedia annotations are the focus of this paper which describes their potential for rescue operations and their integration into the SHARE system.

In the next section, we describe how 2D-3D digital maps enhanced with information more detailed than that available with basic road maps provides a valuable aid to rescue operations. We go on to describe the how an ontology-based Knowledge Base is used to integrate information in the SHARE system. In the final section, it is discussed, how digital maps are used to represent integrated information on mobile end devices.

IMPORTANCE OF ENHANCED 2D-3D DIGITAL MAPS FOR RESCUE OPERATIONS

Rescue officers managing emergency operations must make operational decisions that affect human lives under extraordinary time pressure. Improved access and enriched information has the potential of providing critical support to the decision making process. Information must be presented in a concise and overviewable manner. Digital maps are well suited for the organization and visualization of location specific information critical to emergency and rescue management.

Emergency forces engaged in rescue operations are served in a limited way by digital map data based on in-car navigation requirements. Currently, massive effort has been invested in creating and maintaining global digital map resources that are tailored to the day-to-day navigation needs of civilians drivers. Mobile Location-Based Services (LBS) scenarios, particularly those involving rescue operations, require not only a higher degree of resolution, but a different sort of spatial information as well. Emergency workers must be able to chart pedestrian routes and navigation must be available in multi-story buildings. Additionally, it must be possible to represent points of interest (in the emergency domain these include emergency exits, fire extinguishers and the location of hazardous materials) on a fine scale of resolution and in three dimensions.

Within the SHARE project these requirements will be met by advanced maps offered by Tele Atlas. These maps represent the surroundings with higher geometrical accuracy than basic road maps. Advanced maps are 2D-3D and are enhanced with additional information tailored to the needs of rescue forces. Adding enhanced features that indicate the presences of road furniture, such as trees, electric poles, wires and indicate their heights provides information that is valuable during the planning phase of a rescue operations. Height information for example allows the calculation of flying routes and landing places for rescue helicopters. Other enhanced digital map attributes such as locations of emergency exits, locations of stairs and elevators, are very valuable to plan rescue operations in big public buildings. Emergency workers can plan attacks and exit routes. Moreover, it is possible to estimate how the fire will spread. 2D and 3D outlines of the buildings further improve the rescue operation coordination. An example of a 3D map is shown in Figure 2.

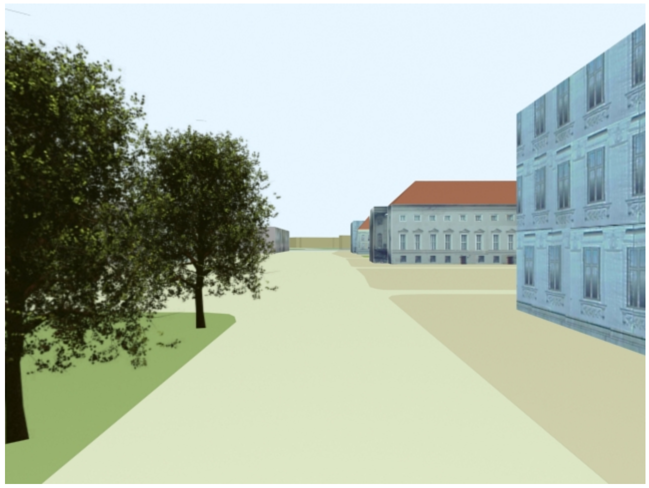


Figure 2 - 3D map with depiction of trees

The 3D map display will be demonstrated in the final prototype of the project. Additionally, the SHARE system makes it possible to enrich enhanced map information with other information generated during the operation. Within the SHARE project, sophisticated information integration techniques facilitate intelligent, comfortable display of information, even on small mobile end devices such as PDAs. The next section describes the process of information integration.

INFORMATION INTEGRATION USING ONTOLOGIES

The core of the SHARE system is the Knowledge Base, an ontology-based system for integrated knowledge management. The Knowledge Base makes it possible to integrate spatial information from the Tele Atlas database with domain-specific information from other data sources. The term ontology is often used in the areas of Computer Science, Artificial Intelligence and Semantic Web as a new way of structuring and representing knowledge. The most cited definition by [Gruber, 1995] describes ontology as “a formal specification of a shared conceptualization.” In other words, ontologies represent a shared and common understanding of some domain that can be communicated between people and application systems [Gruber, 1993]. Ontologies are applied in practice as the basis upon which a Knowledge Base can be developed. A Knowledge Base consists of (a) the Ontology Model, which defines the domain concepts, their properties and relations and (b) the Ontology Instances, which represent the actual individuals of the domain concepts, their property values and their relations with other instances [Noy and McGuinness, 2001].

More specifically, spatial ontologies [Frank, 2003] aim at providing a set of concepts, properties and relations which can effectively represent the space domain. There have been quite a few attempts to design a standard spatial ontology due to the great number of application areas where the awareness of spatial knowledge was needed. Some of the most recognized approaches are the

Geographic Information specifications of The International Organization for Standardization[1] and the Abstract Specification of the Open Geospatial Consortium[2]. However, the complexity of the domain and the variety of spatial semantics has resulted in the creation of a variety of top-level ontologies with large numbers of concepts, properties and relations. This fact has been a constraining factor for the practical application of standard ontologies, which are utilized mainly as templates for designing simpler spatial ontologies that correspond to the requirement of the individual application in which they are used.
The SHARE Ontology is the data model on which the Knowledge Base is built. In this model, geographical, temporal, multimedia, operational data stored in the system are represented as ontology entities and are interconnected with semantic relations, providing an integrated view of the information needed to support the operation (Figure 3).

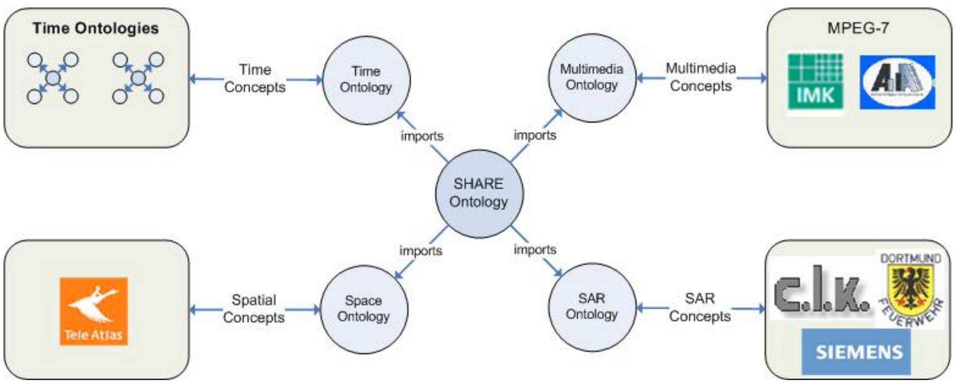


Figure 3 - Integrated Knowledge Representation

Spatial features are represented in terms of the basic concepts utilized for the 2D spatial representation: point, line and region. When map data from the Tele Atlas server is entered into the Knowledge Base during the population process, specific instances of these concepts are created. The properties of the spatial features are inserted as instance properties. For example, the "type" property defines the feature type (e.g. road, building etc). The spatial section of the SHARE Ontology is also enriched with topological and directional relationships which are provided by Tele Atlas and are represented as relationships among the spatial instances.
Multimedia concepts encoded in the multimedia ontology include voice transmissions, thermal videos and text messages. Multimedia instances can be connected to spatial instances through inter-domain relationships. For example, an instance of the "Thermal Video" concept can be related to a spatial region instance through the "spatial position" relationship.
It is possible to use automatic methods to extract higher-level semantic information from multimedia transmissions, in particular from voice communication and from text messages. State-of-the-art video analysis techniques will be deployed to detect the presence of human beings in thermal video. Speech recognition technology will be used to spot keywords [Osang 2004] in voice transmissions. The ontology makes it possible to link multimedia entities to other instances in the Knowledge Base to which the bear a semantic relation. If the name of a firefighting unit, for example, is spotted in a voice transmission a link can be established in the

[1] http://www.isotc211.org/
[2] http://www.opengeospatial.org/

ontology between that unit, which would be an operational entity with a spatial relation, and the multimedia instance containing its mention. Such links make it possible to use ontologies to perform reasoning tasks involving classification or entities, subsumption or consistence checking. The SHARE Ontology encompasses a temporal section in order to provide for spatio-temporal characterization of knowledge entities. The temporal concepts can be time-points or intervals and their instances are connected to multimedia and SAR instances. For example, a SAR instance can be connected to spatial and temporal instances through the "spatial position" and "temporal position " relationship respectively.

The added value of using ontologies in spatio-temporal knowledge representation resides in the application of reasoning techniques [Chittaro and Montanari, 2000], [Cohn and Hazarika, 2002] in order to infer implicit from explicit knowledge, which is stored in the Tele Atlas spatial database and the other external information sources. More specifically, by employing reasoning about change and events, the system will be able to explain past situations or predict future ones. For example, the system could answer questions like "Why has the fire spread north?" or "Where will the vehicle be in 5 minutes?". Furthermore, constraint-based reasoning allows the retrieval of dynamic objects on the basis of satisfying spatial (e.g. contains, overlaps) and temporal (e.g. before, during) relations. For example, "Was the vehicle in the assembly area before the explosion?". In order to provide answers to the aforementioned questions, the system should incorporate an integrated view of the real world, which is achieved using ontologies as a basis of integrating diverse information sources and databases.

In summary, the SHARE Ontology models the concept structure and the semantic relations between of entities that occur in rescue operations. These concepts are instantiated as specific entities during the process of populating the Knowledge Base. Thematic entities can be linked to specific features (e.g. points, lines, regions) of the Tele Atlas database. These links make it possible to represent entities on a digital map. Knowledge Base continues to grow as the event unfolds. Modeling and storing events and changes makes it possible to track entities through space and time makes it possible to chart evolution of entities and draw basic conclusions regarding topology, causality and movement.

The final section describes how digital maps can be used to depict operation information in a succinct and comfortable way.

DIGITAL MAPS FOR VISUALIZATION OF STRUCTURED INFORMATION

Digital maps are critical to be able to present large amounts of information to the user and make it intuitively and comfortably accessible. The rescue domain is particularly suited to the use of digital maps because so much of the information necessary for rescue management includes a vital spatial component. For example, the location of buildings, potentially hazardous material and water supply is critical. As the incident develops, units arrive on the scene and their location, provided by satellite infrastructure (i.e. GPS), must be disseminated to managing officers. If casualties occur their location is important information and can be used to plot them on maps. Video recordings, both thermal and normal, are an important source of information and these can be made available on the digital map by plotting the location of the video camera. The navigation function of the digital map is important for planning escape routes.

Presenting rescue officers with unstructured, unintegrated information creates the risk of distraction from critical incident developments. The SHARE system aims to develop an intuitive interface that will maximize the amount of information that can be presented on the users end device while keeping the time needed for the user to access and absorb this information minimal. Figure 4 shows an initial design for the Map user interface as it would appear on a tablet PC.

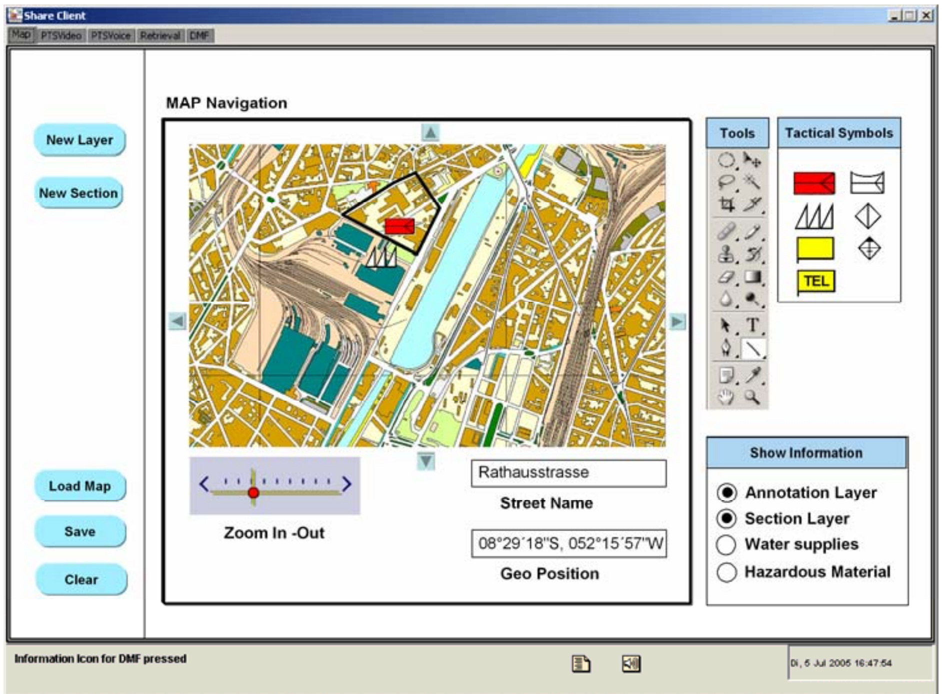


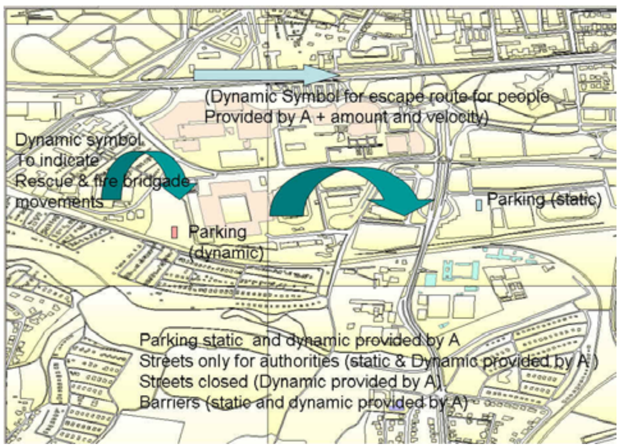
Figure 4 - Map User Interface on tablet pc

The Map interface allows the user to pan, to zoom or to jump to a particular position, specified either by a street name or by geo-coordinates. In the final prototype, these actions will be controlled with either stylus or voice input, or a combination of the two. The user can define sections (regions of responsibility for individual firefighting units) on the digital map using the drawing tools available at the right. For easier visualization purposes, objects relevant to the operation (e.g. vehicles and persons) are represented with tactical symbols, which are widely used in the rescue domain. Symbols also represent the location at which videos have been made. In the final prototype, it will be possible to play the videos by clicking on their symbols.

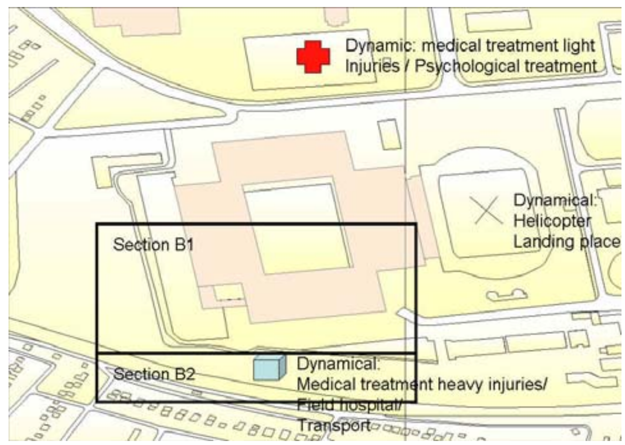
Symbols or annotation belonging to a given kind (for example those designating firefighting units) will be assigned to a dedicated layer. It will be possible for end-users to configure the interface so that the symbols shown is adjusted to meet current information needs. Different profiles will be defined for different officers in the rescue operation. For example, in the operation control center it is necessary to have a view of the entire events, whereas officers leading the individual sections profit from having a view which gives detailed information and focuses on the section that is relevant for their own decision making.

Digital maps scale for different end devices, which in mobile applications tend to have smaller screens, as in the case of PDAs. In order to make interaction with map interface possible on end devices without keyboards and in situations in which hands-free access is critical, manipulation of maps using voice commands will be implemented. The speech recognition used must be robust in the face of the high level of background noise characterizing emergency incidents. Further, there must be alternative stylus input possible, for the case that speech is not possible.

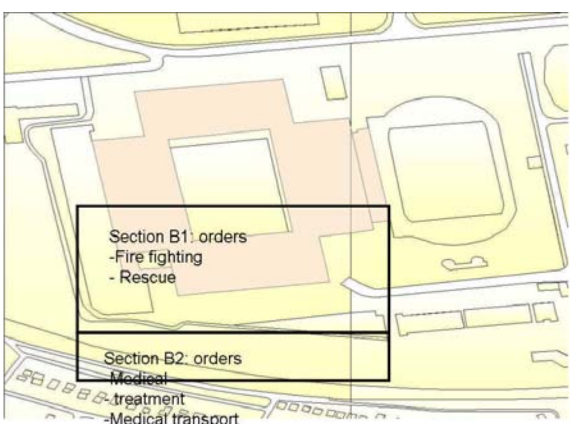
The digital map will also allow speech output. Clicking on the street will cause its name to be read out. The name of the street is not primary information and would otherwise clutter the map display, obscuring more critical annotations. Names will be read out using speech synthesis, also called text-to-speech (TTS). The TTS developed will also be robust to background noise conditions. It is important that the TTS does not hinder communication on other voice channels. For this reason, alternative modes of output will also be implemented. For example, street names appear briefly to be read when the corresponding street is touched with the PDA stylus.
Displaying information relevant to the operation, such as the location of units, vehicles and field hospitals as well as the location and direction of escape routes and tactical movements, in a spatial environment, allows the rescue planners to get an immediate general view on the situation on a certain point in time and allow them to act accordingly. Such display is possible at different levels of resolution.



Overview Level A: Scale 1/10.000



Detail Level A / Overview Level B: Scale 1/3000



Detail Level B/ Overview Level C: Scale 1/2500 Detail Level C: Scale 1/500

Figure 5 - Resolutions relevant for different levels of command

The management of large emergency incidents is distributed over a command hierarchy composed of different levels (Level A, B and C). Lower levels of command are specialized to particular tasks or areas. Each level of command will get only that static and dynamic spatial and non spatial information which is relevant on a certain moment to make fast and intelligent decisions. The resolution relevant for different levels of command is illustrated in Figure 5.

CONCLUSION AND OUTLOOK

The SHARE system is an advanced mobile data service for emergency rescue forces designed to provide mobile access to integrated information in order to support communication and decision making during emergency incidents. Digital maps are in of themselves an essential source of information for officers coordinating a rescue operations, but also provide an intuitive environment for the presentation of background information and information accumulated as the operation unfolds. In the SHARE project, Tele Atlas will provide digital maps which include advanced features such as the presence of road furniture, which is essential for making tactical decisions. In addition to 2D information, 3D information will also be provided, which makes a crucial contribution to rescue operations.

With in the SHARE project information from various sources is integrated via the ontology-based Knowledge Base. Relevant for digital maps is especially the integration of spatial information from the map database with thematic information from multimedia databases. As the operation develops, further information (locations or units, log of multimedia communications) is added to the Knowledge Base and these spatio-temporal objects can be dynamically interconnected with the static spatial information supplied by Tele Atlas.

Emergency workers will access the SHARE system using mobile end devices such as PDAs or tablet PCs. A multimodal interface that combines stylus and speech will make querying or addition of information to the system intuitive and comfortable. Display of query results will make use of the intuitive organization of location information made possible by digital maps. The strength of Share is to integrate and provide only relevant spatial, non-spatial, static and dynamic data to different levels of commands, supporting decision makers in the decision making process.

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