INTEGRATION OF UNMANNED AERIAL VEHICLE DATA WITH GEOGRAPHICAL INFORMATION SYSTEMS

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ABSTRACT

Unmanned Aerial Vehicles (UAVs) are successfully used in many different fields such as military, forest fire, archaeological sites, agricultural applications, traffic control, radiation monitoring, natural disasters, urban management etc. At the same time, UAVs are extremely important tools for achieving accurate and up-to-date information quickly and economically. Today, UAVs can stay in the air for up to about 3.5 hours, and during this time they can take in aerial images that can produce ortho-images of an area of about 15 square kilometers. All of these features make UAV the tool of professional land surveying and ortho-image production that is fast, accurate and easy to use.
The most important basic component in Geographical Information Systems (GIS) is geographical data. UAVs which produces this data quickly and accurately, are one of the most important data collection methods. In recent years, it has been utilized effectively from the production of ortho-images used as basic data in GIS. In this study, the data obtained from the UAV at the study area of Cumhuriyet University Campus (Sivas city, Turkey) were evaluated with the photogrammetric data evaluation software Pix4D and the Digital Terrain Model (DTM) and ortho-images were produced. By interpreting these products, geographical layers such as buildings, electric poles, roads and manholes related to the campus were created on the GIS environment and the infrastructure of the Campus Information System (CIS) was established. Thus, a inquirable and analysable GIS-based system has been created to contribute to the management and planning activities to be carried out on the campus. As a result, UAV photogrammetry is a fast and easy to get economic geographical data for GIS-based studies, and is a tool for updating these systems in efficient times to provide effective and productive results and updates to information systems.

Keywords: Geographical Information Systems, Unmanned Aerial Vehicles, Campus Information System

INTRODUCTION

UAV systems developed so fast over the last decade, it is now placing classical photogrammetric and remote sensing methods efficiently. Not only they are used in strict applications, but also in a variety of fields like agricultural applications [15], surveillance missions [9], aerial monitoring [8], cultural heritage [11], cadastral [7] applications etc [19]. UAV systems have enabled easy, autonomous and low cost acquisition of aerial

photos. Researchers have worked on reliability of these systems for over a decade. Now, still with some issues they are used in a variety of fields as a first hand data acquisition systems.
An UAV system usually consists of related payload, a ground control station for mission planning, real time navigation and communication link between station and vehicle [3]. They require no onboard pilot and can maintain a flight pattern above ground [12]. According to the size of the UAV, there are various launching methods like air, handheld, mechanical and autonomous. Technological improvements in Global Navigation Satellite Systems, digital cameras (pref. consumer digital camera types) allowed smaller UAV to be used in various applications. Eisenbess [5] and Blyenburgh [16] provided valuable reports about UAV classifications. Not only camera sensor are applied to UAV systems. There are also measurement devices like Light Detection and Ranging (LiDAR) scanners [14], Synthetic Aperture Radars (SAR) [10] that can be applied to UAV systems but due to their cost, weight and size, they remain challenging in most ways.

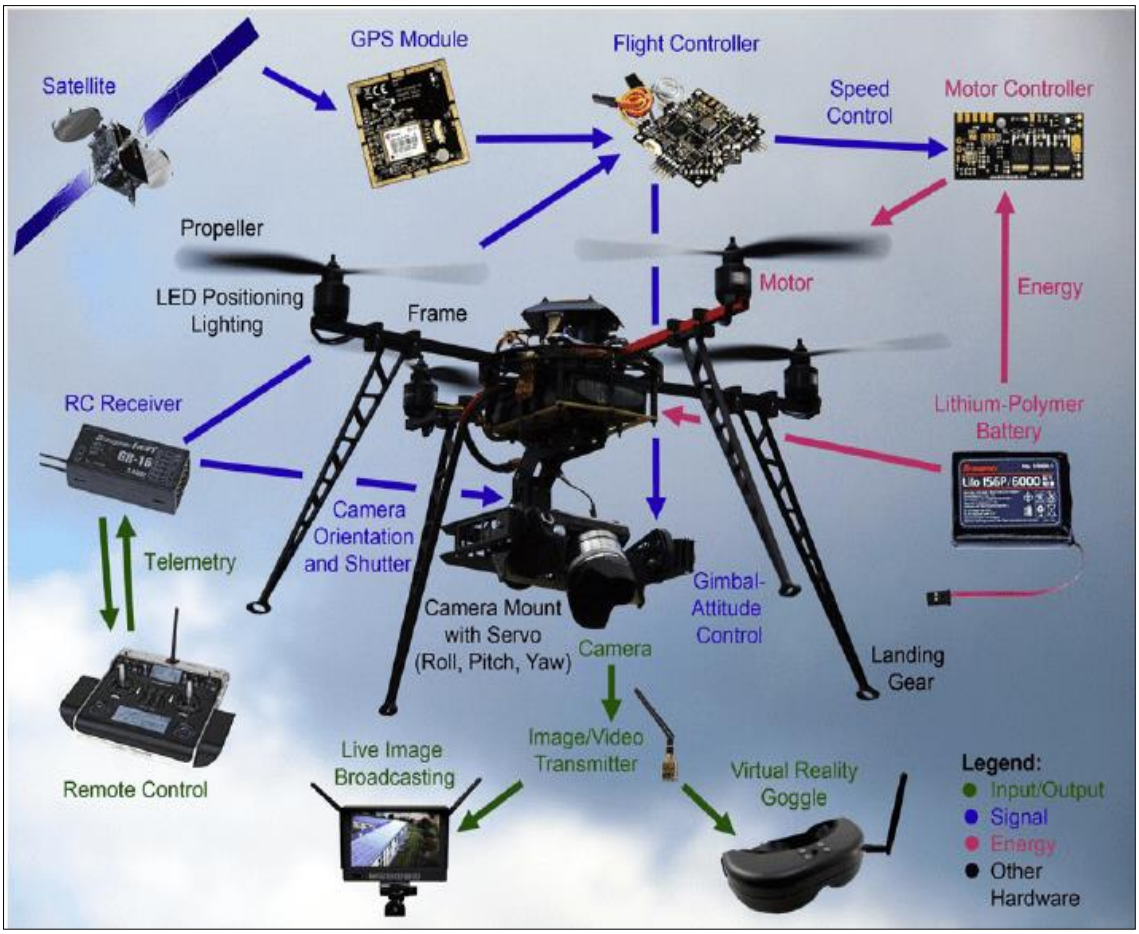

Figure 1. UAV Payload [17]

CIS of a university consists of geographical and non- geographical data of the study area. The main use of CIS is to store, query, analyze and present this data to the user with various formats (ie. Charts, reports, maps etc.) [2]. With the design of a CIS, personnel and facility management of a university and also creating plans for the future would be based on a real time based system that can be updated and analyzed at any time desired. There are a lot of previous works about CIS. Aydınoğlu & Yomralıoğlu [2] and Kahraman

et al. [6], published web based campus information systems in their studies. Asif & Krogstie [1], created a campus-wide information mobile system that provides user-centric information to students.
In this study, it was aimed to create the infrastructure the CIS of Cumhuriyet University of Sivas Province, Turkey by integrating with GIS of data obtained from UAV. Thus, queries, spatial analyzes and documentations can be performed quickly and effectively on the CIS environment.

MATERIALS AND METHODS

The UAV flight mission consisted of 1170 images, also covered approx. 681 hectares. C Astral Bramor model UAV system was used in the study [18]. Nine Ground Control Points (GCPs) were used in georeferencing stage, Ground Sampling Distance (GSD) was set to 3.37 cm and a root mean square (RMS) error of 0.02 m for horizontal and 0.05 m for vertical was obtained. A detailed workflow of the study is given in Figure 2.

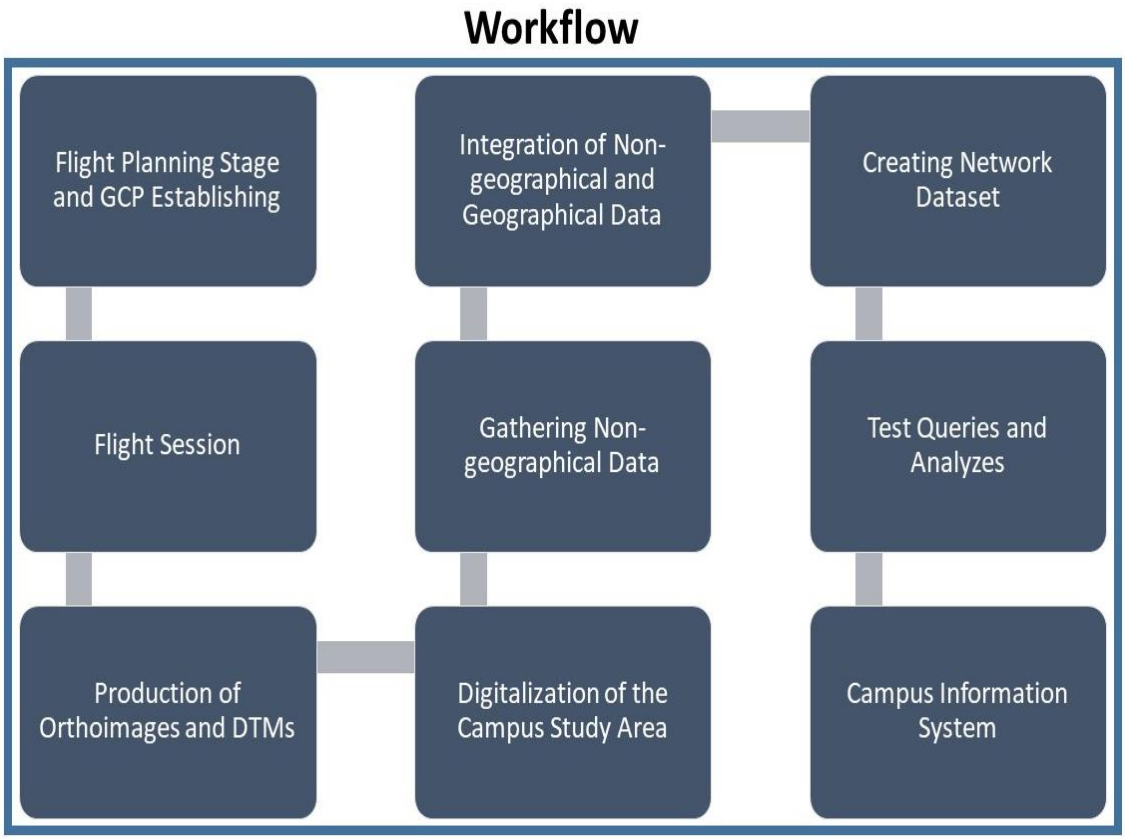

Figure 2. Study Workflow

Creating the infrastructure of CIS of the study area took around like 3 months. Flight session, GCP establishing and Production of Ortho-images and DTMs parts were completed in 15 days. Digitalization, non-geographical data gathering and the integration of geographical and non-geographical data stages were the most time consuming parts of the study, as it involves gathering data from administrative units, digitalization of the entire buildings with their room structures, roads etc., one-on-one integration between these data.

RESULTS AND DISCUSSION

The ortho-image of the study area was produced via data obtained from UAV (Fig. 3).

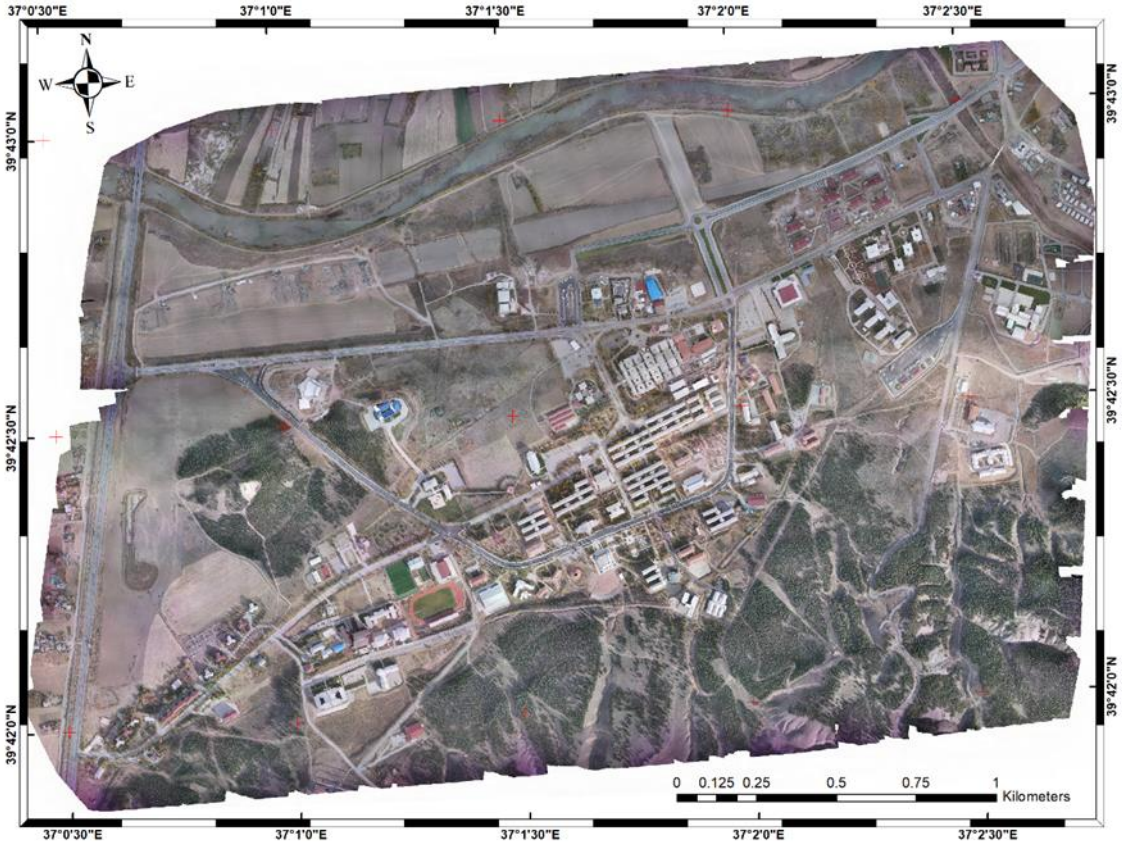

Figure 3. Orthoimage of the study area (Cumhuriyet University)

After processing stage of the raw images, digitalization process of the campus was performed. This process aims to create vector data of the campus area based on the ortho-images and DTM. Non-geographical data (ie. Personnel names, date of birth etc.) is then introduced to the CIS in order to make it available for queries and analyzes. This part is definitely the hardest part of this study. The UAV flight mission with its processing stage took about half a day. Digitalization of the campus, gathering administrative and educational data took months in order to be complete (Fig. 4 and Fig. 5).

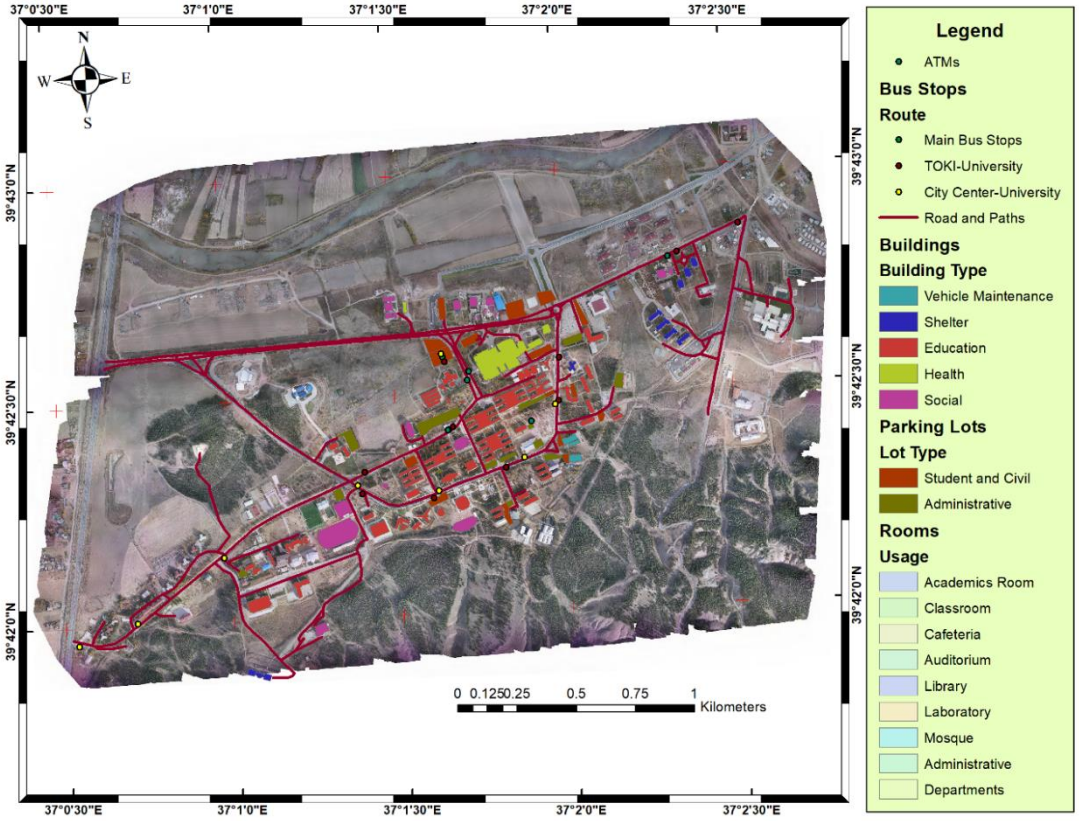

Figure 4. CIS infrastructure for Cumhuriyet University

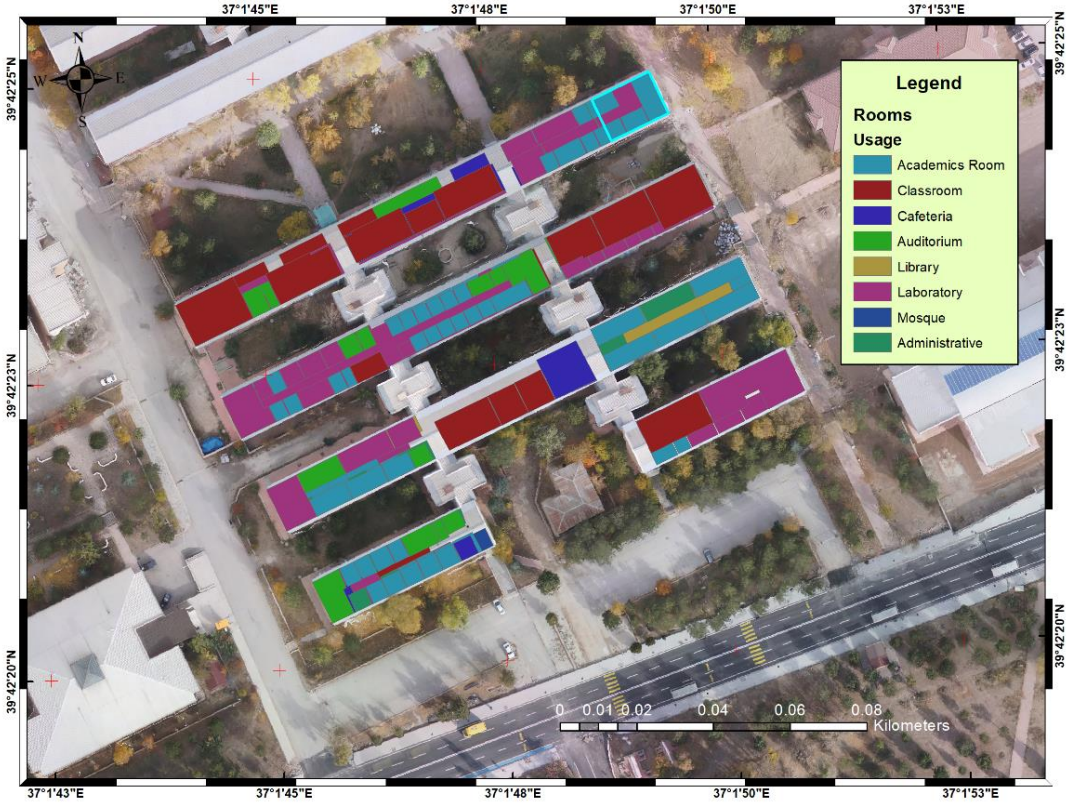

Figure 5. Detailed structure of a building

Geographical data was digitalized from the ortho-image. Non-geographical data was prepared as tables in order to be put into geographical data to make the CIS ready for queries and analyzes. Some examples of tables can be seen in Fig. 6. Note that tables were prepared in Turkish language in order to be presented in the native language. Also, not all the fields but some examples' text data is presented in the Fig. 6.

Academics

ID *	Title	Name	Surname	Research Field	Department Name	Room Number	Building Name	Global ID *
1	Yardımcı Doçent	Ercüment	AYAZLI	Kamu Ölçmeleri	Geomatik Mühendisliği	1018	Mühendislik Fakültesi A Blok	{7EDFE570-DEB6-4A94-89F3-DF6D75FCC516}
4	Yardımcı Doçent	Önder	GÜRSOY	Kartografya	Geomatik Mühendisliği	1027	Mühendislik Fakültesi A Blok	{5E7FBADD-193F-4D18-9819-66C197F8516A}
5	Doçent	Tarık	TÜRK	Fotogrametri Ve Uzaktan Algılama	Geomatik Mühendisliği	1030	Mühendislik Fakültesi A Blok	{8AFF9CA6-360A-45C1-BA3F-3BA2794DDD97}
6	Yardımcı Doçent	Fatih	POYRAZ	Ölçme Tekniği	Geomatik Mühendisliği	1031	Mühendislik Fakültesi A Blok	{4545F115-B743-4632-8908-5D2989DDB8C1}
7	Doçent	Kemal Özgür	HASTAOĞLU	Jeodezi	Geomatik Mühendisliği	1032	Mühendislik Fakültesi A Blok	{2A75EE70-44AA-49F9-9224-8308B5FCDBDF}
8	Yardımcı Doçent	Özgen	KANGAL	S.S.P	Jeoloji Mühendisliği	3019	Mühendislik Fakültesi A Blok	{F7CCCFFB-B27A-4317-8795-6F90682A799E}
13	Profesör	Nazire Özgen	ERDEM	S.S.P	Jeoloji Mühendisliği	3026	Mühendislik Fakültesi A Blok	{BFDBCF5A-B3A0-446B-926F-D297B7EB5370}
14	Profesör	Mahmut	TUNÇ	S.S.P	Jeoloji Mühendisliği	3027	Mühendislik Fakültesi A Blok	{F69D7F10-5DD3-4CFB-A380-F3DC008BB3F6}
15	Yardımcı Doçent	Mehmet	AKYAZI	S.S.P	Jeoloji Mühendisliği	3028	Mühendislik Fakültesi A Blok	{CE22E61A-6FD1-4876-9154-E6CE70903A63}
16	Profesör	Fikret	SELCİ	Yapısal Jeoloji-Tektonik	Jeoloji Mühendisliği	3029	Mühendislik Fakültesi A Blok	{40255406-BFD0-4632-81FC-9113436178E1}
20	Doçent	Nazan	YAKIN ERİK	Maden Yatakları Jeokimya	Jeoloji Mühendisliği	3038	Mühendislik Fakültesi A Blok	{6296BD58-ACF8-4560-940E-78768D0D2B31}
22	Yardımcı Doçent	Ahmet	EFE	Maden Yatakları Jeokimya	Jeoloji Mühendisliği	3044	Mühendislik Fakültesi A Blok	{DB273F90-E32B-42E1-88F9-320DC226D784}
23	Profesör	Osman	KOPTAGEL	Maden Yatakları Jeokimya	Jeoloji Mühendisliği	3045	Mühendislik Fakültesi A Blok	{2373F19D-3BA7-48CD-A5A9-74E3E5A01C8D}
24	Profesör	Ahmet	Gökçe	Maden Yatakları Jeokimya	Jeoloji Mühendisliği	3046	Mühendislik Fakültesi A Blok	{E8704A32-C55D-42BD-AF0E-20991A247EE4}
26	Yardımcı Doçent	Özlem	KAYA	Cevher Hazırlama	Maden Mühendisliği	3063	Mühendislik Fakültesi A Blok	{61EC69CE-E83E-47B6-8D36-182DFC9C6EE0}
29	Profesör	İbrahim	KULAKSIZ	Cevher Hazırlama	Maden Mühendisliği	3067	Mühendislik Fakültesi A Blok	{A4E5AD6F-1918-46E0-9E7F-1FDAEDCB8078}
35	Profesör	Nevzat	ASLAN	Cevher Hazırlama	Maden Mühendisliği	3074	Mühendislik Fakültesi A Blok	{F9738D23-CCDC-41A9-A245-FC40F676877F}
36	Profesör	Ünal	AKDEMİR	Cevher Hazırlama	Maden Mühendisliği	3075	Mühendislik Fakültesi A Blok	{B1E8AACC-139E-4C3D-B5C1-14FE8FB29DE4}
37	Profesör	Yakup	CEBECİ	Cevher Hazırlama	Maden Mühendisliği	3076	Mühendislik Fakültesi A Blok	{2B093EDA-B99A-4FD8-AB01-B77E3C287054}
38	Doçent	Uğur	ULUSOY	Cevher Hazırlama	Maden Mühendisliği	3077	Mühendislik Fakültesi A Blok	{5057D418-131B-4B84-B560-B8B77A73EE78}
39	Profesör	Meftuni	YEKELER	Cevher Hazırlama	Maden Mühendisliği	3078	Mühendislik Fakültesi A Blok	{F901DA24-E273-4164-AD7B-F40A53D0B149}
68	Profesör	Işık	Yılmaz	Uygulamalı Jeoloji	Jeoloji Mühendisliği	4002	Mühendislik Fakültesi A Blok	{8EB5E771-22B4-46B8-BF26-2F70632342F9}
69	Profesör	Mustafa	Yıldırım	<Null>	Jeoloji Mühendisliği	4006	Mühendislik Fakültesi A Blok	{7EB11976-FA5D-42F9-B072-ADAA8B6F1019}
42	Yardımcı Doçent	H. Ali	ERTAŞ	Makine Teorisi	Makine Mühendisliği	3083	Mühendislik Fakültesi A Blok	{1B3F896B-2BDF-4685-BC51-9E55D74F4931}
43	Yardımcı Doçent	M. Şemsettin	ÇİMEN	Konstrüksiyon ve İmalat	Makine Mühendisliği	3084	Mühendislik Fakültesi A Blok	{F34A5148-D04D-4AE5-B478-4886B651FCA3}
44	Yardımcı Doçent	Semiha	BULUT	Makine Teorisi	Makine Mühendisliği	3085	Mühendislik Fakültesi A Blok	{9A529E2E-0005-422B-B861-13266E1348EE}
45	Yardımcı Doçent	Adnan	ÖZTÜRK	Enerji	Makine Mühendisliği	3086	Mühendislik Fakültesi A Blok	{B12DA7BC-0A34-4B60-8D6D-B78FEF4609FE}
47	Profesör	Burhan	SELÇUK	Konstrüksiyon ve İmalat	Makine Mühendisliği	3091	Mühendislik Fakültesi A Blok	{ACD06067-D771-4D62-B381-1DD47437E0B1}
48	Profesör	H. İbrahim	ACAR	Termodinamik	Makine Mühendisliği	3092	Mühendislik Fakültesi A Blok	{C6172DA0-A91B-4214-980D-201003F3232C}

Departments

ID *	Department Name	Building Name	Year of Establishment	Number of Students	Number of Academics	Global ID *
45	Matematik Bölümü	Fen Fakültesi	1974	457	28	{7A86BB7B-3540-4205-9A69-1EDCDB3FC69F}
100	Cerrahi Tıp	Tıp Fakültesi	1974	<Null>	151	{7BC13A24-B688-4E62-89B0-3A78FB364B6E}
101	Dahili Tıp	Tıp Fakültesi	1974	<Null>	215	{1AB9B41D-D593-4CFE-BB28-A4D53FD1D58E}
102	Temel Tıp	Tıp Fakültesi	1974	<Null>	51	{6274D297-40BC-45FE-9304-C07F1FAB855A}
27	Tarih Bölümü	Edebiyat Fakültesi	1978	583	12	{34274D68-E9E5-4AED-B0F2-5C7FA968E046}
26	Sosyoloji Bölümü	Edebiyat Fakültesi	1980	684	15	{E10EE311-B1BD-41E5-B431-D461192AC24F}
19	Fransız Dili Ve Edebiyatı Bölümü	Edebiyat Fakültesi	1982	41	4	{9E5ECA03-3317-4E31-A0D3-2B12298C26AD}
41	Biyoloji Bölümü	Fen Fakültesi	1982	125	13	{67D1895D-04A6-4DCB-84CF-30467C7F157A}
80	Jeoloji Mühendisliği	Mühendislik Fakültesi A Blok	1982	325	22	{67E4EB89-7404-41BB-B109-3660B7DDBB3C}
90	Hemşirelik Bölümü	Sağlık Bilimleri Fakültesi	1982	762	22	{9D16874B-ACAB-47C0-A6CC-E5D1D55B80CF}
42	Fizik Bölümü	Fen Fakültesi	1983	65	13	{D824AC73-BE06-4FA9-92D7-5B69CE521666}
83	Makine Mühendisliği	Mühendislik Fakültesi A Blok	1984	948	18	{FA456ADA-AA65-4B47-A5BF-045E43D3DD65}
72	Çevre Mühendisliği	Mühendislik Fakültesi B Blok	1989	638	14	{C4B08B9D-3D18-48C2-8ABE-BB17DB41A05D}
20	İngiliz Dili Ve Edebiyatı Bölümü	Edebiyat Fakültesi	1990	293	10	{150AB0C3-50DD-4775-836B-5480BEF1368B}
81	Kimya Mühendisliği	Mühendislik Fakültesi B Blok	1993	631	14	{E0C95A26-45B2-47FB-9415-C71F4E6B9C5B}
13	Antropoloji Bölümü	Edebiyat Fakültesi	1995	506	9	{1A830513-59BB-4F7C-92B4-1896D9FF135B}
23	Psikoloji Bölümü	Edebiyat Fakültesi	1995	<Null>	5	{1A0B3732-5C38-4A56-928D-7E352BD70814}
30	İlköğretim Bölümü	Eğitim Fakültesi	1995	2631	36	{A205C132-DC0D-4B85-9893-BAA54FEB43F4}
18	Felsefe Bölümü	Edebiyat Fakültesi	1996	510	10	{2DA8532E-E170-433F-BA42-6C77B9D73EEA}
73	Elektrik Elektronik Mühendisliği	Mühendislik Fakültesi B Blok	1999	656	12	{39B3FB78-D45A-416F-967F-EB4C89926D4F}
14	Arkeoloji Bölümü	Edebiyat Fakültesi	2000	<Null>	8	{51FB45EF-E023-4204-B5F7-2EE148291B99}
76	Geomatik Mühendisliği	Mühendislik Fakültesi A Blok	2000	466	7	{4CC79295-1735-4C23-A23F-1556B7C4CEE3}
47	Heykel Bölümü	Güzel Sanatlar Fakültesi Heykel Bölümü	2001	34	7	{56294DBC-2492-43CB-AC1E-AEE3C9F3096D}

Figure 6. Academician and Department tables

A network dataset is constructed based on the road geographical data in the CIS. An example of shortest car path to a desired point in CIS is presented in Fig. 7. Note that, the closest routes are solved between 1st and 2nd, 3rd and 4th points.

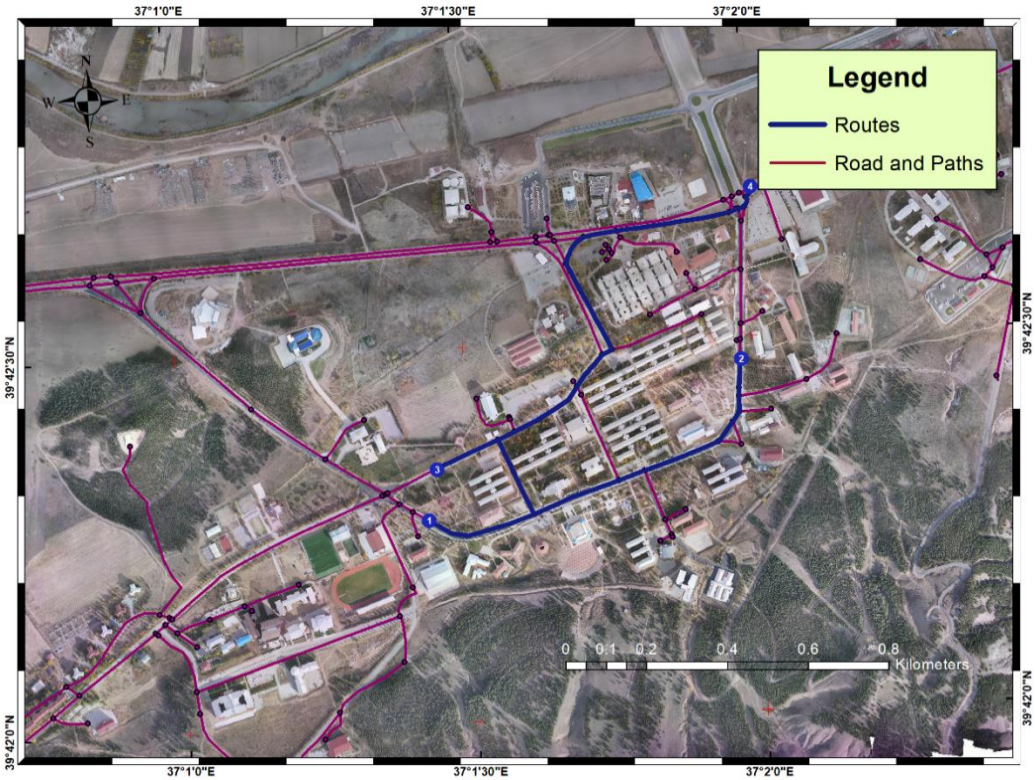

Figure 7. The closest route between 1st and 2nd, 3rd and 4th points

A handful of queries can be done in a CIS. By the help of "Selection" tab of ArcGIS software, every text-based data can be queried from geographical data located in the CIS. A small example of a room query is presented in Fig. 8.

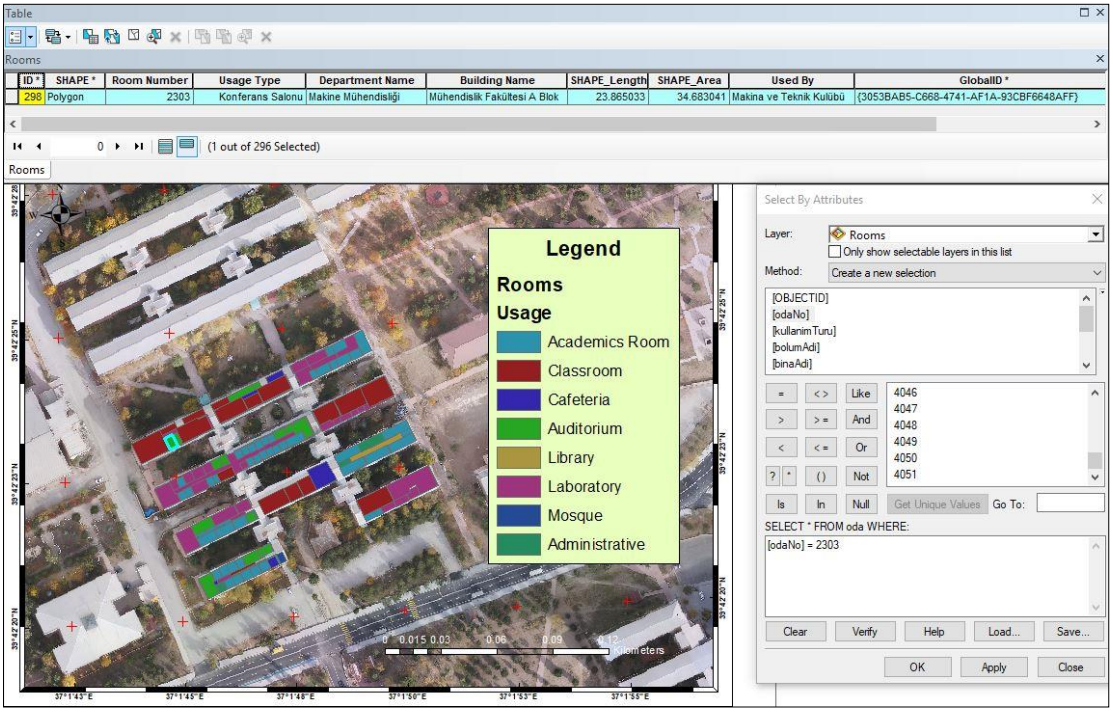

Figure 8. Room number queries with details

CONCLUSIONS

If a CIS is supported by real time geographical and non-geographical information to be up-to-date, it can used to enhance the quality and integrity of administrative works, to select suitable locations for construction works (i.e. suitable location for a student residences/hostels in contrast to locate them closer to shopping places, educational buildings etc.), to create suitable road maps for a possible disaster evacuation scenario and etc.

Nowadays, it is not enough to create the infrastructure of CIS. It will be highly utilized for users in case CIS is published on the web or mobile environment. Up-to-date and accurate geographical data is too important for CIS studies. UAV is one of the most effective and indispensable tool in terms of obtaining geographical data. Consequently, it is reveal that UAV is one of the most remarkable geographical data collection methods for GIS-based studies.

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