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Augmented Reality Mobile Application as a Support in Presentation of Orthodox Iconography

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Abstract. Orthodox Christian icons are a very valuable part of the national historical heritage of Bulgaria. To preserve and properly present data about icons, it was created a web-based platform Virtual Encyclopedia of Bulgarian Iconography (BIDL). It contains icon descriptions and context explanations as well as information about icon painters, drawing methods, and painting techniques used, for a large number of icons all over Bulgaria. Observation and contemplation about the icons can be motivated by religious feelings, in which case icons are viewed as an aid in worship, or by interest in their artistic features. In both cases, it is important and useful to get information about an observed icon at the site of observation and at the time while observing. In this work, we presented a mobile application based on augmented reality technology that facilitates and speeds up access to iconographic content stored on the BIDL platform. The main goal, based on image recognition by a specially designed augmented reality module, is providing instantaneous and on-site information about the concrete icon observed by the visitors of churches and monasteries, or museums and galleries. The classical search over a large database, requiring keywords such as geographical location, name of the church, and similar, to access the proper information is avoided, since the icons are immediately recognized.

Keywords: Augmented reality, Mobile applications, Cultural heritage, Orthodox iconography.

1. Introduction

Icons are pictures on wood, fabric, glass, stones, or other materials, representing God's images, the Lord Jesus Christ, the Mother of God, Saints, holy persons, and biblical scenes

and events. They are expressions of Orthodox Faith, teaching, and worship. Icons are treasured in churches, monasteries, and other holy places, but also in homes, museums, and art galleries. To properly present these immeasurably valued items of Bulgarian national heritage, it was developed a web-based platform called the Virtual Encyclopedia of Bulgarian Iconography (BIDL) [22]. This Encyclopedia contains information about hundreds of Bulgarian icons from the 9th to the 19th century located in many churches, monasteries, museums, and other places.

The primary purpose of icons is to help in worship by aiding the observer to focus on the divine things while observing an icon. At the same time, icons are very valuable artistic artifacts from ancient times to date. For an observer, motivated by either religious or artistic interest, it is important to get more detailed information about a concrete icon, the subject of his interest. It is reasonable to assume that observers desire to get this information on the site and at the time when an icon is in focus of their interest. In that respect, searching over BIDL appears as a time-consuming option, uncomfortable to be performed on-site, and which also requires providing additional data to find the icon in the database. This data necessary for a BIDL search might not be available for an observer which can also misinterpret similar icons. Further, a kind of disappointment would be receiving the answer that the related information is unavailable in BIDL after spending some time on the search. Therefore, in this paper, we present an augmented reality (AR) technology-based application for mobile devices that overcomes these disadvantages.

The main idea is that the AR technology-based application for mobile devices recognizes an icon by the camera of the mobile device and immediately leads to the corresponding link with the desired information or, in rare, but still possible cases, issues the answer that such data is not available. The recognition is performed by a specially designed Augmented Reality Icon Recognition (ARIR) mobile application. This application is realized for both Android and iOS supported devices and it will be freely accessible on the corresponding markets Google Play and App Store, respectively. The ARIR application is implemented as an upgrade to the BIDL, and, therefore, the complete system is called AR-BIDL.

The remaining sections of the paper are structured as follows. In section 2, we review the literature that concerns the usage of augmented reality for the presentation improvement of cultural and religious heritage. In section 3 we present the motivation for this work and identify the main goals. Based on the main goals we define the system architecture and provide the implementation details in section 4. In section 5 we explain how the system is used and identify the potential users of the system. Experimental testing and verification of the system are given in section 6. The scalability of the system of potential growth is discussed in section 7 while section 8 presents the conclusion.

2. Related work – AR at religious places

Augmented reality, as one of the emerging trends and technologies in libraries, galleries, museums, and archaeological sites helps increase interest and knowledge about cultural heritage, especially among the younger generation [18], [11], [3]. Various types of AR solutions have been explored in order to immerse visitors in cultural heritage content [24], [5], [12]. Literature reviews on the application of augmented reality in cultural heritage show that augmented reality mobile applications have a positive impact on the immersion

and engagement of visitors to cultural sites [26]. Such mobile applications can provide guided tours to enhance visitor's experience at cultural heritage sites [15]. Also, applications can provide interactive storytelling to visitors by recognizing the monuments or their parts [28]. AR applications can be used to show educational content about artworks in galleries or outdoors, as for instance pictures on ancient rocks [23], [1], [30].

Special types of applications concern the usage of augmented reality at religious places for digital storytelling about historical and spiritual content. AR in religious places is used to provide an innovative interactive way that enhances visitors' understanding and meaning of the religious content. Moreover, augmented reality technologies can be used to preserve, and display virtual reconstructions of religious places to visitors.

A mobile application based on augmented reality is developed to better present the cultural heritage of the religious place of Piazza dei Miracoli in Pisa [6]. Augmented reality technology is used to provide historical information about important landmarks in the open space of this location. The application guides visitors to nearby places through different periods and shows information about important stages using augmented reality. The visitor chooses between nearby landmarks that he wants to explore and visualize the important data for that selection by using augmented reality. A virtual timeline is embedded to explore data from different epochs and the chosen period overlays 3D models or images over the current state. The study's findings showed that this engaging application can improve visitors' experiences in exploring the information at the location [6].

To preserve and better present religious heritage the AR is used for the virtual outdoor reconstruction of the demolished Reformed Church from Brasov City [2]. The application developed for mobile devices was used to recognize the place where the church existed. The recognition of the current state is based on image recognition and uses photos captured from different angles and stored in the local database. The application shows virtual reconstruction based on the visitor's location and recognition of the place where the church existed. The old photos overlap the current state which is the field of view of the visitor camera. The results of the visitor's survey showed that the AR application for the reconstruction of religious and cultural heritage is easy, interesting, and enjoyable to use.

The paper [14] presents how a 3D scanned model was used to reconstruct the Exeter Cathedral west front. This reconstruction is used to recreate the colors of the façade stonework that existed in the past. The main goal was to optimize the 3D colored model for augmented reality visualization. In this way, visitors can use augmented reality to recognize the current façade and see the colorized reconstruction of stone parts.

The photogrammetry technique for 3D model generation can be used to preserve virtual religious architecture. In [17], photogrammetry is used to create 3D models of the most representative altars of the Cathedral of San Pedro in Guayaquil, Ecuador. Using augmented reality, the photogrammetric generated 3D altar models are used to present religious heritage and increase learning about religious content. The survey results showed that combining AR with photogrammetric technology is effective and improves knowledge about cathedral heritage [17].

Virtual reconstruction of the Ayazini Virgin Mary Church interior using augmented reality is realized with the aim of better presentation of old religious heritage [27]. The interior elements of the church are ruined over time and reconstruction is complex and expensive. Therefore, the demolished church elements such as columns are modeled in 3D based on expert opinions. The mobile application is used to recognize QR codes placed

at the exact places of demolished columns in the interior of the church. When applications capture QR codes inside the church virtual reconstruction of columns is visible. In this way, visitors can better explore and sense the church space.

Illustrated pages of promotional or learning material can be used for AR recognition and immersive presentations for multimedia education about cultural and religious heritage. Interactive brochures created for guiding through the Temple of Debod in Madrid are used for AR recognition [8]. AR is implemented to provide interactive storytelling about important parts of the site. Pictures of the eight most significant engravings from the temple walls were used in the brochure. AR recognition of temple engravings is overlaid with multimedia historical content and enables visitors to acquire more knowledge about them. Similarly, AR applications have been created to attract students to learn better Malang temple history and understand temple relief art [10]. Images of temples and temple reliefs have been used as AR markers printed on flyers and textbooks. Recognition of AR markers shows virtual overlays as reconstructions of temples and colorization of reliefs.

A guide based on augmented reality technology was created to recognize religious artworks in Museo Diocesano of Milan [7]. This is a religious museum that has a collection of sacred artworks. Augmented reality is used to establish interaction with the museum exhibition and provide a deeper meaning of religious artworks. Five paintings have been chosen for recognition with religious scenes and different meanings. Also, the depicted scenes are not understandable to regular visitors. Recognizing the paintings and the depicted scenes with AR technology multimedia content is used to provide detailed explanation and interpretations.

Augmented reality may be used for the recognition of the relics in order to provide interactive storytelling. As an example of such applications, we point out the application designed for the Basilica of Saint Catherina of Alexandria in Galatina as an aid for the enhancement and understanding of religious and cultural heritage [4]. The AR is implemented to recognize the most famous frescoes located on the interior walls of the Basilica. An image tracking solution is used with eleven frescos that are stored as image markers. Recognizing the frescos, storytelling is realized by overlaying relevant multimedia content such as audio interpretation or image reconstructions. The survey results show that this AR application is an effective and attractive tool for interpretation and learning about frescos in this basilica as well as other places with frescos from related periods or artistic styles.

In the related literature, AR technology was used to present, explain, and improve the presentation of cultural and religious heritage. These applications concern the usage of AR technology for solving specific problems on concrete indoors and outdoors in particular religious places. In such situations, the number of AR tracking objects is small, and related multimedia content is limited in quantity and easy to handle with contemporary digital devices and their memory capacities. Thus, all necessary data is stored locally in the memory of the mobile device as a part of the application. Therefore, the authors didn't consider solutions for the storage problems and scalability of the systems.

AR system scalable architecture for large areas that uses large numbers of multimedia objects for cultural heritage is given in [25], [16]. These systems consider outdoor location-based AR tracking technology for showing historical information to visitors

throughout the city. The systems are made for big city areas and discuss the techniques of optimization for content that is used in the application.

In our work, we consider image tracking solutions for a wide area that considers cultural and religious heritage focused on indoor usage. The BIDL platform contains information about many places such as churches and monasteries stored in the database and each of these places typically has a large number of icons. Thus, the number of AR targets is large, as well as the multimedia content associated with them. However, as a visitor can be at only one place at a time, locally stored image markers for other locations can cause unnecessary usage of the local memory of mobile devices. Further, the BIDL platform enables adding new content or updating information in the server database. If icon image markers are stored locally, each content modification in the BIDL, will necessarily require an update of the mobile application AR-BIDL. Accordingly, our solution is created to store the icon image markers on the BIDL server system. This enables scaling the system and overcoming local storage problems. Also, the AR recognition system enables quick information retrieval from a remote server about nearby icons.

3. Motivation

The motivation for realizing this work is based on twofold goals:

- using AR technology to speed up information retrieval about icons in visitors' surroundings,
- to provide optimized AR recognition content concerning storage of icon image markers for the visitor's current location.

3.1. Searching problem

The BIDL platform stores a wide spectrum of places such as churches or monasteries with descriptions of hundreds of iconographic objects stored on the server. That data is available to visitors using web technologies. Concrete information about icons is available using keywords or in a predefined list of icons ordered by title, author, scene, etc. This approach has limitations whenever a visitor is at the exact location and wants to find information about the observed icon. Searching for icon information might be time-consuming if the visitor has no prior knowledge about icons that are of his current interest or hasn't prepared in advance for visitation to that place. Also, the search can be long if information about the observed icon isn't stored in the database.

In this work, we extend the current structure of the BIDL platform and improve search data about concrete icons at the location of the visitor. We created a mobile application based on augmented reality technology. This technology is used to provide a virtual signal or element and notify the visitor about the availability of information on the observed icon. Also, basic information can be obtained by recognizing the icons of interest and more detailed information is provided by interacting with virtual elements. If the icon is not recognized, this can be a signal that information about the observed icon is unavailable.

3.2. Storage problem

To achieve the AR recognition effect, image targets of icons should be prepared for recognition. AR development tools usually have two possibilities to store tracking targets, by using local database storage or cloud recognition services.

When targets are stored locally on the device, the AR application can immediately start icon recognition. A static solution from the point of storage where image targets are embedded locally in the application is good for projects that do not have frequent updates. Using this kind of target organization is unsuitable for the BIDL database since it enables adding new iconographic content or information updates. Thus, this kind of AR application will require editing the project and updating the application each time new material is added to the BIDL. Also, there are local memory concerns as for all locations covered by in the BIDL icon targets should be stored locally although only those related to one location should be used at the time.

Cloud recognition is designed to work with huge amounts of tracking targets that can be stored in a remote database. The popular AR tools have their custom cloud system solutions that can accept about a hundred thousand image targets for recognition. In this way, storage concerns of the AR mobile application are resolved. This solution enables dynamic target editing and integration with other systems and services to store data. Also, cloud recognition solution assumes some costs based on the frequency of targets used per day. As the BIDL database has information about a few hundred and the potential to have thousands of icons this solution is insufficient for point-of-data amount and extra expenses in price terms.

Considering the storage problem, our solution provides only necessary icon image targets for AR recognition. The application dynamically receives image targets stored on the BIDL platform. As the database stores information about various churches and monastery icons, the mobile application receives only content for one location at the time. This is realized through a web service that responds depending on the location of the visitor. The service provides image tracking and icon information that is shown when the icon is recognized. Additionally, any new content added to BIDL will be automatically delivered to the mobile application without updating.

3.3. Modeling AR-BIDL system

The AR-BIDL model in Fig. 1 is proposed as a solution based on the key goals that the system has to address. The BIDL platform is on the server side with an implemented specialized web service. This service enables communication with the client side which is realized as an ARIR application. ARIR application combines several components to communicate with the web service and provide information about nearby icons. When a visitor is at the location of a church or monastery, the mobile application sends the GPS coordinates to the web service. The web service prepares data about icons based on the received location coordinates as a response. The ARIR application processes the response and provides data to the AR module. Then, the AR module loads image markers for tracking, and basic virtual information is provided upon recognition of the concrete icon. AR module enables interaction with virtual elements such as virtual buttons projected on screen. In this interaction, visitors receive detailed information about the icon of interest.

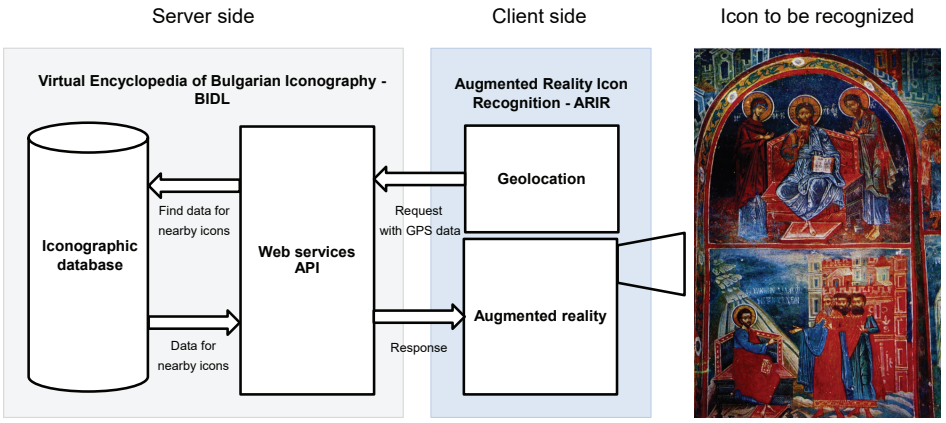


Fig. 1. AR-BIDL system model

4. Architecture of the system

Based on the proposed model, a client-server architecture is developed, and the system realized (Fig. 2). This section provides a detailed description of the BIDL system architecture with necessary web services for content delivery to the client side. Also, the ARIR mobile application as client-side architecture is described as well as the implementation of the entire system.

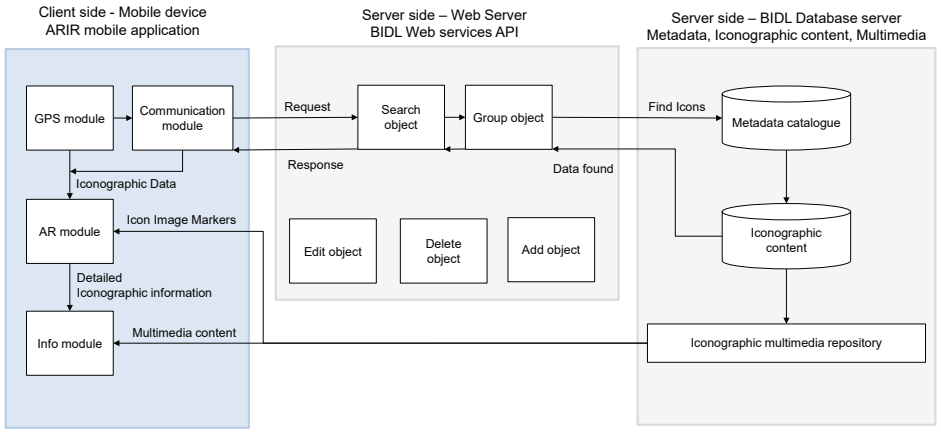


Fig. 2. AR-BIDL system architecture

4.1. BIDL as the Server Side

Virtual Encyclopedia of Bulgarian Iconography is based on the CultIS software platform [13]. CultIS is selected as a versatile, flexible, and highly adaptable digital content management solution developed by the IMI-BAS team [21]. With its active development using modern web technologies (Node JS, MongoDB, VueJS, Bootstrap, Sphinx search, etc.) it is a stable solution for digital libraries, virtual museums, galleries, archives, and other kinds of content management-based installments areas. It is viewed both as a suitable tool for experts in the field, as well as an appropriate learning tool for students.

BIDL database stores detailed information about iconographic objects which are used for semantic annotations and indexing. The iconographic object is described with a title of the icon, iconographical object type, the author or artist, iconographical school, the period when it is created, dimensions, location and source, identification notes, description, iconographical technique, and comments such as current state and restoration details (Fig. 3). Also, each iconographical object can have associated multimedia files such as images, audio, 3D, and video stored in a multimedia repository with metadata descriptions. Especially, for the system presented in this paper, added multimedia data concerns icon image marker information.

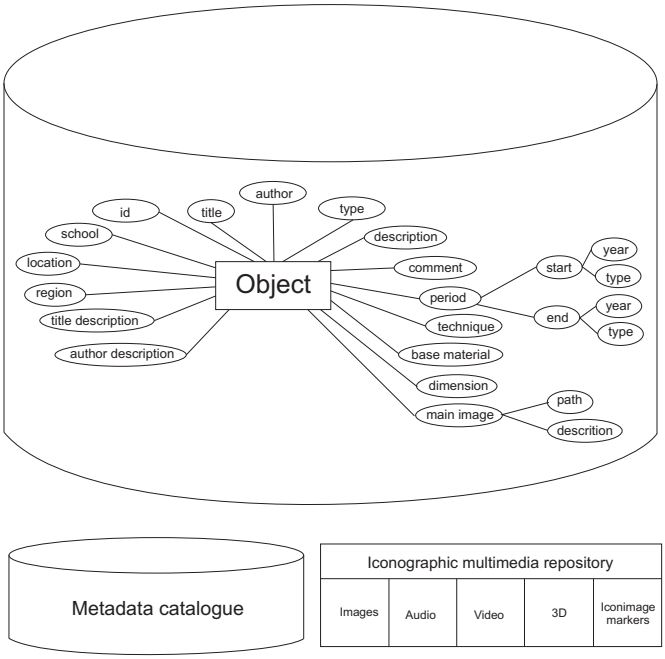


Fig. 3. Iconographic object and iconographic multimedia repository

Metadata structures in CultIS are managed using a dynamic model-building service discussed in Fig. 4, [20]. It provides the ability to maintain complex structures (including

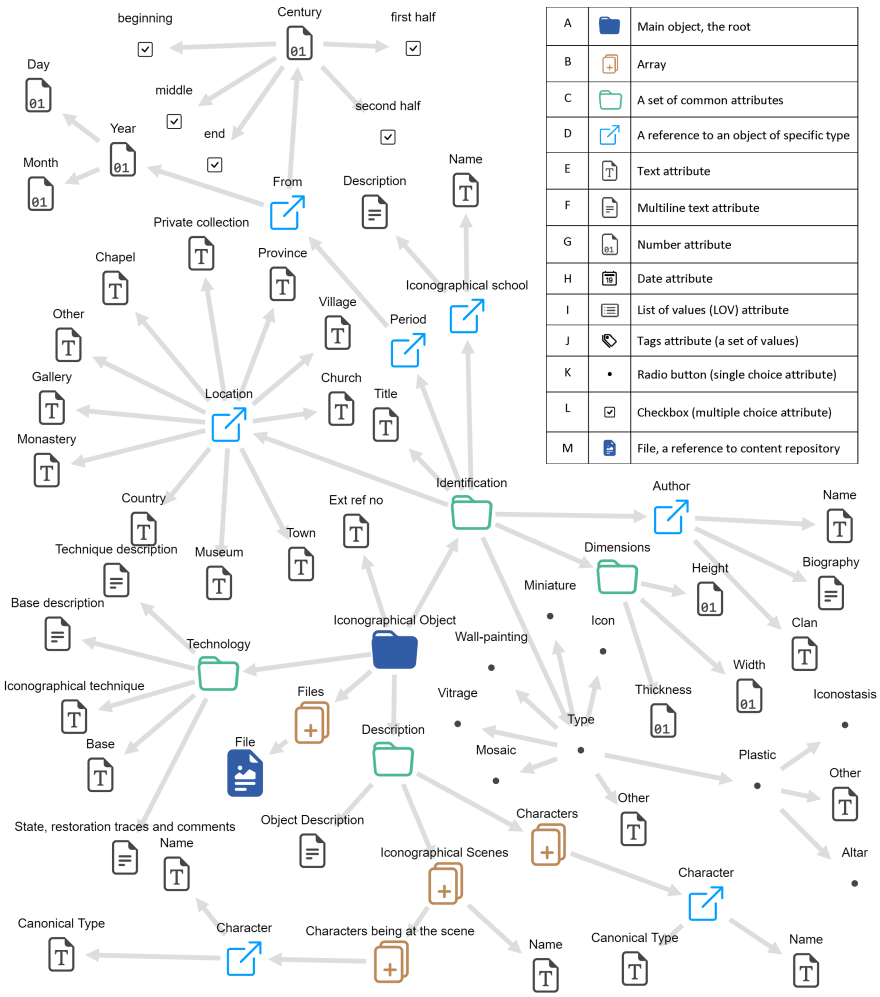


Fig. 4. BIDL metadata structure

arrays and recursive relations) and to extend them anytime. This is used for faster keyword searches of iconography content in the BIDL database.

The BIDL has implemented an application programming interface, an API-based backend, using the REST/JSON standard [19]. This API allows other parties (websites, mobile or desktop apps, etc.) to connect and communicate with the platform, request data using queries, and receive content according to their access level. These features are essential for easy and lightweight integrations with other local or cloud services and software products. Some of those services are:

- Add object service can be used to store iconographic objects in the database,
- Edit object service serves to modify information about infographic objects,
- Delete object service is created to remove information about infographic objects from the database,
- Group object service creates collections of iconographical objects,
- Search object service is used to achieve communication with the ARIR mobile application and provide information about icons.

A specialized search service on the BIDL platform has been developed to receive HTTP requests. This request has implemented the GPS location of the client-side mobile device. The service uses this GPS location to determine the nearest church or monastery. The service does calculations and checks if there is an orthodox object in the range of 1 km. Next, the database query delivers information about icons in the nearest church or monastery. This information is classified by group object service, prepared in JSON format, and sent to the client side. The information stores iconographical objects information and links to the multimedia content such as icon image markers for AR recognition.

4.2. ARIR Mobile Application Modules

The client-side is realized as the ARIR mobile application in the Unity engine. The development is done as a cross-platform application designed for different types of mobile devices with operating systems such as Android or iOS. ARIR consists of four modules realized as Unity scenes. These modules are the Communication module, the GPS module, the Info module, and the AR module as shown in Fig. 2.

GPS Module The GPS module is created to receive the geographical location provided by a location-based service on a mobile device. The received longitude and latitude are used for sending the request to the REST service in the BIDL using the Communication module. Additionally, this module provides notifications about the regularity of service response and whether to move forward with the AR module.

Communication module The Communication module exchanges data with the web service implemented on the BIDL platform. It sends requests about the current location in order to get information related to the iconographic objects in the nearest church or monastery. Next, this module receives as a response data about iconographic objects from the server. These data are parsed to provide textual information about iconographical objects. Also, data integrates links to multimedia content such as image targets for the AR module or photos, audio, video, and for the Info module visualization.

AR Module The AR module is developed by using the EasyAR SDK [29] to recognize and track icons at locations such as churches or monasteries. Photos of icons are stored in the multimedia repository on the server as AR image markers for recognition and tracking. The main components of the AR module and their relations are shown in Fig. 5. Information about the locations of AR image markers on the server is provided as a part of the response for each iconographic object. These data are provided to the special data structure named IconographicDataManager. Iconographic objects, besides descriptive elements about icons, have implemented links to the icon image markers.

The AR module starts when markers are dynamically loaded into the application using ARManager which loads marker links from IconographicDataManager and creates IconImageMarker. In this way, for each provided link, ARManager creates an icon image marker. Next, ARManager creates a virtual object as VRObject associated with the icon image marker. This virtual object will be shown during the recognition. The virtual object has an integrated virtual button, name, and unique identifiers (ID) of the icon.

When an icon is recognized, the corresponding virtual object overlays the icon with a virtual button and basic information such as its name. The other iconographical data can be displayed, if necessary, in this step. In interaction with the virtual objects the AR module links to the Info module. The ID is used to identify more detailed data about the recognized icon from IconographicDataManager and is shown in the Info module.

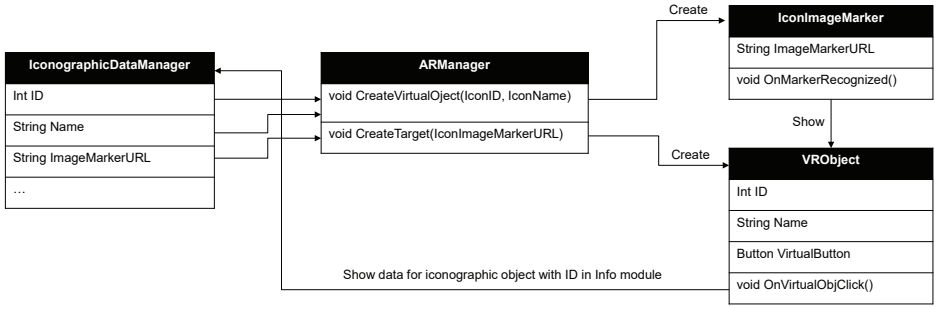


Fig. 5. Important components of the AR module

Info module The Info module is developed to show information about a recognized icon with the AR module. Based on the icon ID detailed information is displayed as textual information. Multimedia content such as audio, video, or 3D, is supported for visualization in this module and it is available via a link to the BIDL multimedia repository.

4.3. Realization of ARIR

The realization of the ARIR mobile application and usage of implemented modules are shown in Fig. 6. The application starts with the activation of a location-based service in the GPS module. This module loads the longitude and latitude of the visitor device to optimize the search for the icons that will be sent from the server. Using the Communication

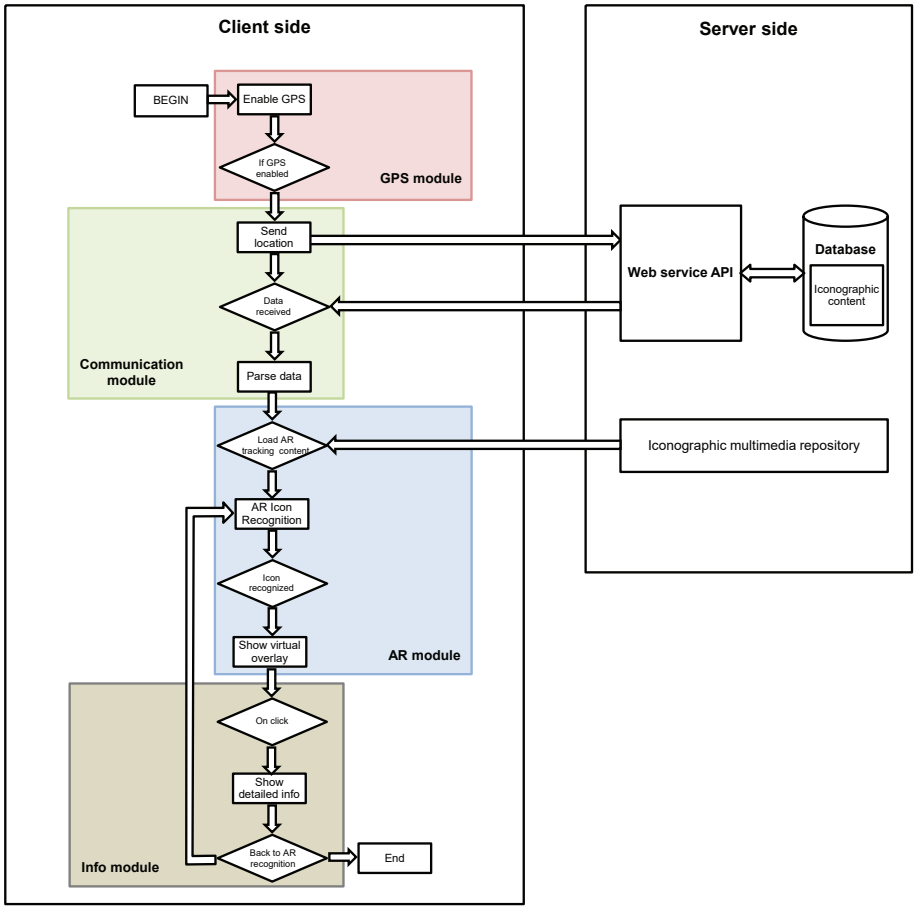


Fig. 6. Algorithm of ARIR application usage.

module these data are embedded as a part of the request and sent to the specialized search service. The search service processes this request by comparing this data with locations of places stored in the database such as churches or monasteries. As a response, iconographic content for the nearest place is prepared and sent in the form of JSON format to the ARIR mobile application.

The Communication module parses response data received from the server. These data have detailed information on iconographic objects and necessary data for the AR recognition. Data necessary for the AR module are the URL of the image markers and basic data of the icons such as ID and name. Based on the provided URL the AR module receives the image markers from the iconographical media repository.

AR module starts when data is successfully received from the search service and image markers are loaded from a media repository on the BIDL platform. Then, the AR tracking can begin and information about icons of interest can be quickly found at the location. When an icon is recognized, the basic information about the icon and interactive virtual object is displayed as an overlay during the tracking. Through the interaction with this virtual object, the AR module activates the Info module. The info module loads and displays detailed multimedia information about the recognized icon.

5. Usage of the ARIR

The ARIR application development concerns the creation of an interface design. As the application is aimed for the usage at religious places, a minimalistic interface design is used. Furthermore, the types of users are determined for the usage of the ARIR.

5.1. Interface Design

The user interface is designed according to the modules functionalities used for data visualization. Fig. 7 shows screenshots of the design of the application user interface. The first screenshot represents the home screen design. The button on the menu activates the procedure for the GPS module. If the location-based service is deactivated, the user has to enable it to proceed with the application. This is presented in the second screenshot. When a visitor enables a geolocation service background process sends a request for iconographic data of the location. The third screenshot shows that data was successfully received from the server, and it provides a brief explanation about the usage of AR. The activation of the AR module, which enables the device's camera and icon recognition, is given in the fourth screenshot. The last screenshot represents the visualization of the Info module, which displays more information about the identified icon.

5.2. Usage of AR-BIDL

This section presents a usage scenario for the AR-BIDL in situations usually met in practice. It is assumed that a visitor to an Orthodox church may be interested in learning more about the interior icons. At the location, he is informed that the application AR-BIDL is freely available at Google Play or AppStore and can be downloaded by scanning the corresponding QR codes printed on an info table provided at the site, or on a flyer, or shown

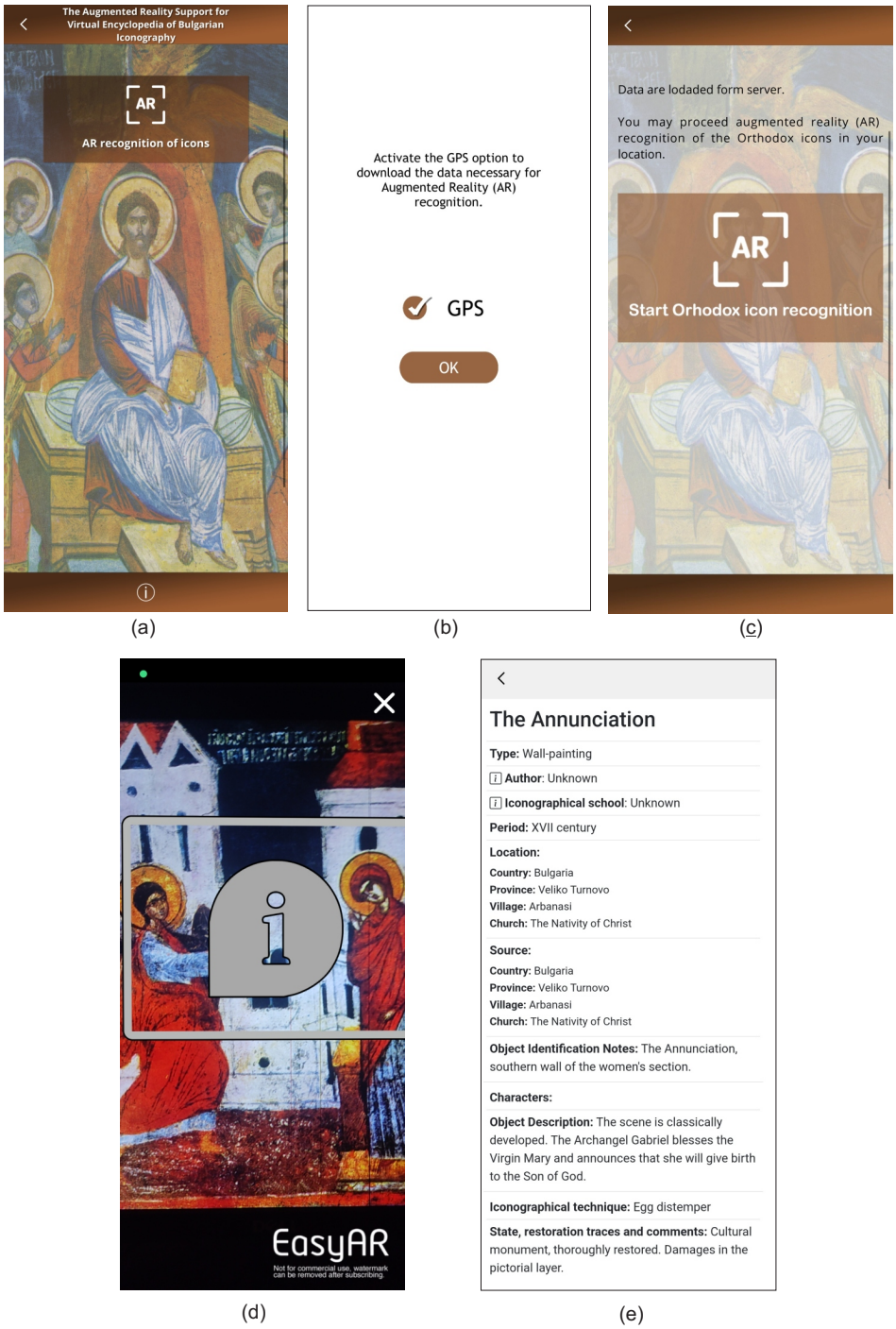


Fig. 7. (a) Home screen of the application, (b) Activation of the GPS module, (c) Data download from a server, (d) Activation of AR module, (e) Visualization of Info module.

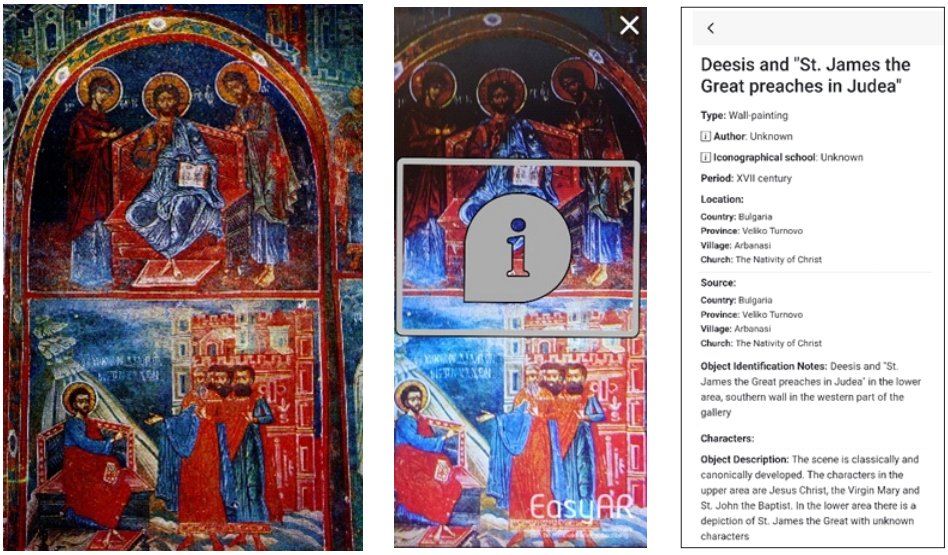
Icon image target			
Name	The Annunciation	Deesis and "St. James the Great preaches in Judea"	All angel-kind was amazed
Type	Wall-painting	Wall-painting	Wall-painting
Author	Unknown	Unknown	Unknown
Iconographical school	Unknown	Unknown	Unknown
Period	XVII century	XVII century	XVII century
Location:			
Country	Bulgaria	Bulgaria	Bulgaria
Province	Veliko Turnovo	Veliko Turnovo	Veliko Turnovo
Village	Arbanasi	Arbanasi	Arbanasi
Church	The Nativity of Christ	The Nativity of Christ	The Nativity of Christ
Source:			
Country	Bulgaria	Bulgaria	Bulgaria
Province	Veliko Turnovo	Veliko Turnovo	Veliko Turnovo
Village	Arbanasi	Arbanasi	Arbanasi
Church	The Nativity of Christ	The Nativity of Christ	The Nativity of Christ
Object Identification Notes	The Annunciation, southern wall of the women's section.	Deesis and "St. James the Great preaches in Judea" in the lower area, southern wall in the western part of the gallery	"All angel-kind was amazed", the southern wall of the women's section.
Object Description	The scene is classically developed. The Archangel Gabriel blesses the Virgin Mary and announces that she will give birth to the Son of God.	The scene is classically and canonically developed. The characters in the upper area are Jesus Christ, the Virgin Mary and St. John the Baptist. In the lower area there is a depiction of St. James the Great with unknown characters	The scene is classically and canonically developed.
Iconographical technique	Egg distemper	Egg distemper	Egg distemper
State, restoration traces and comments:	Cultural monument, thoroughly restored. Damages in the pictorial layer.	Cultural monument, thoroughly restored. Damages in the pictorial layer.	Cultural monument, thoroughly restored. Damages in the pictorial layer.

Fig. 8. Some of the iconographical objects of the Nativity of Christ Church

in some other suitable way. As an example, table at Fig. 8 shows information about three icons in the Nativity of Christ Church.

After downloading and installing, the visitor starts the ARIR application at the location. The GPS module receives the visitors' location when the AR button is pressed and then obtains information about nearby icons from the BIDL server.

The augmented reality scene opens when parameters for recognition and tracking icons are loaded from the BIDL server. The camera on the mobile device is activated and the visitor points the mobile device toward a specific icon as shown in Fig. 9 (a). The image captured by the camera appears on the screen of the mobile device. When the icon Deesis and "St. James the Great preaches in Judea" captured by the camera is recognized, the virtual button appears as an overlay (Fig. 9 (b)). This is also a signal to the visitor that information about the observed icon is available.



(a) (b) (c)

Fig. 9. (a) Icon image target - Deesis and "St. James the Great preaches in Judea", (b) Augmented reality tracking Orthodox icon, (c) The Application displays the detailed information received from the BIDL platform.

Interaction with this button provides a link to the Info scene where more detailed information about the recognized icon is provided. This information given in table at Fig. 8 is displayed in the Info scene in the format shown in Fig. 9 (c).

In this way, through the ARIR, the information about an icon is provided instantaneously at the site while observing the icon. The search over the large BIDL database, with necessary requests for additional information about the geographical location or other data to locate the icon, is avoided. Further, possible misinterpretations due to human errors in recognizing similar icons are eliminated.

5.3. Users of the application

The ARIR application is aimed at contemporary visitors who want to be informed about icons at the location in a fast and comfortable way. Augmented reality enables digital overlays over the icons that could provide information according to visitor's interest. These digital overlays unlock the artistic features and religious meanings of observed icons. Also, the application may deliver interactive storytelling about saints or biblical events, which is supposed to be of a particular interest for the younger users. This can be done by creating more animated material that can be shown inside a mobile application. At the same time, including specific multimedia material can improve presentation for visitors with disabilities. Recognizing the icons of interest audio storytelling can provide significant assistance to visitors with visual disabilities. Embedding video material with sign language can improve the interpretation of religious and artistic meaning for visitors with hearing problems. Moreover, specialized guided tours about iconographical content could be organized during the visitation to one or more places such as churches and monasteries. This enriches the traditional visitations, making them more informative and interactive. In this respect, the use of AR should preserve the spiritual significance of holy places while improving the religious and cultural experience.

This system can be useful as a remote learning tool for students. The AR application used directly on the site will provide educational content quickly upon icon recognition. Especially students of arts and theology can get educational material as interactive learning content to discover information about the observed icons in situ. This simplified interaction can help students to more effectively interpret depicted icons with their spiritual meaning. Also, it can help a deeper understanding of the iconographic techniques, period of realization, and chosen materials for iconography development. Moreover, this system enables professors to organize interactive learning experiences at exact locations. This can be performed as learning tours at remote classrooms where students have tasks to scan and explore the concrete icons at given locations.

This system can be used not just for visitors or students, but also for experts in the field of iconography such as conservators, iconographers, topologists, etc. In this case, the system can be used to share digital documentation stored in the BIDL database. Also, stored global knowledge can serve for analysis and collaboration work for processes such as conservation or restoration. This includes important metadata that can be shown during recognition.

6. Experimental testing and verification of the application

As it is customary practice, we performed experimental testing and verification of the developed ARIR application. Experiments were directed towards checking the functionality and usability of the application and were performed by following recommendations for testing AR-based applications presented in [25], [16], [9]. It should be taken into account that these recommendations are primarily intended for AR applications where the primary tasks are generating 3D models and their correct positioning and good visualization. In the case of the present application, the most important issue is to test the application response when the user is at an appropriate proximity to the location where iconographic objects of interest are exhibited. The application was installed on mobile devices with

various performances typical for ordinary users. Testing was performed at five different religious institutions in Bulgaria, two monasteries and three churches, at locations covered by different telecommunication networks offered by national providers. We also analyzed the response of the application to a request for presenting information content related to particular icons.

6.1. Functionality testing

To test the functionality of the application with respect to the speed of the response to the users' requests, we performed experiments with 5 experienced users familiar with this particular application and also various other similar applications. It was assumed that the user is in proximity to the object of interest. We measured the delay between the moment of issuing the request to the web service for the data until augmented reality was ready for recognition. The obtained average response was no more than 20 seconds. It however can be concluded that the response time primarily depends on the size of the communication package exploited by the user of the application but also the speed of the Internet on the location. After augmented reality recognition of an icon, when interaction with a virtual object is achieved, the application response was within no more than 5 seconds showing the icon information. The application was functional in all cases.

6.2. Usability testing

The usability test is performed with users who haven't used this application previously. A total of 10 users tested the application at three different locations. At each location, it was installed a 100x70 cm table with QR codes for downloading the application and a brief explanation of its purpose. Despite that, a conclusion is that at the beginning, it was necessary to first provide a clear and precise explanation about the way of using it. Later, the demands for assistance were considerably reduced.

7. Scaling of the system

The AR-BIDL is a system that can provide fast information about the hundreds of Bulgarian Orthodox icons at the location. This system has the scaling potential to be extended by including more icons for AR recognition and inserting information about them into the database. A good feature of the proposed approach is that no update is required after expansion of the database by including icons from other locations. This expansion can further concern adding new icons from Serbian churches and monasteries since this system is realized as a joint research project "Development of Software Tools and Multimedia Technologies for Digital Presentation, Preservation and Management of Cultural Heritage" between the Institute of Mathematics and Informatics, Bulgarian Academy of Sciences and the Mathematical Institute of the Serbian Academy of Sciences and Art. This project can be extended to other orthodox nearby countries to serve as a regional database for learning and education about iconography.

The system's limitation is that the AR recognizes only icons whose locations are known in advance in places such as churches and monasteries. If we suppose to add in the BIDL database icons that do not depend on location then it is required to reorganize the

AR BIDL system's structure. This can include home icons placed at traditional Orthodox prayer corners. Also, incorporates icons that are part of museum collections that can be displayed in different locations. Accordingly, the new structure should compare the images captured by the camera with all icon image targets stored in the database. This can be realized using the cloud recognition solution where the database can store and compare up to 100 thousand targets.

In the case of the AR tool that we already used, EasyAR SDK enables cloud recognition service. This cloud solution enables integrated Web services API intended to manage image targets and provide communication with other services. The BIDL solution also enables integration with cloud services and therefore the proposed solution as Augmented Reality Cloud BIDL (ARC-BIDL) is given in Fig. 10.

The specialized service for adding new iconographical content on the BIDL platform should be extended for communication with cloud service applications. This service should send image targets to the cloud application instead of storing them on the BIDL media database. In the BIDL database, only the image target ID is stored as a response from the cloud recognition service.

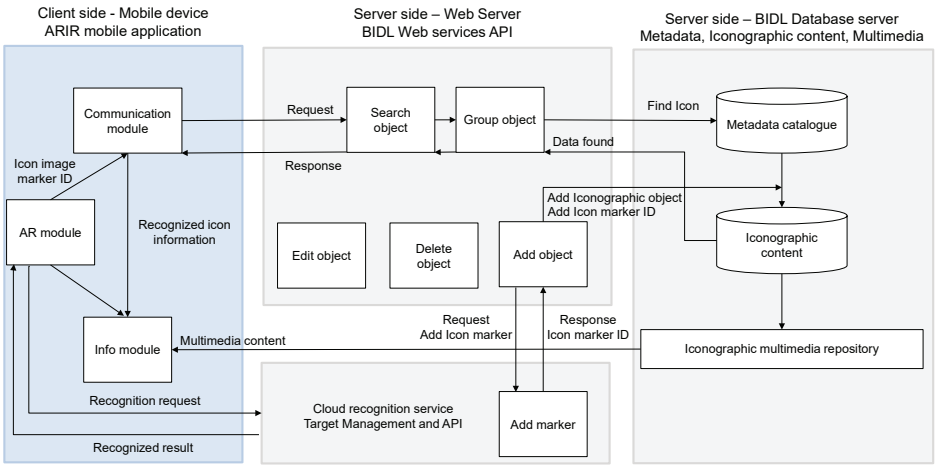


Fig. 10. Proposed ARC-BIDL system architecture.

The proposed ARIR mobile application solution starts and activates the AR module for recognition of Orthodox icons in visitors' surroundings. Then, the AR module sends a request for recognition of the image captured by the camera. As a response, cloud recognition service provides image target information. Overlay in the form of the virtual button appears on the screen of mobile device during the tracking of the recognized icon. Through the interaction with this virtual object, the ARIR loads the Info module. Also, as a background process, the Communication module is activated to send the request for the related content to the BIDL server. The request implements the icon image target ID of the recognized icon and sends it to the BIDL search service. The BIDL service responds

to the request and sends back the content about the recognized icon. This information will be parsed by the Communication module and sent for visualization in the Info module.

8. Conclusion

Virtual Encyclopedia of Bulgarian Iconography (BIDL) contains information about hundreds of Bulgarian iconographical artifacts including data about the holy person or other contents inscribed on the icon, as well as information about the painters and artistic techniques, type of colors, and other related data. As is the case with any web-based platform, the general problem in exploiting BIDL, in terms of speed and comfort, is finding information about a concrete icon on the site and at the time when a visitor observes the icon in a church, monastery, museum, or gallery. Typically for the usage of databases, it is necessary to provide keywords. This is resolved by developing the ARIR mobile application based on augmented reality technology to facilitate and speed up the search for related data over the BIDL platform.

Using the AR module of the ARIR application, the icon is recognized which enables a quicker search for information about the icon of interest at the exact location compared to the classical search using keywords. Manual retrieval results obtained from the database of BIDL by comparing images can be time-consuming and potentially lead to mismatching which is prevented by the AR module where the icon is immediately recognized. Furthermore, if the icon is not in the database, manual searching may cause a time loss, which the AR system prevents. AR overlays the icon with the virtual object as the signal to the visitor that information about the observed icon is available in the BIDL. The related data are projected after clicking on it. The system was experimentally verified by performing usability and functionality testing at several locations. Our further work under the above-mentioned bilateral project will involve different analyses and ways of informing potential users about the availability of the ARIR application and its features.

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