SINGLE IMAGE 3D MAPPING OF AN AREA

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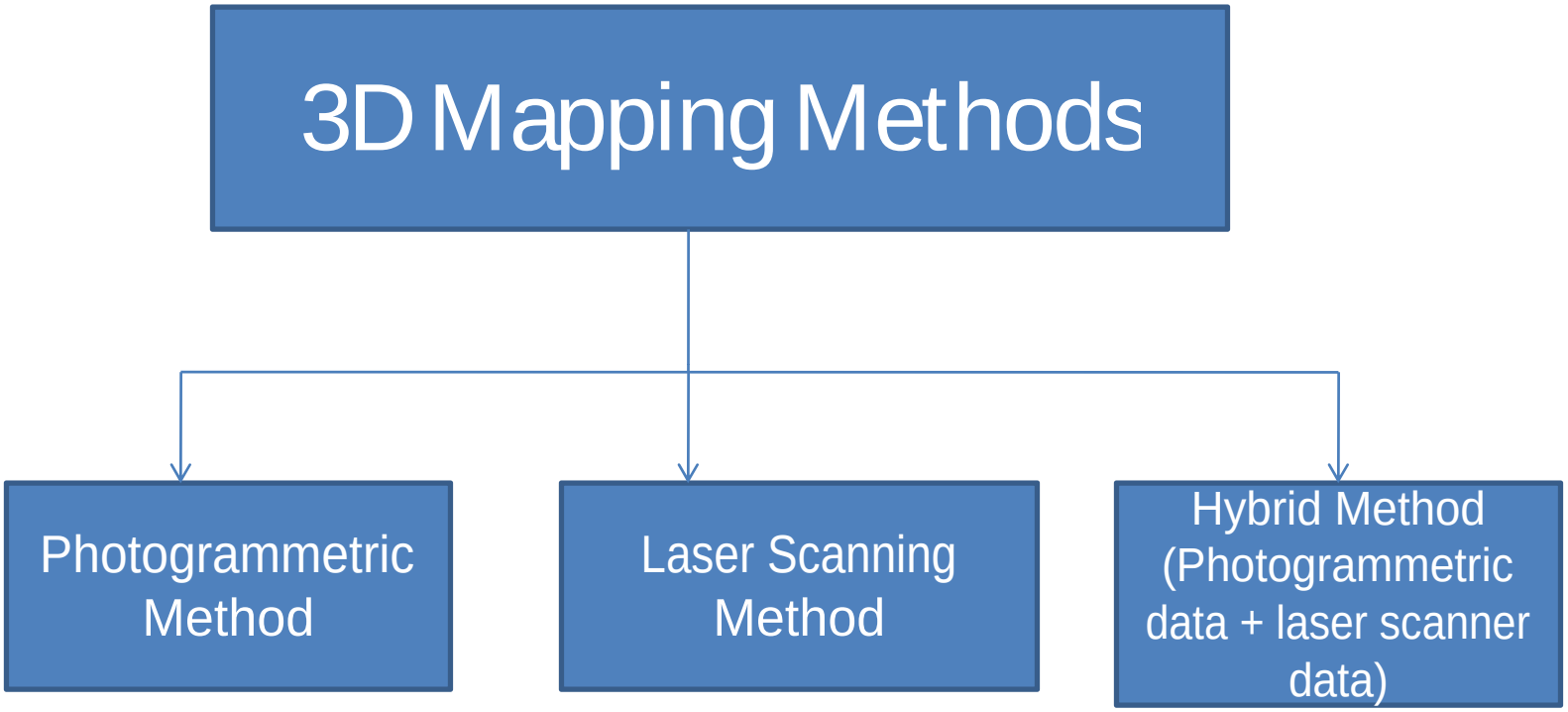
What is 3D mapping?

If a picture worth a thousand words, 3D model is worth a thousand pictures.

- 3D mapping is a digital 3D representation of an area or a city. i.e. each point in that area is represented by 3D space coordinates.

WHY 3D?

- More realistic than 2D drawings.
- Useful for encroachment analysis, virtual tour.
- Urban planning , environmental analysis, and tourism.
- Useful in flight simulation.
- By flying through the 3D city models the user can recognize the location and get the true impression of the height of the buildings around him.


3D Mapping Methods
Photogrammetric Method
Laser Scanning Method
Hybrid Method (Photogrammetric data + laser scanner data)

LIMITATION OF USING LASER SCANNER DATA

- ✓ Laser scanning equipments are expensive therefore the cost of project increase.

- ✓ Laser scanner data require experts to convert it to the useable data.

ADVANTAGES OF USING SATELLITE IMAGERY

- Satellites are functional 365 days of the year.
- The coverage of Satellite Image is large and is suitable to large-scale survey or investigation.
- Re-visit time is very less (~ 4 days).
- Post-processing of imagery takes less time.
- Remote or restricted areas are easily accessed by the satellite.

3D MAPPING USING SINGLE IMAGE

- Due to non availability of Aerial Photographs or its cost factor and availability of satellite imagery at very good resolution (IKONOS, QuickBird) it is being used in various photogrammetric applications.

- The conventional satellite photogrammetry for 3D restitution requires highly expertise personal, stereo satellite images and lot of time.

- However many applications in 3D modeling e.g. mapping of airport surroundings, 3D visualization of city etc. would not require the accuracy at the cost of economy as provided by conventional satellite 3D modeling.

- Majority of high resolution satellite imagery are available in the form of single image (i.e. not stereo imagery). satellite images are inexpensive for most of end users.

- These two factors i.e. availability and cost effectiveness, make single images more approachable by end users and more suitable to work with.

- Various softwares provide facility to extrude the buildings up to the height to give visual 3D representation(this require height to be known for each building).

EXISTING SINGLE SATELLITE IMAGE METHOD

- For creation of 3D model of an area the planimetric position (X, Y) and height (Z) of each object is to be determined.

- The planimetric position of building is extracted from high resolution satellite image (Base of the building in the image gives the planimetric position of the building). Figure 1a shows high resolution satellite image of a building. Figure 1b shows building top is captured and transferred to the base to find planimetric position of building.

Figure 1a: 2D satellite image of a bui

Figure 1b: building top is extracted and transferred to the base.

- The planimetric position of building has been determined, next step is to find the height of building. Figure 2 shows geometry of 3D building with the position of sun and the satellite.

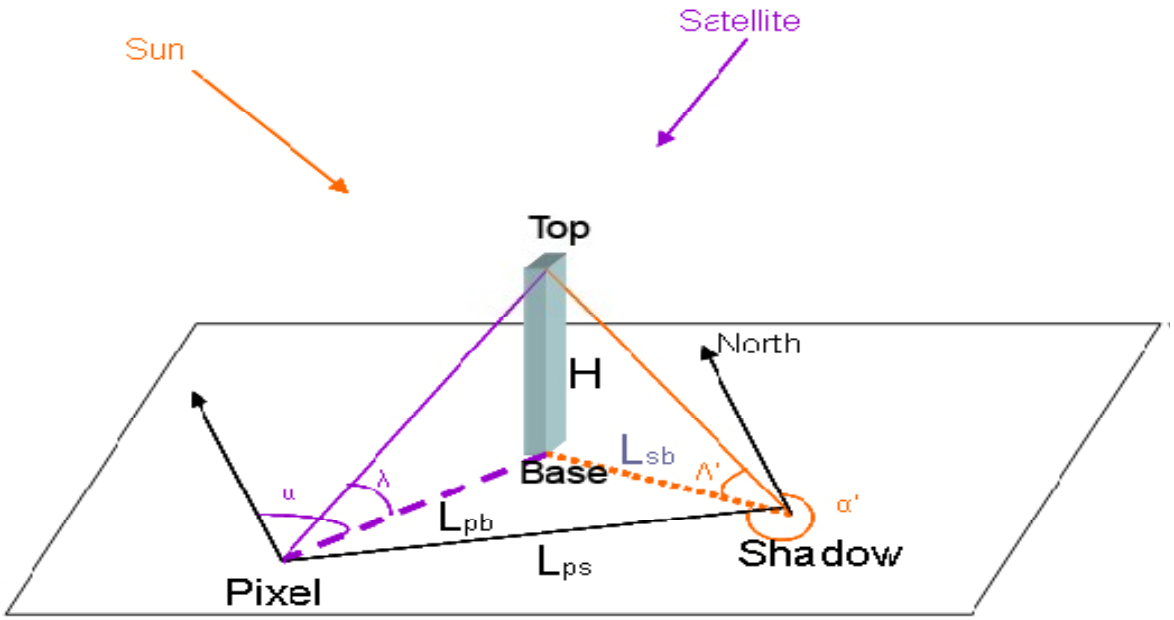


Figure 2: Geometry of the 3D building with the position of the sun and the satellite (Source: Xiaojing Huang et. al, 2008)

Comparison of Calculated Building Height and Actual Building Height

Building Name	Calculated Height (m)	Actual Height (m)
Civil department	10.923	11.820
Geotechnical	9.880	11.100
Jawahar Bhawan F block	10.646	11.560
Building in front of Geomatics	10.880	11.56

Table 1: calculated and actual heights of buildings

- Once planimetric position and height of each building is determined, then 3D model of IIT Roorkee campus is prepared. Following figures shows 3D model of IIT Roorkee campus.

Figure 2: 3D model of Kasturba Bhawan

Figure 3: 3D model of Civil Department

ADVANTAGES

- This method provides a cost effective alternative to the use of aerial photography for 3D Modeling.

LIMITATIONS

- The above method is to be used when image is captured using frame camera because in case of frame camera elevation angle is constant for a particular scene. In case of modern satellite data each line has different elevation angle therefore above method would fail.

Modern satellites acquire image line by line and therefore it doesn't follow real perspective projection which is available in frame cameras. In Satellite image Each line has different perspective centre. Therefore the restitution of conventional photogrammetry based on perspective projection is not valid in case of modern satellites.

Figure 7: Image Acquisition using frame camera

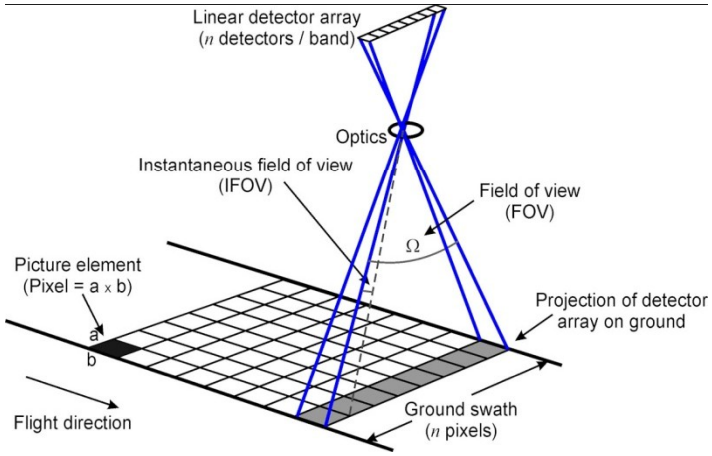


Figure 8: Satellite image acquisition

PROPOSED METHOD

- Therefore to overcome this limitation a new method is proposed which is mainly based on the perspective geometry of regular objects (based on parallel and perpendicular lines of the object) that can be reconstructed. This is the reverse process to project the real world space objects onto a picture plane.

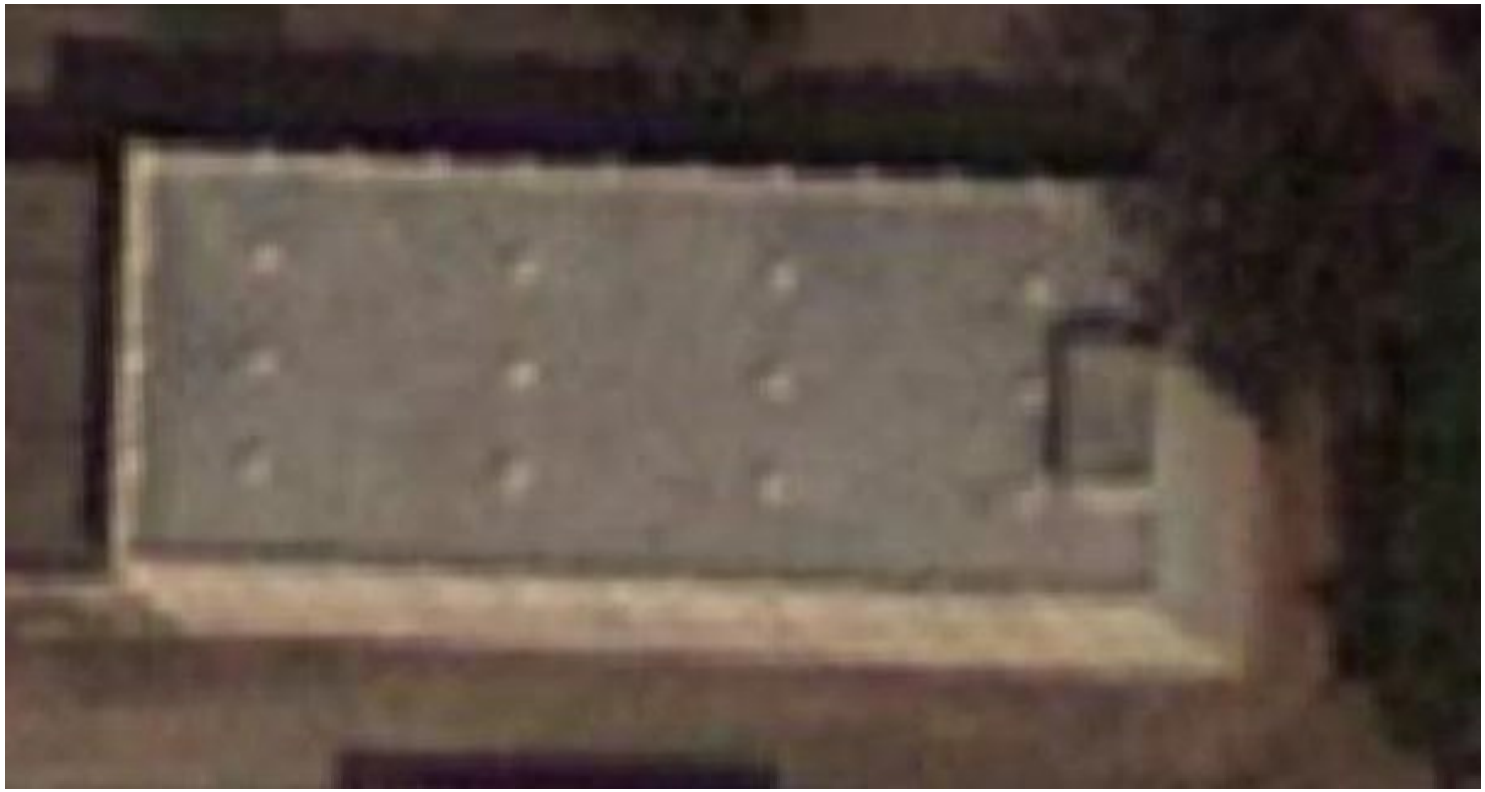


Figure 11: 2D image of building

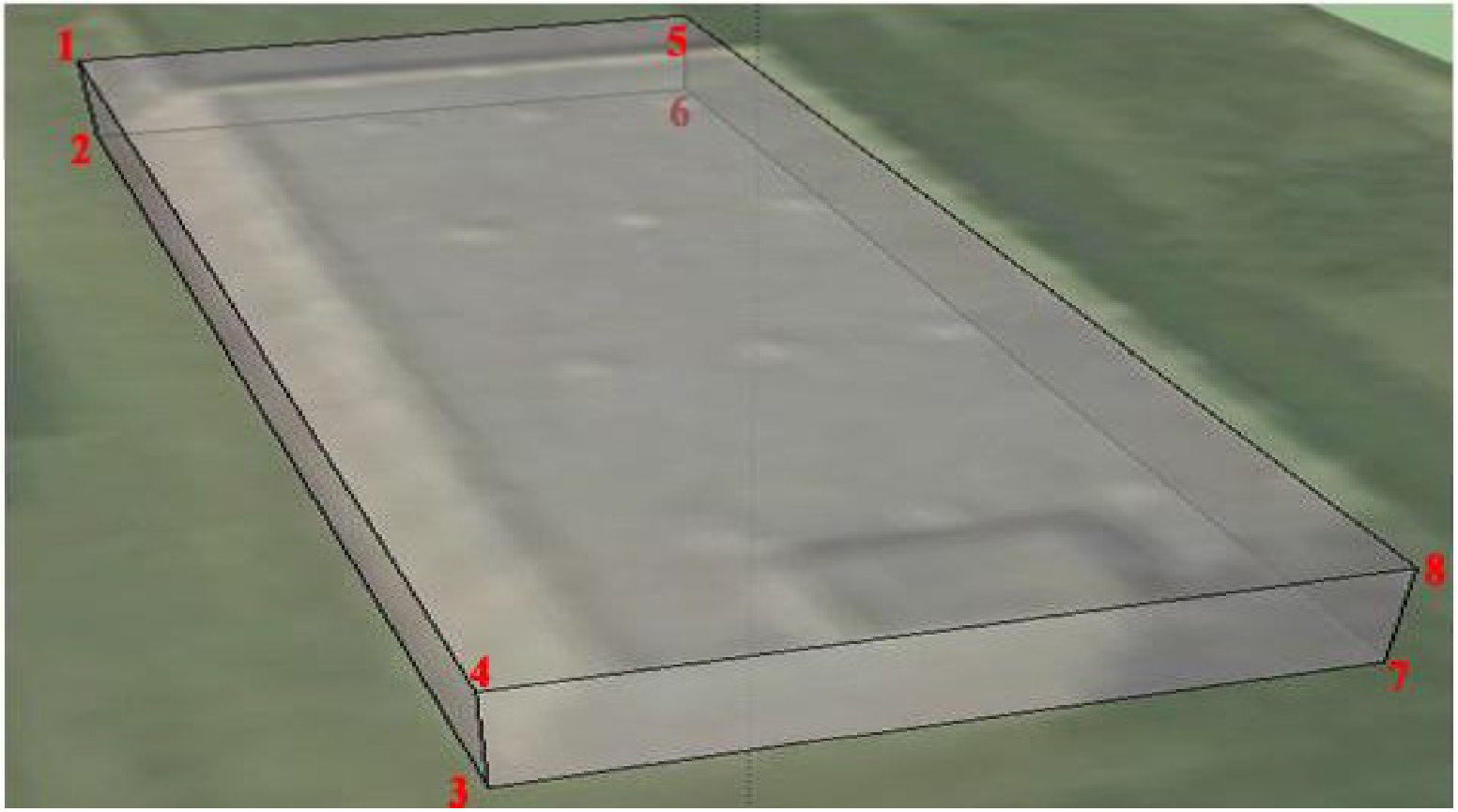


Figure 12a: horizontal traversing of underlying object

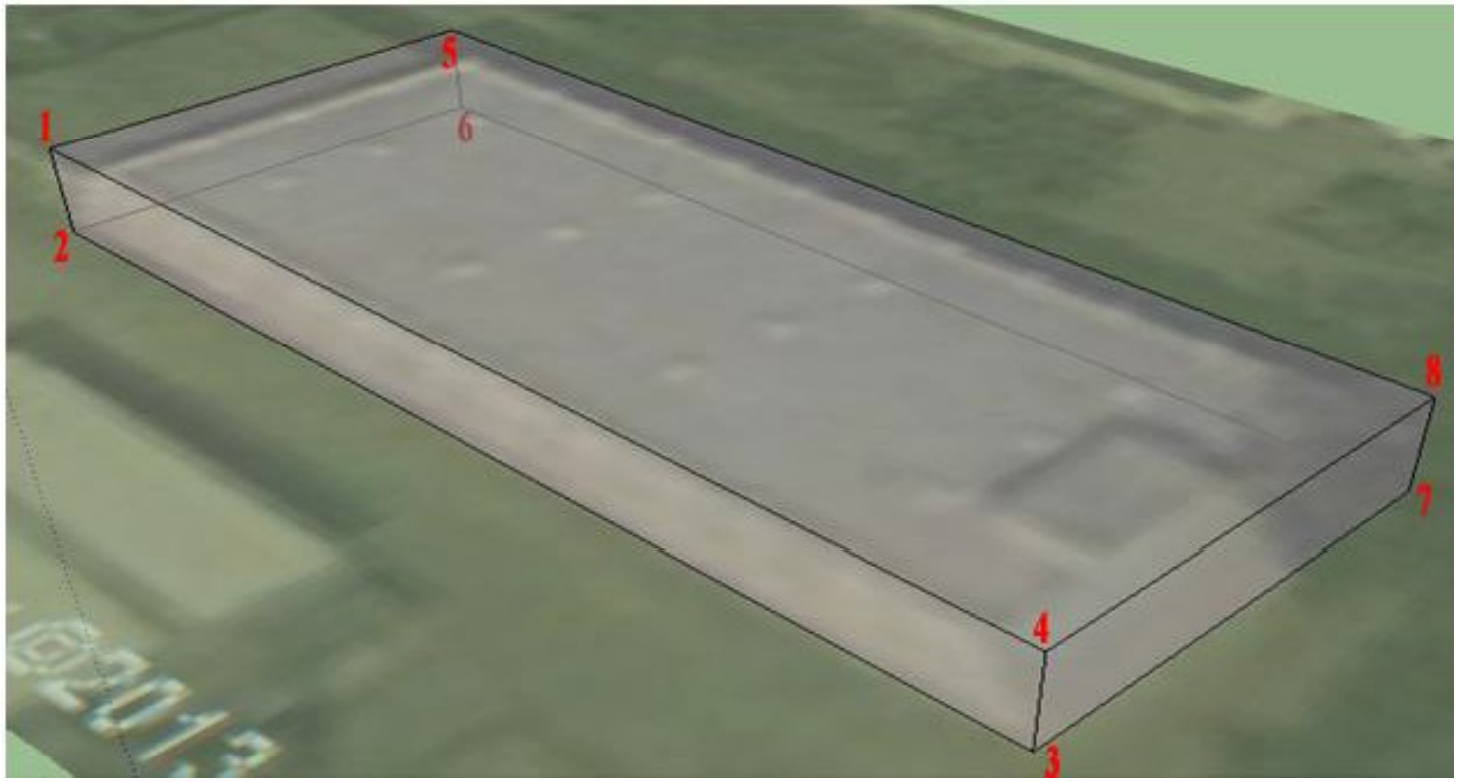


Figure 12b: horizontal traversing of underlying object

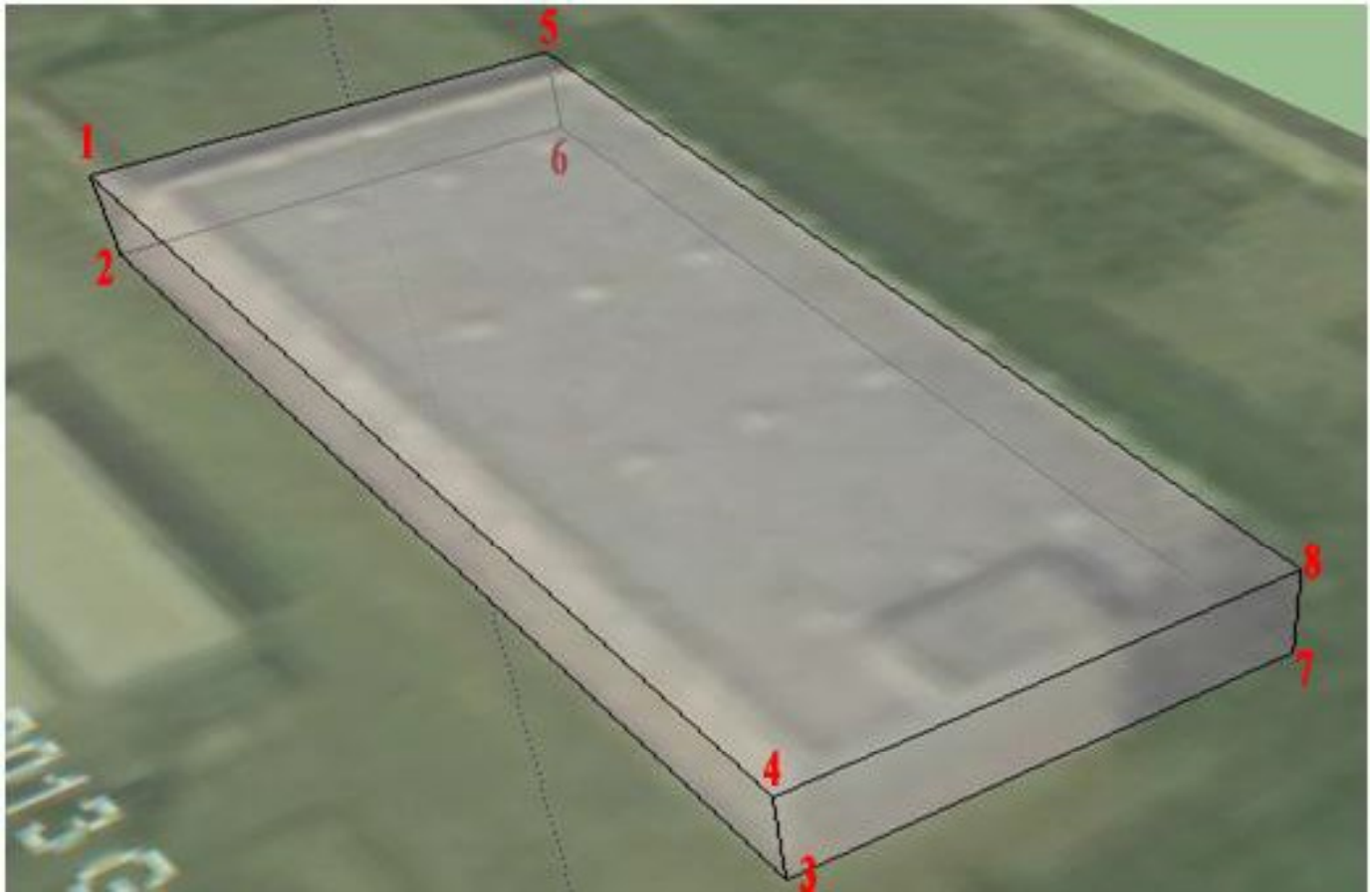


Figure 12c: horizontal traversing of underlying object

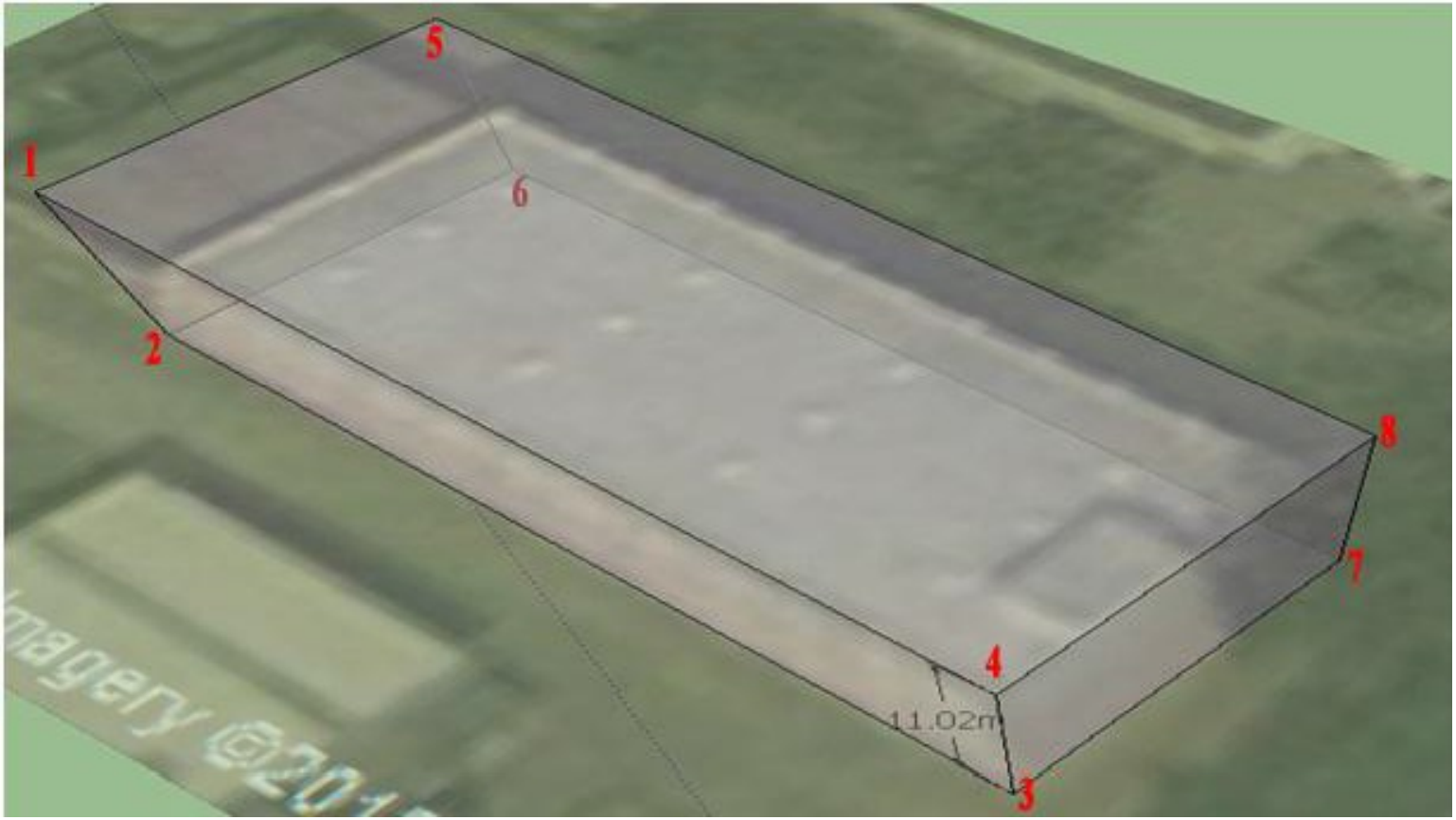


Figure 13: final 3D model of the building

- Using this method heights of other buildings were calculated and 3D model of IIT Roorkee campus area was created. Table 2 shows height of the buildings calculated using above proposed method.

Building Name	Calculated Height (m)	Actual Height (m)
Civil department	11.100	11.820
Geotechnical	10.780	11.100
Geomatics	7.730	7.900
Building in front of Geomatics	11.020	11.560

Table 2: Calculated and actual height of buildings using proposed method

- Above table present the calculated height according to proposed method and the achieved accuracy varies between 2%-6%.
- Figure 14-18 shows 3D models created using this method.

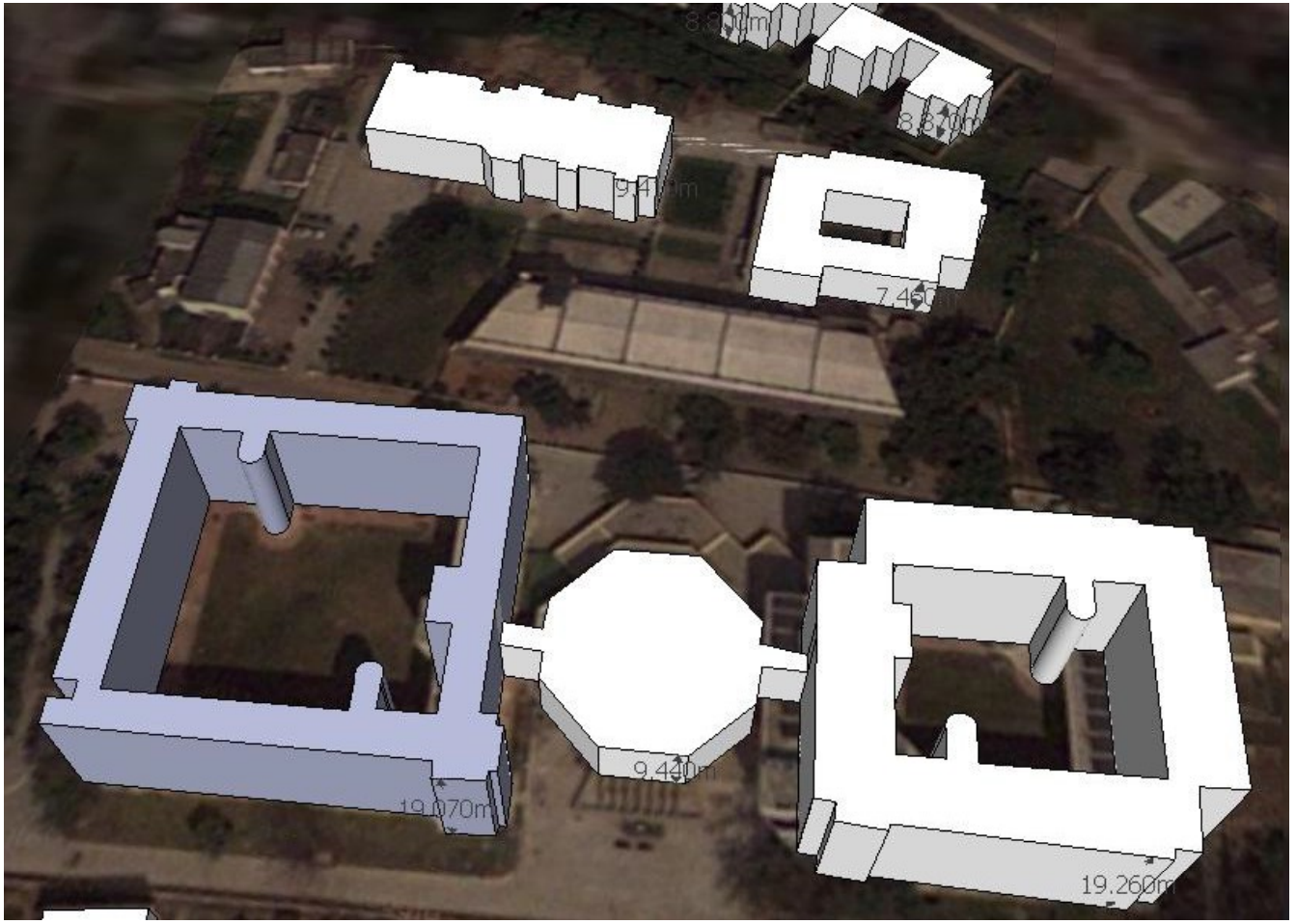


Figure 14: 3D model of Kasturba Bhawan

Figure 15: 3D model of civil department

CONCLUSION

- The current study shows that the 3D spatial information and building features can be accurately extracted from high resolution single satellite image by reverse engineering process.
- This paper starts with implementing a developed concept of 'single satellite image based 3D modelling' and by working on the limitation of the existing concept a detailed 3D modelling method is developed for building extraction and height measurement from single satellite image using the well known concept of perspective geometry.

Thank you