Augmented reality supported model for the use of local data in architectural design

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Abstract. This study presents a model that aims to enable better understanding of local site-specific data in the context of architectural design using augmented reality. It is developed by considering the necessities of local data in architectural design and the potentials of the location based augmented reality. The classification of the local data is provided with the use of a framework, and the structure of the model is based on researches on location based augmented reality applications. The operability of the model is described by an integrated workflow that is explained under the stages of data acquisition, data query and data display. Lastly, it is conceptually presented by use cases that are focus on the necessities of local data from the architectural perspective. By bringing the architect into more direct contact with the site, the model facilitates to understand local data in situ and supports the reasoning process to design.

Keywords: Architectural design, augmented reality, local data

1 Introduction

Throughout the design process, architects interact with a variety of data to inform design decisions. Architectural design is closely related to spatial relationships of site-specific surrounding data. Local data can be used by architects to improve the design process to match the natural and cultural context. Architects need local data of the site in the early design phase, therefore site visits come to the forefront for understanding the context in which a design is going to be located in. It is a well-known fact that architects spend considerable time to explore contextual properties of the site and afterward local data from various mediums are collected to analyse the site before the development of the design [1]. For this reason, the presentation of local data is important over the course of the site visit, site analysis and conceptual design.

Due to the increased amount of data necessary for evaluation, a holistic view of local data is needed. Digital technologies present great opportunities for architects to acquire and use local data, and technological developments have enabled to access large quantities and different types of data. Besides, mobile computing with portable display devices organises and presents spatially referenced data [2]. All these developments reveal new possibilities to inform architects for understanding the context of the site. In connection with the rise of digital culture, augmented reality provides to deal with the interface between the physical environment and virtual environment, rather than focusing on one of these environments [3]. It can be used in a location based approach, that enables to produce constructive relationships on information with the use of the location. It offers an immersive experience of surrounding information from different viewpoints while on the move [4]. Despite all these, augmented reality is generally used to present a completed 3D model of the design for architecture. There are also few studies in which these models are presented on site [1], [5]. However, there is no study regarding the presentation of site-specific data to be considered during architectural design. These types of location based augmented reality studies are mostly encountered in tourism or city guide applications [6], [7]. It is also possible to acquire data of the site and present it in situ via location based augmented reality for architectural design.

This study presents a location based augmented reality model which is based on local data framework to classify the context by categories and provide contextual information about the site. Using such a model for the exploration of the site supports the architect to collect and analyse local data. By bringing architects into more direct contact with the site, the model facilitates the architect to understand the surrounding local data in situ and supports the reasoning process to design.

2 Necessities of Local Data in Architectural Design & Potentials of Location Based Augmented Reality

In architectural design, the architect produces spatial solutions to address architectural requirements using a variety of data on the site. The formation of the architectural design is bound up with the collecting and analysing of the data. Initially, it is necessary to collect data that present the characteristics of the site. For many years, architects have used observational data to research places and regarded the data as input to architectural design. This circumstance is insufficient to evaluate data of a place, it causes certain problems related to accessibility, accuracy and location of the data. The architect may visit the site to view, take notes and photographs, and look for patterns while collecting data. Afterwards, the architect continues the design process at the office to analyse collected data onto the map like studies. For the analysing of the data, the current circumstance also requires the architect to be physically detached from the site [8]. The architect needs to be able to sort, visualize and navigate data to accelerate understanding and decision making. Architectural design solutions are often developed through the analysis of the surrounding context [9].

Depending on the data collection and analysing method of the architect, certain problems could arise in the current design process. Therefore, the concept of local data is essential to cope with data on the site. Local data is formed by any piece of information that has an absolute or relative location. Location as an index into an information space provides a base to the systematic approach in local data. In architectural design, the information of the site can be categorised under the natural and cultural local data. These two main categories contain all of the data that need to be considered while understanding the site and its spatial features in the early design phase. The natural and cultural impacts of the surrounding context are critical to architectural design. Collecting and analysing of local data supports the establishment of the interaction between the site and the design. It helps the architect to determine the suitability of the design proposal with characteristics of the site [10].

During the design process, it is not possible for an architect to map in mind a great number of data on the location without using a computational tool. Augmented reality enables users to interact with their physical environment through the overlay of digital information, and empowers users in activities by spatially augmenting useful information. The combination of real and virtual elements in a mixed environment provides the ideal context for the architect to examine spatial conditions. The exact location of each data can be identified in the spatial context via augmented reality. Location based augmented reality systems have become crucial as a powerful presentation tool, which allows users to request and access information about a specific location [11]. It has strong potential to provide on site experiences and the exploration of the connected nature of local data in the real environment. Especially at the beginning of the design process, local data can be presented via augmented reality to inform architects about the site. Augmented reality may allow architects to gain an immediate check of local data, and quickly contextualise their designs. Architects can thus obtain a holistic view of the possible interactions between the site and its surrounding context, which may eventually provide more effective design solutions. The use of augmented reality during the architectural design offers a number of advantages to present local data. In this study based on the literature research, the necessities of the data collection and analyzing are discussed with the current circumstances, and augmented reality possibilities that meet these needs are associated under following subsections.

2.1 Common Medium

In order to access local data, it is necessary to acquire data from various sources. Therefore, architects often need to search various sources in different mediums for local data. Local data is represented in a number of ways, ranging from traditional methods that include hardcopy documents and physical models to modern methods that include digitally presented documents and 3D models [12]. There is a common medium requirement to bring these various sources together. Considering the other mediums, collecting the local data from various sources with traditional and modern methods is more difficult. Augmented reality produces interactive relationships with information in various sources. It acquires all local data into a hybrid space where both real and virtual share the same environment. Thus, the use of augmented reality lowers the frequency of switching between mediums by integrating the required information into a medium. It reduces the data loss associated with repetitive switching. It is also important to reduce transmission errors between the mediums, such as from hardcopy to digital [13].

2.2 Data Classification

During the exploration of the site, understanding and classification skills of an individual are exceeded under the numerous data on the site. In order to comprehend the local data of the site, natural and cultural data need to be handled under the classifications that are based on general assumptions or individual approaches [14]. One of the largest difficulties of collecting data on site is the large quantity of uncategorized data problem. Augmented reality systems need to display the most relevant information to the classification instead of overloading too much information onto the user's attention [15]. A data classification framework needs to be used to manage and filter local data. Depending on the user's goals, the classification can be changed in the presentation of information on the site. Augmented reality systems are proper to work under a classified system due to its informatics based structure.

2.3 Spatial Approach to Data Mapping

The process of understanding correlations or associations between the data and the site, imposes an additional cognitive load to an individual to map data [16]. Thus, a considerable amount of time and effort may be undertaken to determine the location as well as related information. Besides, the barriers have directed for many years to transform the communication of a 3D space into 2D representation methods. 2D data representations are often considered insufficient to address comprehensive 3D design problems [17]. It is necessary to provide 3D representation environment to overcome limits related to 2D representation. Instead of being handled in 2D representations, evaluating the data under the 3D conditions is important to analyse spatial relations. Above all, the main problem is the being separation of mapped data and the physical site. Augmented reality can be used to solve these mapping relationships by carrying local data onto the site. 3D representation of the properties can be visualised directly on the site with augmented reality. It can also indicate more clearly the potential source of the existing data on the site. Besides, mapped data in 3D form of representation within the augmented reality may inspire conceptual thoughts related to architectural design [18].

2.4 Holistic View

The holistic view of the local data is essential due to the increased amount of data necessary for architectural design. It provides to evaluate the data together with other categories rather than within their category [19]. Augmented reality can increase the legibility of layers in complex relations. It makes easy to detect overlaps between different data on site. The causal links between data and site can be better recognized and understood in a holistic view through augmented reality visualization [20]. It is also important to overcome intensive data exposure in urban sites and weak data problem in rural sites. Augmented reality helps to control the density of data in urban sites and increase access to the cultural data as much as natural data in rural sites.

2.5 Data Visibility

In the site, there are properties that are not visually apparent with the naked eye. Even though most of the local data are observable on the site, some of them are unable to be recognized. Augmented reality is an opportunity to make hidden data visible, such as subsurface properties, or properties obstructed from the view. It can also visualize what cannot be seen, such as site boundaries, flood level, air quality, and so on [21]. Augmented reality can be seen from all viewpoints, thus it enables users to experience a site from different perspectives [22]. Different distances and angles can be used to capture the interrelationships between data in a holistic view. Augmented reality helps to improve the visibility of the local data on the site.

2.6 Representations with Time Component

Local data with a time component offers the understanding of the site in temporal dimensions. Architects sometimes find it difficult to imagine the spatial impact of the past, existing and possible future conditions. 4D representations of the local data can be built to reflect the past, existing and possible future conditions of a site with the actual or proposed appearance [17]. With overlaying time-sensitive local data onto the physical site, augmented reality enables a new way of looking at information. It can provide an on site realization of historical ruins, underground cities, future buildings, future arrangements and so on. In augmented reality, local data with time component not only show the historical development and future planning, but also show a comparison to the current situation [23]. Moreover, real time data that represent a feature can be visualized on site, such as sunlight & shade, surrounding traffic pattern, air quality, and so on. It could allow a better understanding of the needs in the temporal dimension and help to create spaces that better meet those needs.

2.7 Data Analysis

In the analysis process, architects use their collected data as a basis for the generation of the required analysis. The traditional method of architectural analysis evaluates the collected data for each category in itself and between categories. Analysis of the site creates the opportunity for architects to create designs that are better attuned to the site [24]. Currently, architectural analysis typically occurs outside the site after the site visit and data collection, and delays the starting of the conceptual design. Progress in technology also allows enabling advanced possibilities of analysis in augmented environments [25]. There is a limited field that analysis in situ in professional practice today, but opportunities abound in augmented reality. Augmented reality can make much easier to carry out an analysis by visualizing interactively while on the site and help architects to make design decisions based on these analyses. As an example, the analysis of the topographic change can be provided on site by the use of topography elevation data. Thus, the architect can readily decide on more suitable parts of the site for building placement. This provides analysis for evaluating a data category in itself. Within the scope of this example, when the topographic change is analyzed together with the legislation about the legally useable area, the suitable parts of the site can be specified more precisely for building placement. This also provides to evaluate data between different categories for data analysis related to the site. As a basic method, maintaining multiple versions of each data according to time or change can be a basic way to get analysis for augmented reality systems [26]. It is also important to use BIM data that is quite suitable for analysis as the information source of augmented reality systems. Augmented reality can visualize and analyse BIM data in the context of the site [13].

2.8 Taking Note & Sharing

In architectural design, the site visit is important to make observations about the site. During the site visit, architects need to take notes and share their observations of local data with other colleagues. These notes that may direct the architectural design, are recorded while on the site for preventing to forget. Thereafter, these notes are shared with other colleagues to draw attention to the current state of the site. Augmented reality allows users to directly place their own observations on site, and to use annotations for drawing attention on existing local data. All commentary information can be fed to a data store accessible to other users [23]. For architects working on large and complex sites, the ability to quickly leave a note about local data via augmented reality on site may enhance communication between the members of a project team. Moreover, it enables the precise placement and arrangement of digital content over the physical site to be augmented. In an augmented reality system, multiple users may share the same physical space and help the data collection through crowdsourcing. It allows the users to participate data collection in such a way, that they can create their collaborated content rather than only using content presented by other sources [27].

2.9 Helping Architects & Providing Expertise

It is not possible to have knowledge about every detail about architecture and other associated fields. In architectural design, architects may need help about interpreting local data, and there may be situations where more experienced or specialist professionals' opinions may be needed. Incorrect interpretation of local data can be prevented by the use of augmented reality [28]. For instance, legal distance to a pipeline that is defined in legislation can be visualized on the site for construction limit. It is often difficult for architects to gather knowledge and expertise from other professionals at the starting of the architectural design. The architect interacts with other professionals about certain data related to architectural design, and augmented reality systems can easily provide expertise to related data from a database or communication platform [8]. For instance, the structural system can be proposed for the special conditions of the ground in the site from civil engineering expertise.

The advantages of augmented reality, and the necessities of the local data collection and analyzing are discussed around common medium, data classification, spatial approach to data mapping, holistic view, data visibility, representations with time component, data analysis, taking note and sharing, helping architects and providing expertise. In order to summarize, Table 1 shows the current state of local data in architectural design and the potentials of location based augmented reality. It clearly states that the advantages of the augmented reality are incontrovertibly more than the current state. From data collecting to analysing process in architectural design, augmented reality can be appropriate for the site to manage local data complexity. A model in which location based data is presented using of augmented reality, can be used to support the architect's relation with the local data. This model can be seen as the augmented representation of the site, by nourishing the physical site with local data. The use of this kind of a model, prevents the architect to be detached from the site, and supports the integration of local data with the site to interpret more realistically in terms of the spatial awareness.

Table 1. Current state of local data in architectural design and the potentials of location based augmented reality.

	Current State of Local Data in Architectural Design	**Potentials of Location Based Augmented Reality**
Common Medium	searching various sources in different mediums	common medium to bring various sources together
Data Classification	data classification based on observations	managing data classification with a framework
Spatial Approach to Data Mapping	understanding the spatial relations in/between 2D/3D representations	spatial approach to data mapping on the site
Holistic View	bringing together local data outside the site	holistic view of all local data on the site
Data Visibility	observable local data with naked eye	providing visibility of hidden properties
Representations with Time Component	imagining the spatial impact of temporal dimension	representations with time component on the site
Data Analysis	using collected data after the site visit for analysis	advanced possibilities of analysis on the site
Taking Note & Sharing	taking note and sharing observations	commenting on site and placing observations
Helping Architects & Providing Expertise	needing help to interpret and meeting for expertise	providing interpreted local data and expertise on site

3 Augmented Reality Supported Model

Augmented reality supported model is developed on the purpose of providing in situ data for architects in this study. It is observed that this model can be put forward in line with the fulfillment of certain architectural needs and technical requirements. Firstly, a data framework is needed to categorize data, and it has to be organized from architectural point of view. When all data is obtained from regarding area, it is categorized according to used data framework. In the workflow of the model, this part provides organized data acquisition, and it has to be processed with queries to get effective data in the next step. While displaying queried data, it can be filtered according to the selected categories in the last step of the workflow. When the selected field diameter and the device attitude are changed, it has to react to new condition. All of them can be realised with components of augmented reality systems.

This study is a part of a comprehensive study that is connected to previous studies. A local data framework is developed [10], and location based augmented reality systems are evaluated [29] for this model in the previous studies. They are based on the literature review and comparison of related works. These researches are used to structure this model for use in the field of architecture. For explaining the contributions of the model, use case examples are handled from the necessities of local data. While presenting them, use case examples are focused on common medium, data classification, spatial approach to data mapping, holistic view, data visibility, representations with time component, data analysis, taking note and sharing, helping architects and providing expertise.

3.1 Local Data Framework for the Model

The site includes natural and cultural factors that vary in terms of categories for architectural design. Primarily, the proposed model needs a data classification framework to manage data. The classification of the local data comprises various categories and subcategories under the main categories. Local data framework is developed as the main part of the model in previous studies to manage local data for architects [10]. It enables the classification of location based data in the model. For understanding easier in the model and the use of the sample interface, local data framework is illustrated as seen in Figure 1. The framework of the local data is structured around a combination of natural and cultural data. Natural data categories are held on the left side, and cultural data categories are held on the right side of the illustration.

The classification of natural and cultural data can also be carried out under different categories and subcategories. This classification is realised according to data classes of reviewed sources. This framework is not absolute, it’s open to development. It is also possible to classify a framework in different ways depending on the varied classification approaches. The model is conceptually presented with the use of this data classification. Today, it’s not possible to find a totally completed database for this model. But, it will be possible in the near future with the increasing approach to digitalization and generation of data in daily life. In order to benefit from the model effectively, there should be a limit to be determined for essential data. This limit can be revealed by a more comprehensive study on the effects of every data on design. This model can work with limited data, and obtain them from open access databases. General databases are advised to use because of being trustworthy. Besides, data can be obtained in different ways other than standard databases, but then there will be a need to rate for reliability.

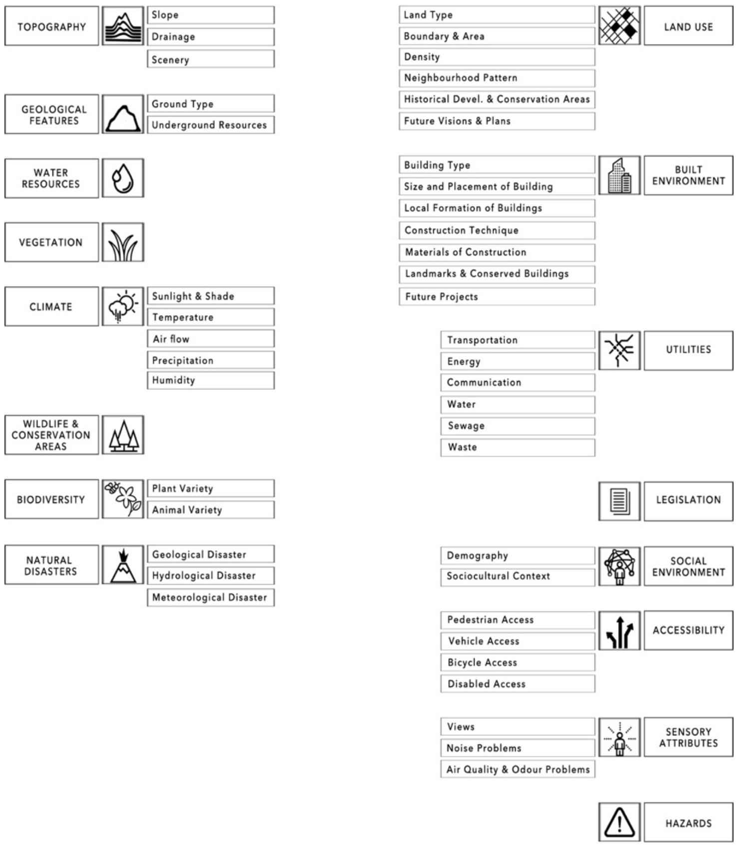

Fig. 1. Illustration of local data framework.

3.2 Operation of the Model

The operability of the model is provided by an integrated workflow. The workflow of the model is extensively explained under the stages of data acquisition, data query, and data display (Figure 2). In the acquisition of data, commonly used methods and different methods which emerged with developing technology are discussed in relation to the model. The query and display infrastructure of the model is explained based on the working principles of the studies carried out in the field of location based augmented reality [5].

Data Acquisition on the Model. The data acquisition system is needed to provide, manage, and filter the data of the model. The data is obtained from sources according to the data classification in local data framework that is specified for architectural design in the model. It is presented as a well-structured framework which could be readily used by augmented reality systems to support architectural site survey. On the other hand, this model also needs access to available and reliable data sources. It is necessary to link the model to databases that contain necessary information associated with the site.

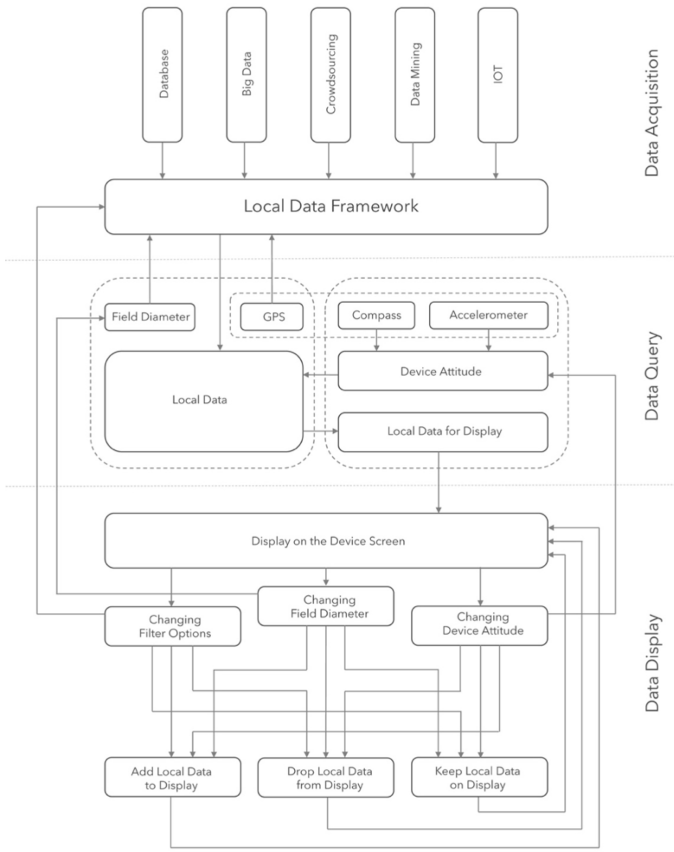

Fig. 2. Workflow of the model.

Regarding databases, firstly, the model can acquire data from relational databases. Relational databases provide structured data according to required parameters and different levels of accuracy depending on the source. In the case of a data format, it may be necessary to convert or adapt to other formats for local data, compatible with the model. Therefore, standardization of data type formats may facilitate communication between different databases. If databases contain different data associated with a location, they can be compared directly to provide a way to validate by data comparison facilities. Generally, these databases are stored in a cloud system to access information about the current location when needed.

Beyond the relational databases that are primarily used in data acquisition, big data and crowdsourcing methods can be utilized to acquire data [30], [31], [32], [33]. Big data can analyze the data that has a location information without any data classification. Any data fed into this model with big data has to be pre-processed, in this way it provides classified data that can be used. Therefore, it is necessary to develop an automatic and intelligent domain information extraction mechanism to always provide relevant information with respect to the local data classification. By crowdsourcing method, users can upload their individual data to a cloud database system that is integrated into the model. This allows users to actively participate in the local data creation process by sharing content in situ in an augmented environment [34]. Besides, IOT allows a variety of information to be collected by sensors linked to the internet [35]. It allows users to access heterogeneous data from different pervasive sources in a site visit.

Data Query on the Model. In the model, data is queried in specific steps. Firstly, GPS as location, compass as direction, and accelerometer as orientation information are acquired to provide sensor data. When the acquired location information is sent to the query to obtain local data, direction, and orientation information are used to calculate the point of view. By the use of location information and effective field diameter, local data is queried from the data arranged in the local data framework. The effective field diameter allows the querying of data in a specific distance from the current location. In addition, the use of filtration through data categories affects query results. By the calculation of the point of view with the use of direction and orientation information, local data results are queried to display.

Data Display on the Model. In the model, data display is performed with the data obtained from the query process. Local data is presented to the user when it is covered by view angle, filter options, and effective field diameter. The change of the point of view affects the data to be displayed. According to the new point of view, the local data acquired during the query process is taken into the display process. Besides, the change of the filter options affects the data to be displayed according to the preferred data classes. When the effective field diameter is changed, local data is queried again according to the new field diameter. According to changing situations; local data newly included in the display is added, local data outside the display is removed, and local data that remains in the display is preserved. In addition, the model allows local data to be displayed on site with appropriate visualizations of the data. Data visualization is to be considered for the representation of each local data in the local data framework.

3.3 Model Components

Augmented reality has received increasing attention as an interactive medium that allows users to search for information in a realistic 3D space [35]. Especially, the improvements in mobile devices and the use of location as the basic resource for context aware services have provided useful components for using augmented reality in the field of architecture [36], [37], [38]. Most of the location based augmented reality systems are designed to present information about point of interests, similarly, the proposed model offers local data regarding an architectural site survey. In the determination of the model components, the study related to structures of the location based augmented reality systems are taken into consideration [29], [39].

The current devices on location based augmented reality use hand-held or head-attached displaying. This model targets hand-held and head-attached devices to display local data while on the site. Hand-held displays come to the forefront with the widespread access, while head-attached displays provide a natural platform with hands-free working environment. For introducing the model, hand-held displays are used because of being widely available range from smartphones to tablets.

Augmented reality encompasses user interfaces that allow for interaction with digital content embedded into the physical environment of users. Information browsers, as an augmented reality user interface, provide to monitor and control information that is registered to the physical site. When the capabilities of the information browsers are taken into account, the facilities of the filtration and the radar are the significant tools during the display of the site. Consequently, information browsers are the most suitable interface type for this model and can be used without any experience. The design of the user interface in the model should be simple and user-friendly. Therefore, the interface needs to be organized based on the user, the environment and the data. The sample visualizations of the model in the use cases are kept as simple as possible.

Hybrid tracking based on GPS and inertial sensors is sufficient with the development of the model. Nowadays, mobile devices from smartphones to tablets are already equipped with GPS and inertial sensors. It also shows that these types of equipment are provided automatically by the hand-held devices. These display, interaction and tracking types can be used to realise this model.

4 Conceptual Use Cases from the Architectural Perspective

The use of the model is explained in detail to point out how this model works. According to local data requirements in architectural design and the potentials of the augmented reality, conceptual use cases are selected to explain what this model can provide from the architectural perspective. Their places are fictional and every use case focuses on easiness that is provided by the model. They are designed to show contributions of the model regarding common medium, data classification, spatial approach to data mapping, holistic view, data visibility, representations with time component, data analysis, taking note and sharing, helping architects and providing expertise in the site visit.

Before starting to use the model, the user should be ready on the site where local data to be observed. The model can be used on portable display devices, because of the need to move freely on the site. Initially, the model sends current location information to request the related local data. Then, local data is provided based on the selected categories to display on the site by scanning in a given field diameter corresponding to the current location. When the user looks at the site through augmented reality, surrounding local data is shown on the display device (Figure 3).

The model as being a common medium via augmented reality represents local data overlaid on reality. The model helps to present local data in the augmented environment without being in different environments for hardcopy or digital sources. This circumstance makes it easier for the user to focus on local data. The user observes all the virtual content directly with the real environment.

Fig. 3. User interface with tools of interaction for the model.

Without any classification and filtration, an explosion of data occurs in the augmented representation of the site. Though the user can access information from various categories, it is necessary to classify data in the model. Therefore, local data framework is used to manage data by the model. It provides local data under certain categories in accordance with the data classification required by the architect. In order to avoid getting mentally overloaded by viewing lots of content, the user should be able to choose the preferred local data from each category. The user can filter the local data by the selection of the categories on the provided framework. When the user selects a category in the model, all of the local data that are connected to this category corresponding to the location, are shown on the display device. The user can filter the local data by multiple selections of categories. The user also may choose specific categories to view the local data in a less crowded scene. This makes it easy to find out the content that the user is interested in. It clearly shows that filtering is an important tool to obtain effective data for the model (Figure 3).

The selection of each data is carried out on their icons or short descriptions by tapping or gesturing it to depend on the display device. Each category can be described by a specific icon that is a representative thumbnail image in the model. When the user selects a category to bring the content, a detailed view of the local data is overlaid on the screen. This detailed view can provide various types of contents to explain the associated local data. The types of content can be text description, 2D image, 2D video, 3D wireframe, 3D data, 3D model, 3D animation, audio, and so on. In addition, content can consist of many media types like text descriptions and 3D models to describe the local data. Thus, the user can access further details related to the selected local data. If needed, a translucent background can be used to draw attention to local data. Besides, different colours can be used by the model to provide the visibility of the interface. In order to see other local data, the user can then bring back the category filtration screen.

The model enables a fully interactive augmented environment that allows the user to navigate in the real environment. Instead of being fixed to an environment, the augmented reality encourages users to move freely within the space. In the model, data visibility is provided firstly by the user's perspective of view. Besides, the model presents local data around the user according to the field of radar which is controlled over the interface. Changing the field diameter is useful for displaying local data among the crowded data (Figure 3).

The model provides a spatial approach to data mapping on the physical site. There is a strong need for 3D representation to visualise the data in a proper form. The model breaks the constraints imposed by 2D representation, moving toward 3D representation of the environment. For this model, a particularly important aspect of the augmented reality is its ability to make the user feel naturally surrounded by local data. The model can give users powerful new ways to observe relationships and connections between the local data. Augmented reality is able to display integrated views of local data in a spatial context. Figure 3 shows the mapped data in 3D form of the representation within the model. Moreover, 2D representation of the properties can be visualized by changing into a map mode in which each local data is presented 2D. Through its map mode, the model allows the user to explore local data on the map view in case of need by holding parallel to the ground plane (Figure 4).

Fig. 4. 3D & 2D representations on the model.

In addition to working on the site, the model can also record during the site visit and afterward display local data with the site. Local data can be taken from the site to use in design through the model. The data to be considered in the design can be marked among the local data presented in the environment. Besides, the user can take location based notes, photographs, and so on to add data or comments. Thus, the user also can share added local data with other users through the model.

As a sample to architectural use of the model from the site, topographical contour lines, and legal boundaries can be visualized on the site. Generally, architects take drawings of the site from the local municipality to consider height changes and boundaries of the site. Then, architects need to interpret these heights and boundaries for their designs without breaking the relationship with the site. Architects can have a printed copy of the site drawing with them during the site visit, otherwise they wait for working on the digital format of the site drawing. This model can present height changes and boundaries from the digital drawings that can be provided open access by the local municipalities or national government databases. It can draw topographical contour lines from height points in a computational process (Figure 5).

Fig. 5. Visualization of topographical contour lines and legal boundaries via augmented reality.

When evaluating the site from the architectural perspective, the use of the surrounding area and the built environment must be taken into consideration. Therefore, the architect firstly checks the current state of the surrounding area and the built environment through the site visit. Although it is important to observe the site with the current state, it does not provide comprehensive data for the architect. It is necessary to obtain the city development plan that contains the data of the existing structures from the related municipality or its web service. This model can present land use and built environment data by covering the view of the site (Figure 6). The user of the model can easily evaluate the current state providing data for architectural design. In this model, the scope of the databases that are used to provide the data is important, because it may be restrictive on data. For example, it may be comprehensive enough to provide data about the residentials on a building block for architects. Therefore, municipalities and government agencies are important in providing such data.

The presentation of local climate data can be provided through the model for the architect while on the site. When the user selects the climate category, sunbathing and prevailing wind direction data can be visualized on display. Besides, graphical comparisons based on annual periods such as temperature, daylight, precipitation and humidity can also be presented to the user from related databases (Figure 7). The databases of meteorological research institutions can be used to obtain such climate data. By observing and considering climate data on site with the use of this model, the architect can develop design decisions against natural conditions such as sun and wind effects.

As an example of the effective use of natural data, this model can provide detailed data about the vegetation. Taking advantage of the natural vegetation of the environment is important in order to act respectful to nature and to increase the comfort of the building. In this context, the model can present data of the local vegetation to the user while on the site (Figure 8). In addition, if there are specific trees in the site where the design is to be performed, the model can provide in situ data about these trees by matching from the database. These are possible with the databases of national government agencies or universities that conduct inventory studies on the natural environment.

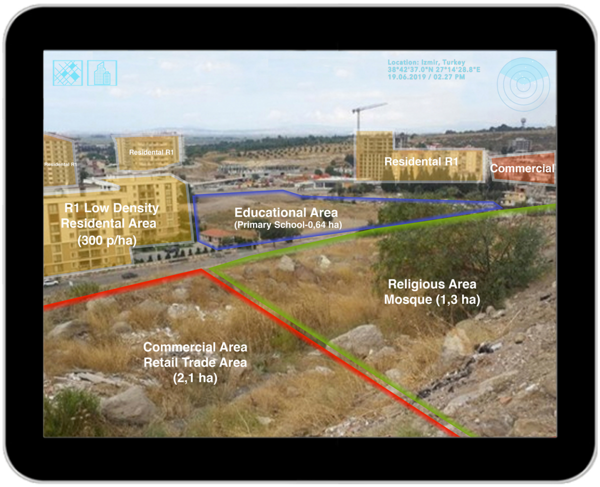

Fig. 6. The presentation of land use and built environment data on site.

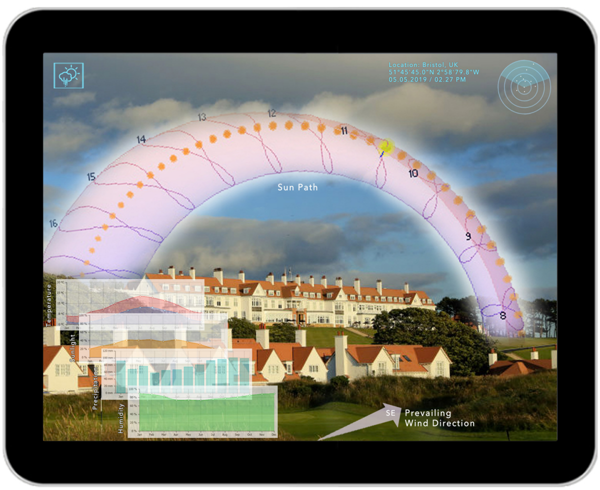

Fig. 7. On site access to local climate data with the use of model.

Architects do not always design in new urban development areas. Most of the time, architectural design needs to be carried out in areas of cultural importance in specific contexts. In this case, the architect must obtain data about this context. The building components which are used in the architectural design may be determined for the preservation of areas under specified inventories. Besides, the architect may keep using the cultural context of the area in order to maintain integrity in the environment.

For such a work, it is necessary to investigate the current local data extensively. As shown in Figure 9, the local door and window styles can be displayed via the model on site. In addition, the windows or doors on the existing buildings can be matched from the library of the local door and window styles with the image matching structure that can be developed in the model. With the help of this matching system, architects can easily experiment and decide about architectural design components, materials, and general adaptation of new building with the existing building at the site. That kind of approach gives architects decision making opportunities in urban form, building façade, and opening/solid ratio in the design as soon as the architect visits the area. Moreover, the matching system can collect other similar inventory from the database and show them for use.

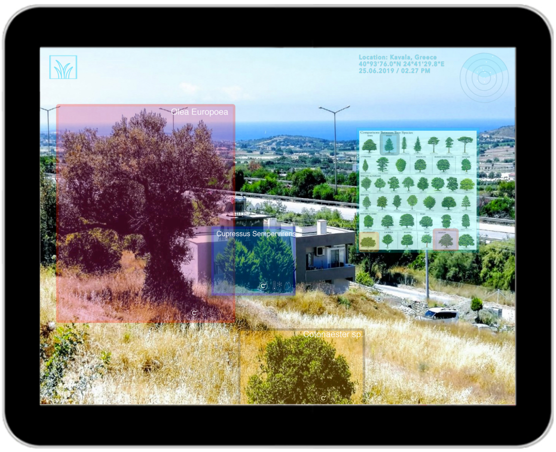

Fig. 8. The presentation of local vegetation data on site.

Fig. 9. View of the local components of the buildings.

This model especially supports interaction with the properties of a physical site that do not have a natural or perceivable visual representation. The user can also focus on the invisible properties of the site beyond the visible properties. For instance, subsurface infrastructure elements can be superimposed into the view of the user. Figure 10 shows a subsurface infrastructure of the city that contains natural gas distribution shafts, electrical cable shafts, internet cable shafts, sanitary shafts, and future infrastructural shafts which are projected but not built yet. In the representation, information of subsurface infrastructure shaft can be obtained by local municipal authorities. It also gets infrastructural information from transportation ministries, private companies about energy, internet, or heating. Therefore, architects can easily get data about provider opportunities and designing details about infrastructural usage. In another example in Figure 11, the model can provide local flood data of a site that occasionally live flood emergencies. By the vision of that, architects can get architectural design decisions with the data of annual flood levels. These data can easily be collected and then provided by institutions about natural reservations and disasters. This kind of data augmentation of local environmental characteristics saves the architectural design from fatal mistakes.

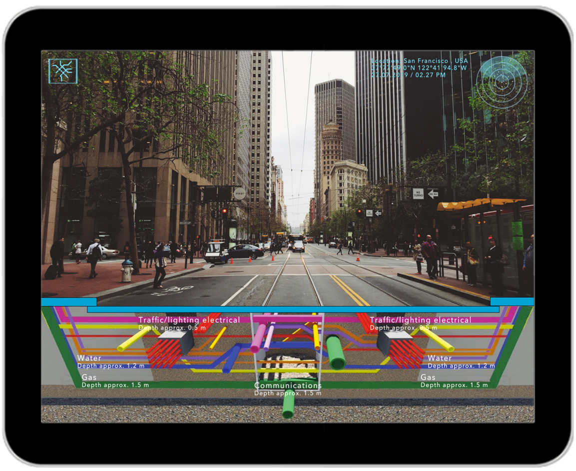

Fig. 10. The representation of invisible properties on site.

The model provides glimpses into the temporal dimensions of the site. The users are able to view the historical elements and planned projects on site via augmented reality. As in Figure 12, the model can expose archeological conservation areas under sites that are selected by an architect or a construction company as potential construction areas as soon as the first site visit of the architect. Such a scenario makes architectural design easier for the conservation of the archeological sites and the design of the site plan from the very beginning of the work. These data can be obtained by the councils of conservation of cultural and natural properties, and local universities. Moreover, the model can allow users to view the old images that are matched to their locations, virtual reconstructions of historical elements onto the historical site.

Fig. 11. Visualization of flood data on site.

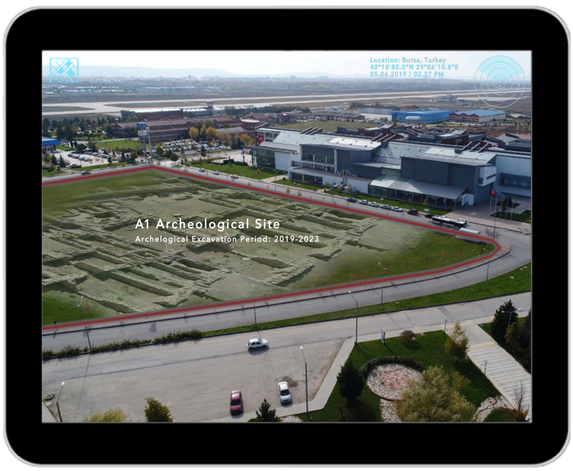

Fig. 12. Exposing archeological conservation areas with the use of the model.

Figure 13 shows an example of how local data can be presented with the time component. Recently developing BIM systems can also be used as design documentation and delivery of the projects to the local municipalities or national authorities. Additionally, BIM systems can be used for programming the construction stages upon financial or developmental projections. Therefore, municipalities can easily upload projected data of the city, such as projected architectural designs of the buildings, to the system and model can easily share this information with other user architects. This kind of access provides architectural design data by projected building to the architects of other surrounding projects. For instance, when the architect starts to check how the other buildings impact the view from the site, the architect can realise that a new building totally blocks the view of the site in future planning with the use of this model. While on the site without losing time, the architect is therefore forced to reevaluate the position and orientation of the design according to the local data.

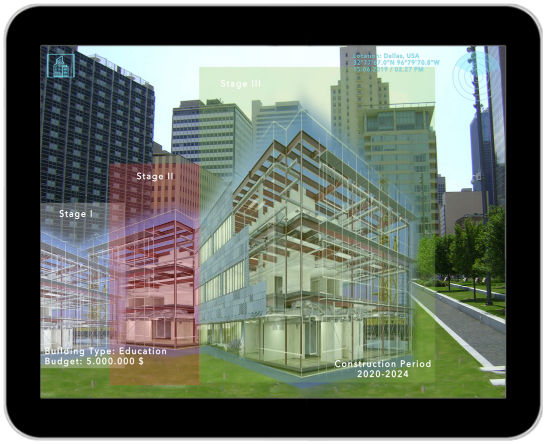

Fig. 13. BIM based local data with time component.

The model can help architects to provide interpreted local data of the site. Especially for architects as an example, legal regulations that generally require a translation from regulation to 2D plan can be shown on the site in 3D visualization via augmented reality (Figure 14). Moreover, users may need knowledge about various elements from different fields and learn relevant knowledge with this model. The model can provide expertise from related fields such as civil engineering and geological engineering.

Fig. 14. Helping architects with interpreted local data.

This model puts in order local data that can be used during architectural design by responding to the natural and cultural context of the site. It is presented as a conceptual scenario of how local data can be used in architectural design through augmented reality. This model facilitates greater awareness especially when it is used during the architectural site visit. It enables users to more profoundly explore the site by interacting with local data. The use of augmented reality can make a decisive contribution to collect and analyze the local data, thereby encourage users to consider the surrounding context.

It is necessary to analyse local data for architectural design, and the model can provide local data directly on the site. Users can gain an extensive contextual understanding of the site during the site visit by knowing outcomes. With the use of this model, site analysis can be obtained without losing time in any research process on the site where the design is to be performed. Thus, the architect can highlight the analysis of the local data that is considered important in the design process. It allows the architect to make strategic decisions about the design is to be realised.

5 Conclusion

The general priorities of the architectural design related to the site are to get a sense of the physical site, find patterns, and discover new insights about the physical location and its characteristics. This study introduces a model that can help architects to understand the spatial impacts of the surrounding context better. Focusing on the data need of the architect during the site visit and site analysis before starting a conceptual design, the model provides data on site according to the local data framework through augmented reality. By considering the necessities of local data in architectural design, the potentials of location based augmented reality are utilized in the development of this model. Using such a model for the exploration of the site supports the architect about common medium, data classification, spatial approach to data mapping, holistic view, data visibility, representations with time component, data analysis, taking note and sharing, helping architects and providing expertise. As local data can be made easily available within the context of the site, architects can carry out site survey more effectively and efficiently. This model has potential to be the base with the local data framework to the applications of architectural design in augmented reality. It presents a medium around the user in order to be aware of surrounding conditions accordingly to the current local data.

As an important limitation, there is no integrated database that provides access to all data classified in the model. Therefore, data must be obtained from different databases and these databases vary by country and its organizations. Within the scope of the study, it is emphasized what kind of data acquisition approaches can be used rather than where data can be provided. It is necessary to link the model to existing databases that contain all the necessary information associated with the site. With developing technology, existing databases are not the only data source. Different methods that allow accessing data such as big data, crowdsourcing, data mining, IOT can be used for the model. The use of these different data acquisition methods may provide data analysis even more easily for augmented reality applications.

Moreover, the model can be moved one step further with the change of working styles. It is possible to widespread acceptance of the platforms and tools to design on site beyond designing at the office environment, in the near future. This model with the improvements to be realised can also allow the user to design on site interactively with local data. Thus, it can serve as an in situ design platform for architectural design. Besides, the structure of the model which is intended only for a single user to observe local data, can be transformed to design facilities on site for multiple users. It is also possible to improve model components to access more comprehensive data. In this context, drones can be added to model components for a better field view. In this way, the user can observe the site with local data from different heights and more dominant positions.

In terms of architectural perspective and technical structure, the study has been put forward in detail to be applied as a model. The realization of the model as an application is not covered in this study. It can be carried out with long-term work under a scientific research project and it needs a team working in interdisciplinary structure both in architecture and computer fields.

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