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3d Documentation and Preservation of Farhat Baksh Kothi And Chhatar Manzil, Lucknow, Uttar Pradesh Using Terrestrial Laser Scanning

Mr. Swasata Saha

Banker

Abstract:
3D terrestrial laser scanning has become an increasingly popular technique for the digital preservation of historical monuments due to its completeness, accuracy, and speed compared to traditional methods such as hand measurement and tachometry. This study demonstrates the capability of terrestrial laser scanning technology for documenting historical monument facade data in a 3D environment, followed by the generation of a 3D model for visualization using registered colourized point clouds. The Lieca P40 system was used to record the surface data characteristics of the monument, while a Lieca digital camera was integrated with the Lieca P40 system to capture colour information of the geometric object.
The resulting end product allows for the generation of a 3D coloured visualization model of the historical monument with an automatic colourization process. The attachment of RGB value from the detailed high-resolution digital images onto the 3D point clouds data was completed using Lieca cyclone software, which allows for the visualization of the 3D model in a much more photorealistic way. The case study presented in this paper focuses on Kothi Farhat Baksh & Chhatar Manzil, two important heritage monuments in Lucknow, Uttar Pradesh, India.

1. Introduction:

The utilization of advanced 3D measurement technologies for digital preservation of historical monuments has emerged as a promising and effective tool for 3D mapping solutions. In addition to traditional techniques such as manual measurements and tachometry, 3D terrestrial laser scanning is increasingly becoming one of the most commonly employed methods due to its comprehensive, precise, and rapid characteristics. This present study presents the potential of terrestrial laser scanning technology for documenting facade data of historical monuments in a 3D environment. Subsequently, a 3D model for visualization based on registered colorized point clouds was created. For this purpose, the Lieca P40 system was utilized to capture surface data characteristics of the monument. To capture the color information of the geometric object, a Lieca digital camera was integrated with the Lieca P40 system.
The final product enables the generation of a 3D colored visualization model of the historical monument with an automatic colorization process. The Lieca Cyclone software was used to attach the RGB value from detailed high-resolution digital images onto the 3D point cloud data. This results in a 3D model that can be visualized in a more photorealistic manner. This case study of LiDAR based scanning was conducted on the Kothi Farhat Baksh & Chhatar Manzil, important heritage monuments located in

Lucknow in the state of Uttar Pradesh, India. The data fusion of TLS and digital photogrammetry is presented and explained in detail to create a photorealistic model in a 3D environment.

To produce a photorealistic model in a 3D environment, the data fusion of TLS and digital photogrammetry is presented and explained in detail. A 3D virtual fly-through animation of Farhat Baksh & Chhatar Manzil was created based on millions of colourized point clouds. This technique of 3D modeling and visualization can aid in the conservation and preservation of historical monuments and provide an efficient tool for 3D mapping solutions.

2. Objectives:-

The objectives of this project survey are multifaceted and include several key goals. Firstly, the project aims to utilize the Terrestrial Laser Scanner technology to capture high-resolution 3D data of the exterior surfaces of two culturally and historically important monuments in Uttar Pradesh, India. These monuments are protected by the Uttar Pradesh State Archaeology Department and it is critical to accurately document and preserve their surface characteristics for future generations.

Secondly, the project aims to analyze and interpret the surface data collected through Laser Scanner. This analysis will involve a detailed examination of the surface characteristics of the monuments, including any damage or deterioration that may have occurred over time.

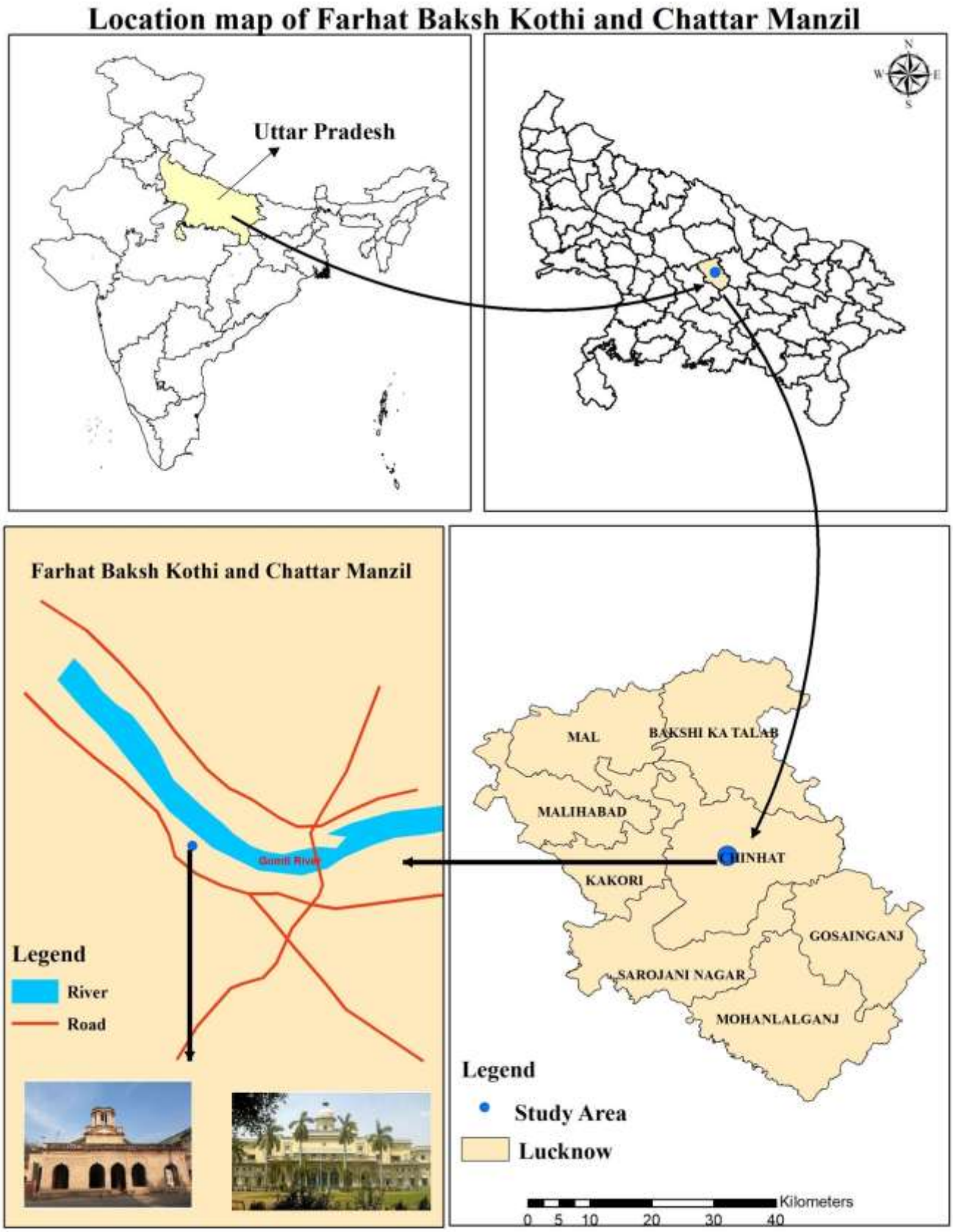
Thirdly, the project aims to generate a 3D model of the monuments based on the collected data, which can be used for visualization, analysis, and documentation purposes. This 3D model will provide a detailed and accurate representation of the monuments, allowing for the identification and analysis of various features that may not be visible through traditional documentation methods.

3. Study Area:

The study area, Farhat Baksh Kothi and Chhatar Manzil, are located in Lucknow, the capital city of Uttar Pradesh, India. Lucknow is a major cultural and historical center, with a rich heritage and a plethora of historical monuments and buildings. The city is easily accessible by road, rail, and air, making it a popular tourist destination.

The exact latitude and longitude of the *Farhat Baksh Kothi* and Chhatar Manzil are 26.8674° N, 80.9256° E and 26.8681° N, 80.9254° E, respectively. **(Fig.1)** The location of these monuments makes them easily accessible to tourists and provides an opportunity for the preservation and documentation of their historical and cultural significance.

The *Farhat Baksh Kothi* and Chhatar Manzil are located in the heart of Lucknow, in close proximity to major tourist attractions such as the Bara Imambara, Rumi Darwaza, and the Chota Imambara. The Kothi and Manzil are situated on the banks of the Gomti River, which is also a popular tourist destination.


Location map of Farhat Baksh Kothi and Chattar Manzil
Uttar Pradesh
N
W
E
S
Farhat Baksh Kothi and Chattar Manzil
Gomti River
Legend
River
Road
MAL
BAKSHI KA TALAB
MALIHABAD
CHINHAT
KAKORI
GOSAINGANJ
SAROJANI NAGAR
MOHANLALGANJ
Legend
Study Area
Lucknow
Kilometers
0 5 10 20 30 40

The nearest airport to Lucknow is the Chaudhary Charan Singh International Airport, which is located approximately 12 km from the city center. The airport is well connected to major cities in India, as well as to international destinations. The city is also well connected by rail, with several major railway stations, including Lucknow Junction, Charbagh, and Gomti Nagar.

In addition, Lucknow is well connected by road, with several national highways passing through the city. The city has a well-developed public transportation system, including buses, taxis, and auto-rickshaws, making it easy for tourists to explore the city and visit the historical monuments.

3.1 HISTORICAL BACKGROUND

Farhat Bakhsh is a historical monument located in the city of Lucknow, Uttar Pradesh, India. Originally built as a residence by Claude Martin, a French adventurer and soldier, the structure underwent several modifications and additions over time. One such addition was the annexation of a separate structure, which later came to be known as Chhatar Manzil. The name Farhat Bakhsh translates to "bestower of joy", while Chhatar Manzil translates to "umbrella palace" in English.

In May 1781, during the construction of the house, it was attacked by some members of the fleeing troops of Raja Chet Singh of Banaras. The attack was repulsed by Martin by placing two small guns at his door, but it goaded him to fortify his house. He dug a moat on three sides of the house and provided a lofty arched gateway with a drawbridge as the entrance. The fortification of the house not only served as a defensive measure but also as a symbol of power and prestige for Martin.

Several attempts of restoration and conservation of the historical significance and architectural features of Farhat Bakhsh/Chhatar Manzil are done but the restoration and conservation efforts carried out on the structure to preserve its cultural heritage was not completed due to the complexity and the structural behavior of the building under different loads and conditions. The serious attempts by Uttar Pradesh State Archaeology Department in 2014 and again in 2019 highlighted from the importance of preserving and studying historical monuments such as Farhat Bakhsh/Chhatar Manzil for their cultural, historical, and architectural significance. Discovery of wooden boat, dating back some 200 years, on the western side of building with dimensions of plank more than 50 and 12 Feet in length and width affirms the water transportations system and building structure made in accordance.Restoration efforts from Uttar Pradesh Rajkiya Nirman Nigam (UPRNN) 2017 can also be quoted however now there are plans to conserve the building as a tourist destination Hotel by Uttar Pradesh Tourism Department (2022).

The halls of the house of General Martin served not only as living quarters but also as a repository for his extensive collection of books, paintings, and curiosities. Martin's collection was known as a "perfect Museum" and was full of "infinite amusements" according to an English visitor. Martin had nearly 4000 books in French and English, along with 500 handwritten volumes in Persian. He also had a large collection of paintings, which included works by renowned artists such as Sir Joshua Reynolds and Benjamin West. Martin's collection included a wide range of objects such as mirrors, china, and glassware, a room full of fireworks, Chinese toys, biological specimens (including a female skeleton), puppet theater accessories, watches, and technological innovations of his time such as steam engines, printing presses, and magic lanterns.

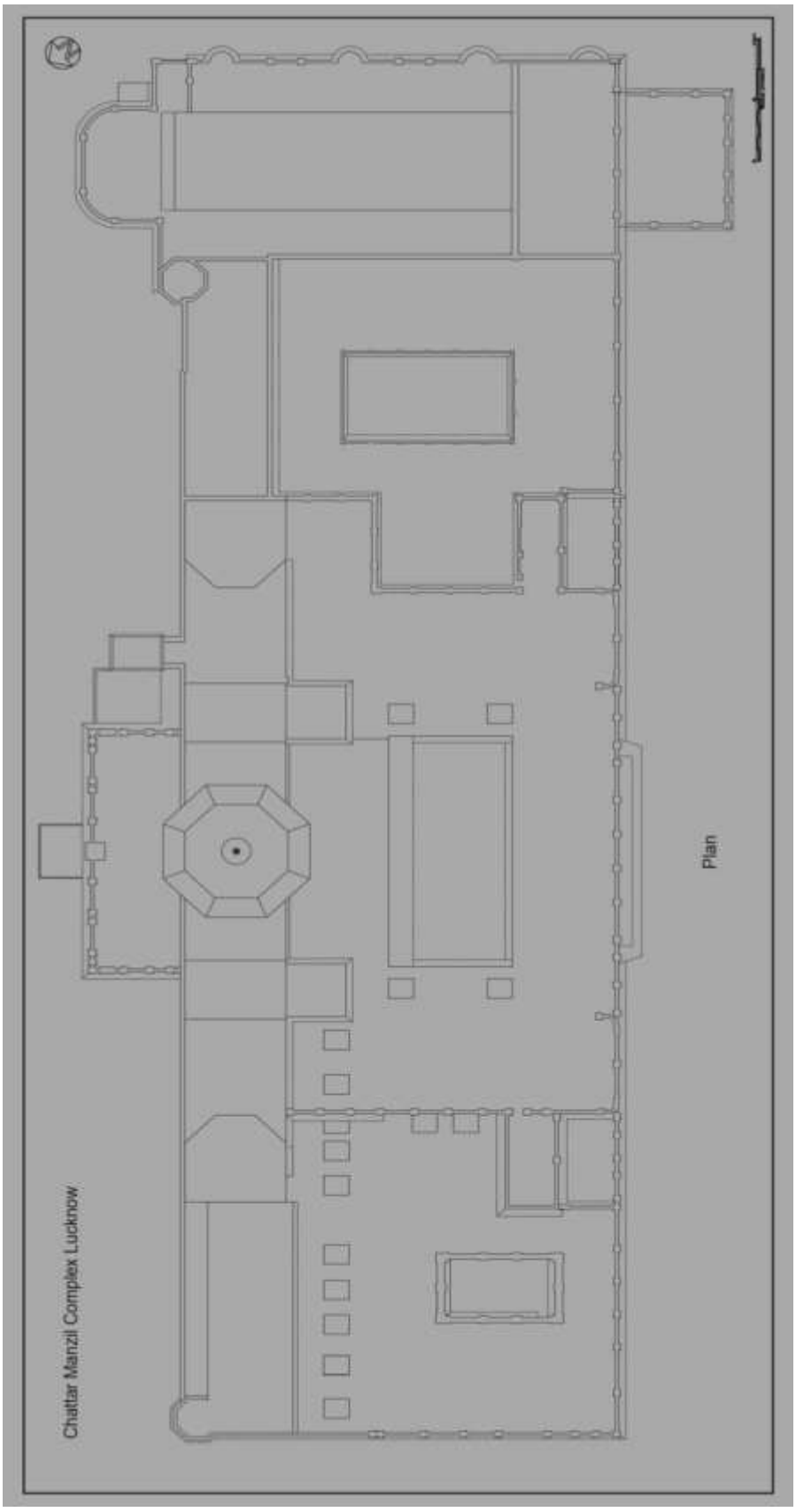
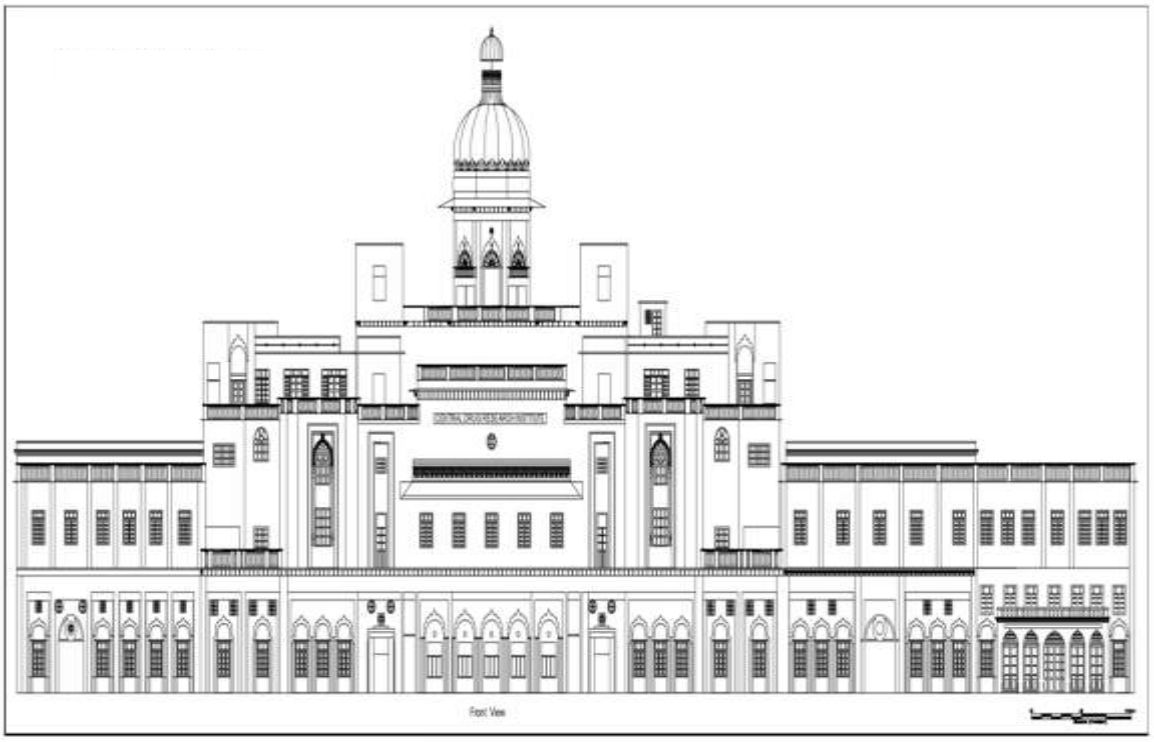
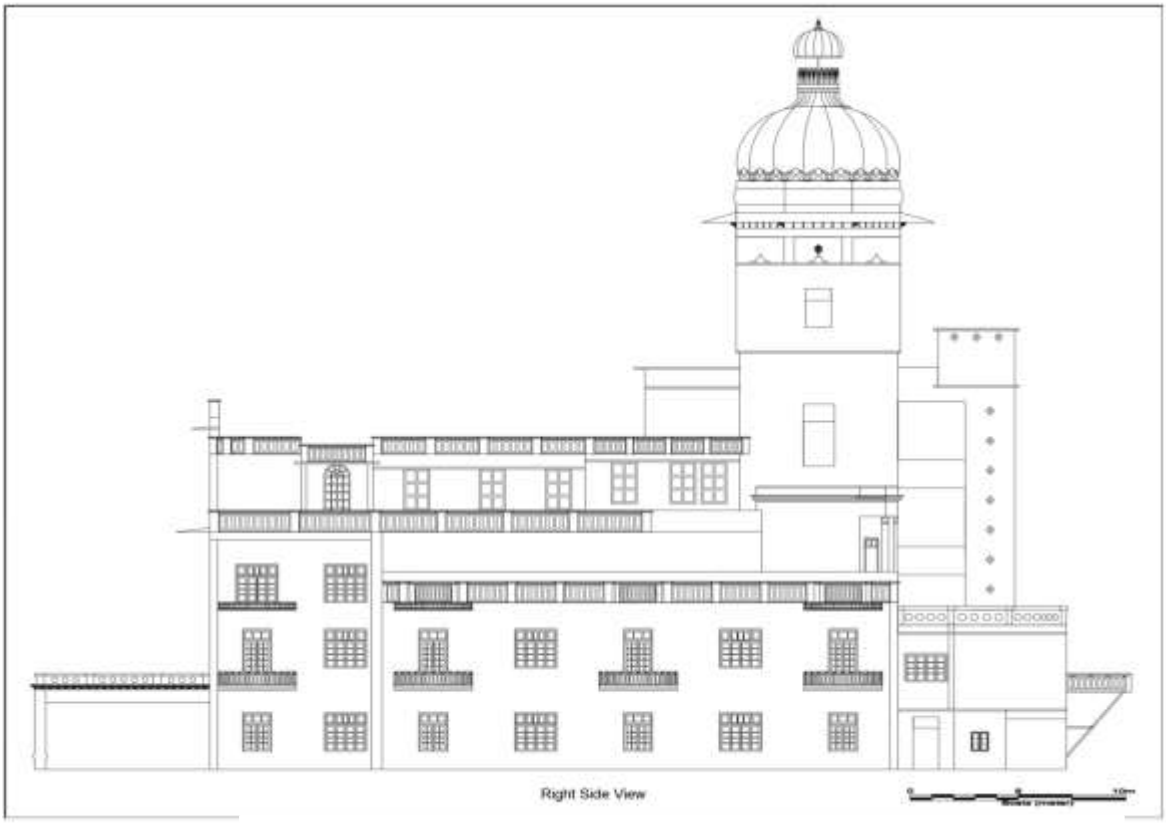


Figure: 1 Top view Plan of Chhatar Manzil complex




Right Side View

Governor General Shore, who visited the place in 1797, was impressed by the vastness of Martin's collection and remarked that it would take nearly a week to examine all the items. Martin's collection was not only impressive for its size but also for its diversity, which included items from different cultures and fields of study. His collection was a testament to his curiosity and interest in the world around him.

The extensive collection of General Martin has been described in various historical accounts and research papers. For instance, a research paper by Jasanoff (2004), provides an in-depth analysis of Martin's collection and its significance. Another account by Rosie Llewellyn-Jones with minute details made six month after death of Martin explores the collection and its contribution to the cultural history of Lucknow. These account shed light on the cultural and historical significance of Martin's collection, which is an important part of the heritage of Lucknow.

The monuments being surveyed in this project are situated in Lucknow, Uttar Pradesh, India. They are now joined and share common walls, with the western portion being older and originally constructed by French General Claude Martin as his 'town house' after clearing the forests south of the river Gomti in 1781. After his death, the place was auctioned and bought by his Spanish agent, Joseph Queiros. The Nawab of Awadh, Saadat Ali Khan, took the building for a change of air during an extended illness, and upon recovery, he purchased the building and named it Farhat Baksh, which means bestower of happiness. The building then served as a residential palace for the Nawabs of Awadh until Nawab Wajid Ali Shah in 1856, and the area around it can be called the Farhat Baksh Complex, which includes many civil constructions that still exist.

The eastern or larger portion of the present surveyed building is called Chhatar Manzil and has emerged from the additions and modifications made by Ghazi-ud-Din-Haider, son of Nawab Wajid Ali Shah. After his death in 1827, his son Naseer-ud-Din Haider completed it. He also built another similar but smaller structure called Chhoti Chhatar Manzil, while the earlier or big complex was referred to as Bari Chhatar Manzil, known as such for the golden umbrellas or Chhatar placed at the top of their domes. The larger Chhatar Manzil served as an exclusive club for the British after 1857.

The history and architecture of these monuments have been studied and documented in various research papers. For instance, a research paper titled–"Indo-Saracenic Architectural Heritage" by J. Sheeba, et al.(2018) discusses the influence of European and Indian architectural styles on buildings constructed during British rule in India, including Chhatar Manzil.

After India gained independence, Kothi Farhat Baksh and Chhatar Manzil were acquired by the Central Drug Research Institute (CDRI) and used as research facilities. However, in 2012-2013, the CDRI vacated the premises and ownership was transferred to the Uttar Pradesh State Archaeology Department. Since then, the building has been under protection by the department and has been utilized for various events such as art exhibitions, cultural programs, and heritage walks. Additionally, the unique architecture of the building has made it a popular location for filming Bollywood movies such as "Daawat-e-Ishq, Jolly LLB 2 and latest Bawaal". The utilization of the building for various events and purposes has helped to generate interest and awareness of the historical and cultural significance of the building, thus ensuring its preservation for future generations.

4. Data Used:

The primary data used in this project was collected through Terrestrial Laser Scanning (TLS), a surveying technique that uses a laser scanner to capture millions of points on the surface of a monument. The scanner emits a laser beam that measures the distance to the surface of the monument, creating a point cloud data

set. This data set provides a three-dimensional representation of the monument with high accuracy and detail.

The TLS data was supplemented with secondary data, such as historical maps, photographs, and architectural drawings, to aid in the analysis and interpretation of the data. This information was obtained from the archives of the Uttar Pradesh State Archaeology Department and other relevant sources.

Additionally, the project utilized software such as Cyclone, AutoCAD, ArcGIS, and few others to process and visualize the data. These tools were used to create detailed 3D models of the monuments and to analyze the surface characteristics and features of the structures. The models were then used to generate reports and visualizations that could aid in the preservation and maintenance of the monuments.

5. Methodology:

Planning Phase:

- Define the scope of the project, including the area to be surveyed, accuracy requirements, and deliverables.
- Identify potential obstructions, such as buildings or trees, that could interfere with the LiDAR survey.
- Determine the placement of Ground Control Points (GCPs) and their spacing for survey accuracy.
- Select the LiDAR scanner, based on the accuracy, range, and resolution required for the project.
- Identify the survey equipment, including the DGPS, targets, and other accessories.

Field Survey Phase:

- Install the GCPs at predetermined locations using DGPS.
- Set up the LiDAR scanner and ensure it is level and calibrated.
- Conduct a pre-scan to verify that the scanner is working correctly and that the GCPs are accurately positioned.
- Begin the survey, ensuring that the scanner is capturing all necessary data, and moving it to the next scanning location while keeping in mind the potential obstructions.
- Record weather conditions, equipment used, and any other relevant information.

Data Processing Phase:

- Register the point clouds using GCPs and targets, ensuring that all point clouds are correctly aligned.
- Filter out any unwanted data points and remove noise from the data.
- Classify the points based on their characteristics, such as vegetation or buildings.
- Create a 3D model of the survey area using software such as Cyclone or Recap.
- Perform quality checks to ensure that the model is accurate and meets the project requirements.
- Export the 3D model into a format that is suitable for report writing.

Report Writing Phase:

- Create a plan for the report, including its format, content, and intended audience.
- Include an executive summary, introduction, methodology, results, analysis, and conclusion sections in the report.
- Include images and diagrams that help to explain the LiDAR survey and the 3D model.
- Present the assessment, highlighting any limitations or constraints that may affect the results.
- Provide recommendations and suggestions for future work.

In summary, the methodology for Terrestrial LiDAR Survey using DGPS and Processing for Creating 3D and Report Writing involves planning the project, conducting the field survey using LiDAR and DGPS, processing the data to create a 3D model, and finally, reporting the findings of the survey. Accurate data collection and processing are essential to produce high-quality results that meet the project requirements.

6. Observations:

The unique structure of General Martin's house consisted of multiple floors, including two underground levels that remained hidden unless the river's water level was at its lowest. These spacious rooms were prone to flooding during the monsoon season, forcing occupants to evacuate until the water receded. Two octagonal towers were built on either side of the basement, allowing for proper ventilation and cooling. On the ground level, a large hall extended partially over the river on the north and was supported by arches and piers placed in the river. The house also featured open pavilions on the rooftop and was equipped with two telescopes for astronomical observations, imported from England. Despite being unmarried, General Martin had a separate living quarter for his mistresses, along with a garden, located on one side of the house.

The Farhat Baksh Palace was constructed in the Pseudo Italian style, as noted by Fergusson, with similarities to the Constantia. However, the European influence is not apparent beyond the facade. The building features ornate decorations, such as gilt work and the dome on the Chhatar Manzil, which sometimes border on over-ornamentation. The credit for building this stunning edifice goes to Major General Claude Martin, a French national who was reputed for his extraordinary character. The palace was constructed on the heavily wooded bank of the river Gomti, in an area that housed around a lakh of trees, which is unimaginable in the present world.

The palace was a remarkable achievement of the last century, with a moat, drawbridge, and roof kiosks adorned with stucco swags. The drawbridge led up a few steps to an elegant piazza, which led to an octagonal room. From there, other rooms led off, and the apartment nearest to the river led in turn to the great hall overlooking the river and the north bank of the Gomti. One of the most striking features of this majestic edifice was the use of Gomti's waters to cool the house, demonstrating the ingenuity and engineering skill of its builders. Truly, the Farhat Baksh Palace is a testament to the rich cultural heritage and architectural legacy of India.

Close observations revealed a series of arches supported the great mirrored room at first floor level, giving a watery Venetian feeling, particularly during the monsoon when the Gomti river rose. The palace had two basement storeys, one above the other, set into the river bank, which contained extensive cool and damp rooms, even during the height of summer when the river fell rapidly. The open arches in the basement were hung with tatties that were kept constantly watered by servants. There were also baths and fountains that sprinkled water against the windows and maintained a constant temperature inside. It is fascinating to think how Martin would retire to these rooms during the hottest months.

Every year during the monsoon, as the Gomti river rose, Martin would ascend from the lowest basement storey to the one directly below ground level, and then to the ground floor. And as the waters started to recede, the underground rooms would be cleaned and redecorated, ready for the next season. This is an amazing and fanciful feature for a building that was constructed almost two hundred years ago. The most noteworthy feature of this remarkable building is that the rooms were built to be cooled naturally by the river waters. The upper storey rooms were used for recreation and rest, while the attic reportedly housed a museum and an observatory furnished with the best of astronomical instruments.

The palace halls were beautifully decorated with oil paintings, and the doors were provided with velvet and atlas curtains, Iranian rugs, chandeliers carved out of 'Almas,' Sagaun wood furniture, mirrors of different shapes, and multi-coloured birds kept in cages of gold. Saadat Ali Khan must have made great additions and improvements to the palace. This building not only served as residential accommodation but was also well-designed to adjust to the climate of Lucknow, surrounded by beautiful arcades and adjoining rooms.

To meet the rigours of summer, Claude Martin had constructed a large hall in the basement of his palace. This hall was oval-shaped with small chambers attached all around, and the roofs of these rooms had beautiful paintings in Gothic style with rectangular designs. The entrance to the basement was from the river side, and there was a stone on top of the entrance with the name of Claude Martin and his birthplace "Lyons" inscribed on it, which does not exist today.

As observed and recorded from historical evidences, there was an observatory located at the top of the palace which housed the best astronomical instruments. It was said that William Herschel, a member of the Royal Astronomical Society, created the telescope used by Martin for his astronomical studies. However, over time, the palace was subjected to indiscriminate usage and neglectful treatment which has caused significant damage to the structure. The Chhatars have been lost except for one, and the Chota Chhatar Manzil collapsed in 1961 and was subsequently demolished in the name of progress.

The palace underwent crude repair work and was subject to civic indifference, which further damaged the building irreparably. As a result, it has become imperative to preserve and protect the unique heritage assets of Lucknow for future generations. Although the Central Drug Research Institute (CDRI) has been shifted, repair and renovation work is currently underway at the historic edifice. Excavations have revealed buried storeys from the past, but much more needs to be done to restore the palace to its former glory.

Fortunately, restoration of the Chhatar Manzil has started using traditional cementing materials such as Chunam, Surkhi, Bel, Urad Dal, and Jaggery. This news has come as a relief to heritage enthusiasts in Lucknow. The recent discovery of an old boat remnant and basement within the Chhatar Manzil has added to the excitement of heritage enthusiasts, and has contributed to the folklore surrounding the hidden treasures and tunnels that connect the Choti Chhatar Manzil, Lai Baradari, Kothi Darshan Bilas, Gulistan e Eram, and other monuments in the vicinity.

7. Results and Conclusions

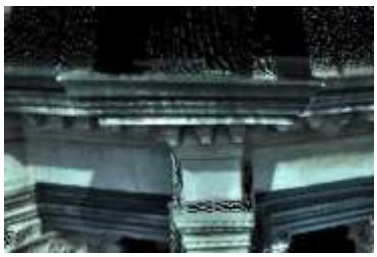
LiDAR technology offers a fast and efficient way to collect 3D data, as it uses non-contact laser pulses to measure surface profiles of objects. Laser scanning has become a popular method for producing high accuracy 3D data in recent years due to its speed and efficiency. LiDAR technology has been widely used in cultural heritage documentation and preservation, as it allows for the precise measurement and visualization of historical structures and objects.

Studies have shown that LiDAR technology is particularly effective for the documentation and preservation of historical buildings and monuments. For example, a study conducted by Jo et al. (2019) found that LiDAR scanning was effective in documenting the intricate details of ancient Chinese Buddhist sculptures. Similarly, a study by Tapete et al. (2015) demonstrated the effectiveness of LiDAR scanning for the documentation and preservation of historical architecture in Italy.

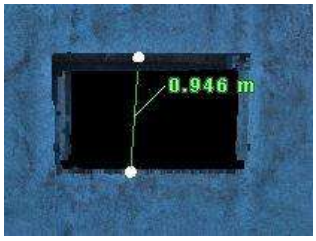
The Terrestrial LiDAR survey of Farhat Baksh Kothi-Badi Chhatar Manzil, Lucknow, conducted by the Remote Sensing Applications Centre, Uttar Pradesh, Lucknow, using the Leica Scan Station P40 equipment, provided accurate and detailed information about the structures. The length and width of each

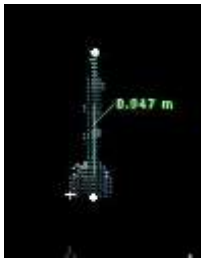
part, entrance door, and other objects and civil structure present on the façade of Building Complex was accurately measured. The measurements of each section of the Kothi were conducted using the measuring tool of the software integrated with LiDAR survey equipment, which provided millimeter accuracy. The data collected through this survey can be used to produce 3D models for efficient documentation of historical heritage.

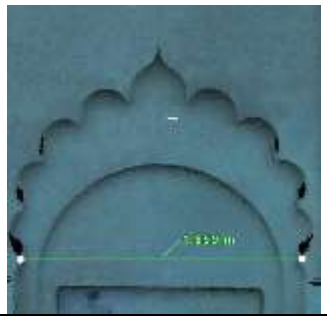
Few examples of the dimensions measurement of few features that were extracted from model of point cloud data are as follows-

S.No	Feature	Dimension (m)	Descriptions
1		0.743 m	Chimney like structure which is closed
2		0.757 m	Dimension of ornamentations on pillars
3		5.129 m	Height of pillar
4		2.556 m	Height of door frame
5		0.291 m	Width of single rectangular run design

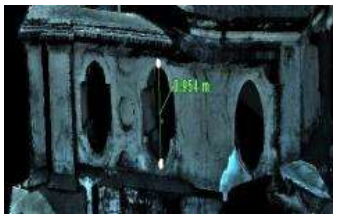
6		0.363 m	Circumference of circular design
7		0.818 m	Measurement of width of rectangle over Nature inspired ornamentation within
8		0.848 m	Octagonal mortar design
9		4.117 m	Underground door height
10		2.588 m	underground design beside the door opening
11		1.196 m	Length of Elliptical architecture over the wall

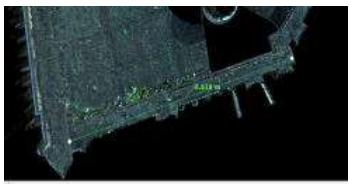
12		0.946 m	Width of ventilation opening
13		2.504 m	Height of door frame of Chhatar manzil
14		0.110 m	Height of the wall design Gap
15		5.170 m	Height of pillar
16		0.384 m	Design dimensions of ornamentation

17		0.612 m	Max. Length of elliptical vent
18		0.947 m	Arrow on Umbrella of Chhatar manzil
19		1.832 m	Chhatar measurement
21		2.592 m	Window frame diagonal dimensions
22		2.199 m	Outer Width of Mehrab frame

			
23		1.859 m	Inner max width of curve and dome ornamentation
24		3.984 m	Wall window dimensions
25		0.591 m	Railing dimesion

26		2.071 m	Diagonal length measurement of window
27		6.139 m	Pillar height measurement

			
28		0.912 m	Circular window/ventilation
29		5.425 m	Height of wall
30		5.500 m	Dimension of side wall
31		0.954 m	Railing design dimension

32		4.000 m	Pillar height
33		5.649 m	Railing top view dimension
34		3.690 m	Connecting beam dimension
35		5.676 m	Railing top view length
36		2.521 m	Height of pillar
37		0.817 m	Measurement between pillar

38		0.229 m	Thickness of roof design
39		3.257 m	Gap between 2 roof pillar

As the terrestrial LiDAR survey which aims at Light Detection and Ranging, a remote sensing technology , uses laser pulses to measure distances and generate 3D representations of objects and environment; Farhat Baksh Kothi-Badi Chhatar Manzil, Lucknow documented spatially with point cloud generated by the LiDAR survey and has captured the outer features of the Building Complex with precise coordinates of each point in the cloud, allowing for accurate reconstruction of damaged features and monuments.

In conclusion, the terrestrial LiDAR survey of Farhat Baksh Kothi-Badi Chhatar Manzil, Lucknow has provided high-accuracy 3D data of the outer features of the Kothi, which can be used for the reconstruction and preservation of the historical monument. LiDAR technology has proven to be an effective tool for cultural heritage documentation and preservation, and its use in documenting historical structures and objects is likely to become more widespread in the future.

The use of LiDAR technology has become increasingly popular in archaeological research due to its high accuracy and efficiency in collecting data. It has been used in numerous archaeological sites and cultural heritage management projects around the world, including the documentation and preservation of historic structures in India.

LiDAR technology has also been used in the documentation and restoration of historic structures in other countries. A study conducted by researchers from the University of Granada used LiDAR technology for the documentation and restoration of the Nasrid Palace of the Alhambra in Spain (Sara Satoh, 2020) highlighted the potential of LiDAR technology in providing highly accurate and detailed information about the structures, which is crucial for their restoration and preservation.

The Terrestrial LiDAR survey of Farhat Baksh Kothi and Chhatar Manzil, conducted using the Leica P40 instrument, has proved to be a valuable tool in creating a comprehensive and accurate 3D mapping of the historical structures. The LiDAR technology has provided precise measurements of various structural elements, as well as the ornamentation work on doors, windows, walls, and ceilings.

The 3D point cloud data generated by the LiDAR survey has been stored for future restoration and preservation purposes. The data will serve as a guiding line for the generation of similar data for other monuments of historical importance. Moreover, the archived data will be useful for any plans of developmental activities in the future.

The use of LiDAR technology for spatial information, combined with recording of shape and surface characteristics of the structures, has enabled efficient monitoring of infrastructure for conservation, repair,

management, and development work. The technology has reduced the time required for 3D measurement and monitoring of infrastructure, which can have significant benefits for the Ministry of Culture, especially the Archeology Department, as well as boosting tourism potential and research activities.
Concluding, the Terrestrial LiDAR survey of Farhat Baksh Kothi and Chhatar Manzil has been successful in providing accurate and comprehensive 3D mapping of these historically important structures. The data generated by the survey will be useful for future restoration and preservation work, and the technology used for the survey will have significant benefits for the cultural and research sectors.

8. Suggestions & Recommendations:

The survey of Kothi Farhat Baksh and Chhatar Manzil by Leica P40 has provided invaluable data that can be used for the conservation, preservation, and development of these historical monuments. However, the survey has also revealed several challenges that need to be addressed in order to ensure the long-term sustainability of these sites.
Firstly, the hot and humid climate in Lucknow can cause significant damage to these structures. High humidity can lead to the growth of mold and fungus, which can weaken the structural integrity of the buildings. In addition, high temperatures can cause the expansion and contraction of building materials, leading to cracks and other forms of damage. To mitigate these risks, it is important to develop climate control measures that can regulate the temperature and humidity inside the buildings. This can include the installation of air conditioning systems and the use of dehumidifiers.
Secondly, the presence of bushes and snakes in and around the buildings were constant threats and survey work was done with caution and avoided at several places. In order to prevent accidents, it is important to maintain the grounds and regularly remove any overgrown vegetation. Furthermore, staff should be trained on how to handle encounters with snakes and other wildlife.
Thirdly, the mud in the basement of these buildings poses a significant challenge for their conservation and preservation. Moisture can seep through the walls and floors of the basement, leading to decay and other forms of damage. To address this issue, it is important to implement waterproofing measures that can prevent the infiltration of moisture. These can include the application of sealants and the installation of drainage systems.
Finally, the proximity of these buildings to the river Gomti can result in water logging in the lower parts of the buildings. This can cause significant damage to the foundation and other structural elements of the buildings. To prevent water logging, it is important to develop drainage systems that can effectively channel water away from the buildings.
In conclusion, major challenge faced during the terrestrial LiDAR survey of Farhat Baksh Kothi and Chhatar Manzil was the presence of dense vegetation around the structures. This made it difficult to obtain accurate measurements of certain areas and also hindered the capturing of detailed features such as the carving on the walls and the ornamentation on the doors and windows. In order to address this issue, it is recommended that the vegetation be trimmed or cleared in certain areas to allow for better access to the structures.
Furthermore, it is suggested that the Ground Penetrating Radar (GPR) technique be employed to investigate the possibility of buried structures or objects beneath the ground around Farhat Baksh Kothi and Chhatar Manzil. GPR is a non-invasive geophysical method that uses radar pulses to image the subsurface. It has been widely used in archeological investigations to identify buried objects, structures, and features (Conyers and Goodman, 1997). In a study conducted by Ristić A et al. (2020), GPR was used

to investigate the subsurface features of ancient monuments, and the results showed the presence of buried structures and objects that were not visible on the surface.

Therefore, the use of GPR in the investigation of Farhat Baksh Kothi and Chhatar Manzil has the potential to provide valuable information about the presence of buried structures or objects around the area. This information can be used to guide further archeological investigations and conservation efforts.

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