VR-Herbarium Application: The Case of KATO Herbarium in Karadeniz Technical University

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Abstract

It requires a significant amount of time, money and effort to visit institutions containing different collections in different parts of the world, for many reasons such as transportation, visa, and research permit. In this study, it is aimed to develop a virtual herbarium with both mobile and browser support, which will enable to access the panoramic view of the herbarium and the visual and botanical characteristics of the herb samples in the herbarium. Karadeniz Technical University Faculty of Forestry (KATO) Herbarium, established in 1973 and registered in the International Herbarium Index, was chosen as the study area. The virtual herbarium (VR) KATO application was carried out in three stages: production of panorama images of the herbarium, creation-connection of the database and programming of the application. Within the scope of the study, a database containing the botanical features and images of 20 herb samples in the herbarium was also created using the MongoDB Atlas connection, and a dynamically-updatable herb library was presented to the online visitors. This study is a pioneer with the concept of virtual reality and a distinctive example of mixed reality technologies' usage in the forestry discipline. Besides that, the study is a unique example for different fields related to forestry, which contains different libraries such as flora, fauna, endemic species, and national parks, and for other sectors.

1. Introduction

The concept of virtual reality (VR) was introduced by Jaron Lanier in the 1970s, and it has also been used by different terms such as cyberspace, artificial reality, virtual world or virtual environment over the years [14]. VR can be defined as giving a sense of existence to the mind of the person in a three-dimensional virtual environment created by a computer and enabling him to interact with the objects in that environment [21]. Parallel to the development of computer technologies, the use of VR applications has become widespread in many different fields such as medicine, engineering, architecture, sports, education and tourism. There are usage areas such as visiting around or inside the buildings designed in architecture, practising industrial devices, and giving virtual war training in the military [26]. In the education sector, there are benefits of use for all students, especially students with special needs, such as experiencing the real world, practising dangerous tasks safely, and providing instant and consistent feedback [18].

Visiting institutions which have various collections such as museums, libraries and herbariums requires a notable amount of time, money and effort. In recent years, the pandemic disaster, economic crises, the difficulty of obtaining a visa to some countries, and the need for special permission to enter the institutions or to examine the objects make it difficult to visit these collections and collect data from them [1]. Additionally, the examination of the collection parts by different people could cause damage to the objects. This situation causes less sensitive new research on the objects and challenges about research permissions. Therefore, it is important to develop virtual surveys in order to allow examinations to be made without touching and deforming the relevant objects.
Herbariums are a kind of museum where various herb specimens grown in different regions are placed according to certain systematic categories. These centres are environments where dry herb samples are collected according to certain rules, labelled and stored in order by keeping their attributes on cardboard [9]. Herb labels include various information such as the Latin name of the herb, the place of collection, the time of collection and some other features. In this aspect, herbariums are places that bring together time and space, give an idea about the changes in the external morphological (leaf, stem, seed, fruit) characteristics of herb species and allow for the comparison of herbs [27]. Herbariums are generally established to diagnose and classify herbs, learn where and when the herb grows, and provide specimens when it is impossible to reach the herb [6]. Herbariums also have purposes such as providing material for morphological and floristic studies conducted in many branches of science such as Taxonomy, Palynology, Archaeology, Biology, Medicine, Pharmacy, Agriculture and Forestry, and also providing information about the phenology, distribution and location of herbs [24]. Wallich (Kew), Edinburgh (Scotland), Berlin (Germany), Leningrad (Russia), Paris (France), De Candolle (Geneva-Switzerland), Clifford (British Museum) and Genova (Italy) herbariums can be assumed as the most known ones. In Turkey, there are approximately 60 herbariums, either individually or in different institutions [28]. 37 of these herbariums are registered in the International Herbarium Index (Index Herbariorum) [23].

Many institutions that host private collections have started to create websites where textual and visual information about the objects in their inventories are presented digitally according to the actual technology. Digitization is the digital representation of a collection by converting the data about each object of the collection into an electronic format [15]. Digital or virtual herbariums containing label information and images of herb samples were started to be established in various countries about 30 years ago [3]. The major herbariums that have a digital database are Australian Virtual Herbarium, Kew Royal Botanic Gardens, Canada Colins Herbarium, New York Botanical Garden Herbarium, Netherlands Virtual National Herbarium and Charles Sturt University Virtual Herbarium. The Global Biodiversity Information Facility (GBIF) data portal has also digitized records of more than 500 million herb samples [12]. Thiers et al. [22] analyzed in detail the digitization process of the William and Lynda Steere Herbarium of the New York Botanical Garden (NYBG). The digital herb databases in Turkey are Turkey Herbarium Database (TUBVET), Turkey Central Herbarium Database (TURKHERB), Turkey Herbarium Data Service (TUBIVES), Turkey Labiatae Database (TULAB), Turkey Endemic Plants Database, Turkish Folk Medicines Database, Turkey's Spore Plants Database (TURKKIRP), Turkey's Transmission Bunch Plants Database (NOMVET) and Turkey's Freshwater Algae Database (ALGVET) [2, 8]. IZEF Herbarium, Turkey's first interactive herbarium, makes it possible to access images of herb samples [17, 7]. The other visually supported interactive herbariums in Turkey are Van 100. Yıl University Herbarium, Gazi University Faculty of Science Herbarium (GAZI), Istanbul University Faculty of Forestry Herbarium (ISTO), İstanbul University Faculty of Science Herbarium (ISTF) and İstanbul University Faculty of Pharmacy Herbarium (ISTE) [16].

In digital platforms where there is no VR environment, the interaction of the user with the information is limited to the functions provided by the platform interface. Hence, it is not possible to present a sense of depth and environmental control similar to the real-world view that can be provided by VR in such
traditional digital environments [11]. By the virtue of VR applications, researchers can access the data they need for their study via computers or mobile devices and conduct one-on-one examinations [25]. Researchers can carry out their research faster, economically and with less effort without the need of going to the relevant institution and contact directly with the objects.

The aim of this study is to develop both a mobile-based and a web-based virtual herbarium that will enable a 360-degree view of the various herb samples in the herbarium on both desktop and mobile devices. As a result, users will be able to log in from their phone or computer without going to the herbarium, feel themselves inside the herbarium and examine the herb samples. The database connection in the developed application also provides the opportunity to search for herb samples in the herbarium. In this interactive system, the characteristics of the new samples included in the herbarium can be directly queried and accessed by saving them to the database. Besides, online herbarium visitors have the opportunity to easily share their observations and comments on the application.

2. Methodology

Within the scope of the study, KATO Herbarium, located in the Karadeniz Technical University (KTU) Faculty of Forestry, was chosen as the research area (Fig. 1). KTU Faculty of Forestry is located in Trabzon province, on the northeast coast of Turkey.

KATO Herbarium was established in 1973 and is registered in the Index Herbariorum. The herbarium ranks 13th among herbariums in Turkey with 23,240 herb specimens. The herbarium, which consists of a preparation room, drying room and 3 sample storage rooms, has a total area of 300 m². Herb samples are dried by artificial drying method and sample labels of 300 mm*430 mm are kept by sticking them on cardboard with masking tape. The dried samples were placed in 37 wooden cabinets in the storage room according to the Flora of Turkey and The East Aegean Islands system. Sample labels include the family, genus, species and habitat characteristics of the herb samples, the location where they were collected, the collector person, the identifier person and the herbarium sample number. KATO Herbarium offers the opportunity of studying herb samples to visitors who are researchers, graduate or undergraduate students from different institutions and different disciplines.

In order to be transferred to the database of the developed application, 20 of the herb samples in the herbarium were selected, photographed and uploaded to the Amazon S3 Bucket cloud service (Fig. 2).

To obtain a 360-degree panoramic view of the herbarium in a virtual environment, photographs of all rooms in the herbarium were taken with a fish-eye lens-mounted smartphone. Afterwards, these panoramas created using Panoweaver 10.0 software through fish-eye photographs were transformed into a VR application via the Unity game engine and C# programming language. Unity game engine has been chosen in VR development because it can be used for cross-platform output to various platforms such as browsers, Android, iOS, Windows or PlayStation, and facilitating the user movements required for VR [10].
A herb search function was also created by using the MongoDB database connection. This function allows online visitors to search and view herb specimens collected in the herbarium through a dynamic database.

2.1. Application Design

The process of the VR Herbarium development consists of three main stages: producing the panoramic views, creating the database and providing the connection, and programming the application (Fig. 3).

2.1.1. Producing the panoramic views

Photographs of the physical structures of the herbarium, such as corridors and rooms, were taken with a fish-eye lens, and were used to produce the 360-degree panorama of the KATO Herbarium. Stereoscopic overlap of images is provided with a fisheye lens [19] (Fig. 4).

Correct overlap of images, in other words, correct warping and stitching of images require the precise selection of conjugate control points (CPs) located in the overlap regions between images. Panoweaver 10.0 software was adopted by the virtue of its user-friendly interface for selecting CPs and performing the stitching process [29]. The distribution of CPs and the balanced propagation of the error in the stitching process can be achieved by ensuring that the distribution geometry in the overlap regions is as homogeneous as possible [13]. Panoweaver 10.0 software makes it possible to calculate initial CPs using feature detector algorithms such as SIFT or SURF [20]. The software also allows the user to correct CPs or add new ones. Distribution geometries and matching of conjugate CPs are illustrated in Fig. 5.

The white dots in Fig. 5 show the CPs between the overlapped images. H is a homography matrix containing the transformation parameters required to stitch the right image to the left image [4]. On the bottom line of the figure, the panorama obtained after stitching could be seen. Using these CPs, the images were warped and stitched to form a wholeness inside of a spherical surface and a panoramic view of the imaged environment obtained (Fig. 6).

2.1.2. Creating the database and providing the connection

Within the scope of the study, an online database was created which includes attributes and images of 20 herb specimens in the herbarium. The attribute fields of this database and the data types of these fields are given in Table 1.

Tablo 1. The attribute fields of the database
Images in the database were provided by taking photos of herb samples and transferring them to S3 Bucket Cloud Service. Some characteristics of the herb samples such as family, genus, species, the location of the place where they were collected and the collector person were determined and transferred to the database by using the labels affixed on the samples and, when necessary, the literature review. Hence, besides the VR tour, a herb library that can be automatically updated using the MongoDB connection was also served to the online visitors (Fig. 7).

Using Atlas, the cloud-based system of MongoDB, MongoDB documents can be directly mapped to dictionary objects in any programming language. Choosing MongoDB as the database system is in consequence of its providing JSON-like (JavaScript Object Notation) document structure and schema-free development (Fig. 8). This flexible structure also allows records with different attribute fields to be found in the same database document [5].

2.1.3. Programming the application

The coding of the application used in the creation of the VR herbarium was carried out by transferring the panoramas to a new Unity project. Here, the camera was defined as a game object to allow users to view the environment. A game object is a 2D or 3D solid object [30] that contains the code files required for game physics, textures, scene transition or in-game progression (Fig. 9).

Following the definition of the camera, a sphere that contains the camera in the middle of itself was defined. The panorama was placed inside the sphere surface to allow the user to see the panorama after the application has been launched. This sphere identification was repeated for each panorama (Fig. 10).
The scene transitions between the spheres were executed by the scripts that were written in C# programming language. The scripts could be found at https://github.com/alpertungakin/VR-Herbarium. For triggering the scripts, a trigger object should be defined inside the spherical surfaces. If the user shooter focuses on this trigger object, the trigger script runs and the scene transition happens (Fig. 11).

The same triggering process happens to gather herb information according to the relevant locations onto sphere surfaces. If the user focuses on a herb cabinet on the panorama, the trigger script runs and the herb information and the herb image associated with the location of the cabinet appear on the user screen (Fig. 12).

After the development process, the application was exported to run on a cloud server. Since Unity is a cross-platform development environment, the target platform can be many platforms like browsers, Android, iOS, and Windows. The application developed within the scope of the study can work both as a web page in the browser and on smartphones with the PWA concept without the need for any further update or installation. The user interface of the application is shown in Fig. 13.

The herb library created with MongoDB Atlas was presented from a web interface as an addition to the virtual tour application. In this interface, there is a list of herbs in the herbarium, an information panel that displays the information and photo of the selected herb, and a map panel that shows the location where the herb sample was collected on the satellite image (Fig. 14).

The web mapping library Leaflet.js was used to acquire the base satellite image and to display the data retrieved from MongoDB Atlas [31].

3. Result And Discussion

This study covers the application of VR, one of the current trends in the digital presentation of information, in the KTU Faculty of Forestry KATO herbarium case. When users visit this developed application it is possible to visit the herbarium by viewing the physical facilities of the herbarium panoramically, such as the corridors and rooms, and to access some features and visuals of the herbs by opening the cabinets containing the herb specimens they want to examine. The rooms and corridors inside the herbarium can be viewed in 360 degrees using the panoramic views obtained from the photographs taken with the fish-eye lens, and the visitors can feel themselves there. The VR herbarium KATO makes difference from the existing digital herbariums where only the features and visuals of herb samples are presented. Thanks to the developed virtual herbarium, researchers and students from all over the world feel like they are inside the herbarium, and they are able to travel around and access the features and visuals of herb species. This opportunity makes it possible to present information about herbs to the use of society by providing both financial gains and saving on time.

During the development and testing of the application, an experimental database containing 20 of the existing herb samples was created. This database was turned into an online dynamic herb library that can be updated automatically via MongoDB Atlas connection. With this feature, the characteristics of
both the existing herb samples and the newly-added herb samples can be easily accessed on the database.

Thanks to the application’s being web-based, users can access the VR herbarium from anywhere with an internet connection, either with mobile devices such as mobile phones or desktop internet browsers.

This study is a pioneer in the use of the forestry discipline with the concept of VR and sets an example for the use of augmented and mixed reality in the forestry discipline. The study is also a model for different fields related to forestry, which contains different physical information collections such as flora, fauna, endemic species, national parks, and other sectors.

In the future, it may be possible to enhance the user experience by adding all of the herb samples from the herbarium to the database, scalability of the server where the application is hosted, and response time optimization. Furthermore, images of the physical structure of the herbarium taken with a smartphone camera and fisheye lens could be replaced with high-resolution 360-degree camera images which can increase the sense of reality that users will experience.

Declarations

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Author Contributions: A.A.T and A.K.C. performed application development processes and prepared figures. A.A.T, A.K.C. and U.S. wrote the main manuscript text collaboratively.

References


28. URL-3: https://tr.wikipedia.org/wiki/T%C3%BCrkiye%27deki_herbaryumlardan_listesi

Figures
Figure 1

The location of KTU Faculty of Forestry KATO Herbarium
Figure 2

A few of the selected herb samples
Figure 3

The overall workflow of the development
**Figure 4**

Image overlays in cardinal directions
Figure 5

Distribution geometries of CPs and stitching of the images [4].
Figure 6

Fisheye images and a panorama from these images

Figure 7

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Figure 8

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Figure 9

A camera object and its preview
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Figure 11

3D “Entrance Hall” text (a) and another panorama (b) when focusing on the text “a”.
Figure 12

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**Figure 13**

The user interface, home page

**Figure 14**

Information panel (a) and map panel (b) of the herb library