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3D GIS – RETROSPECTIVE FLOOD VISUALISATION

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Abstract: This paper discusses the possibilities of 3D GIS to analyse the Kerala Flood 2018. The study area is Meloor Panchayath, Thrissur District, Kerala, where huge destruction happened and the flood level was up to double storied buildings. 3D models can communicate effectively and it can be used to study the flood inundated area and can measure the destruction caused. The ArcScene 3D capabilities are tested and it came out to be not that effective. Therefore multiple software was used for creating an aesthetically appealing 3D model. This 3D model was used to analyse the temporal flood level and was used to create an animation video.
Keywords: 3D GIS, Flood, modeling, disaster

INTRODUCTION

Flooding occurs because of weather condition which creates a large volume of surface runoff flow that goes over the holding capacity of artificial drainages. This kind of high-intensity rainfall in a very short time can cause the problem of exceeding the limit of the infiltration capacity of soil and interception capacity of vegetation. This creates a huge surface runoff towards downslope due to gravity [1].

GIS collects data from different sources like GPS, soil samples, weather conditions, remote sensing, stream gages and also censuses. Once flooded area will be flooded again so checking the history of flood occurred areas helps us to identify flood risk areas. Using the acquired data, an analysis is done based on GIS to estimate the amount of influence and impact of each factor. GIS helps in the various process such as locating, planning, mitigation actions, aiding in response, and helps in recovery management [2]. Flood-prone areas can be founded by overlaying different layers of space hence more mitigation can be provided at the time and take necessary response. GIS is also used to display flood-related data in 2D and 3D to understand it in a better way. GIS generates maps that are used to inform the public and the government about flood events, evacuation routes, etc. [3] These records can be disseminated using internet technologies, developing interactive maps with the query option provided and updated in actual time, linked to the extra available information.

In 3D hazards like a flood can be visualized in realism. A 3D visualization project on flood was presented by [4] with the help of relevant images and overflowing water to show the land surface where the flood occurred. Köninger and Bartel 1998 states that the unavoidable part in the management of land is 3D GIS. Through 3D GIS a virtual city is made which is the natural add-on to the planning of City. In this technology, we give similar shape and depth to the objects as we see them in reality to increase the chances of understanding the environment [5].

The 3D model is a mathematical representation of 3D space. 3D models represent an important source of information in crisis situations. Some of the possibilities are visualizations and simulations of various disasters, planning evacuation, training rescue teams for emergency situations, etc. Also, 3D models record the shape and configuration of the city and they can be used to assess the extent of the damage, guiding helpers and rebuild the damaged area after a severe disasters [6]

3D visualization can be used for the presentation of hazards, vulnerabilities, and risks. It can help and improve efficiency in the decision-making process because it reduces the amount of cognitive effort. 3D modeling depends very much on the type of disaster to be presented and a group of users. The user is related to elements of risk because various users are interested in different elements of risk. The type of objects that will be modeled for a disaster situation, their representation and resolution/level of Detail are crucial in 3D modeling [7, 8].

There are many 3D modeling software but 3D modeling software with GIS capabilities is less [9]. So this study is about the way to create an aesthetically beautiful, realistic looking 3D space with floodwater inundated. Every feature in the model like building, river, and DEM will be overlaid using the coordinates and no compromise is given to the spatial accuracy, to create a 3D model. We are using software like ArcGIS, AutoCAD, Sketchup Pro, Lumion, Camtasia and using this software's 3D model and animation would be created.

STUDY AREA

Kerala gone through the heavy flood in the year 1924 which caused great damages to Property, Crops even it led to the loss of many lives. This flood started from 16th July 1924 and lasted till 18th Jul 1924 as 15th July 1924 south-west monsoon arrived in Kerala. Due to the arrival of south-west monsoon heavy rainfall occurred which led to the intense flood in many districts of Kerala. The affected regions recorded

maximum one-day rainfall on 17th July, maximum 2-day rainfall on 16th July 1924 and 17th July 1924 and maximum 3-day rainfall on 16th July 1924 to 18th July 1924. Devikulam is the place in Kerala which experienced rainstorm with 484 mm and 751 mm of rainfall on 1-day and 2-day respectively. Munnar experienced a 3-day rainstorm of 897 mm rainfall which lasted for 3 days [10]. After the tragic flood occurred in 1924, Kerala again went through a heavy flood in the year 1961. Generally, 7 to 10 days of the monsoon is the time period when water in the rivers rises than their banks which causes an overflow. But in the year 1961, there was an unexpected overflowing of rivers not only in the expected duration and intensity which resulted in a heavy flood in the State. Towards the end of July, monsoon became violent and persisted till the early days of August which affected the southern part of the State. The intensity of rainfall was gradually increased from the first week of July and it took a disastrous phase by the mid of the July in which Kerala suffered a lot. Periyar sub-basin was affected to a greater extent by the continuous and heavy rainfall which also influenced some sub-basins in Kerala. The highways were submerged in water during this period. Both the northern and southern part of Kerala was affected by this flood since the rainfall recorded was 56% more than the normal. Surveys concluded that 115 people died, more than 50,000 houses were damaged and 1,15,000 acres of fields in which paddy cultivated were affected by this flood and landslides which shows that the damage caused to a great extent (Centre water commission 2018).
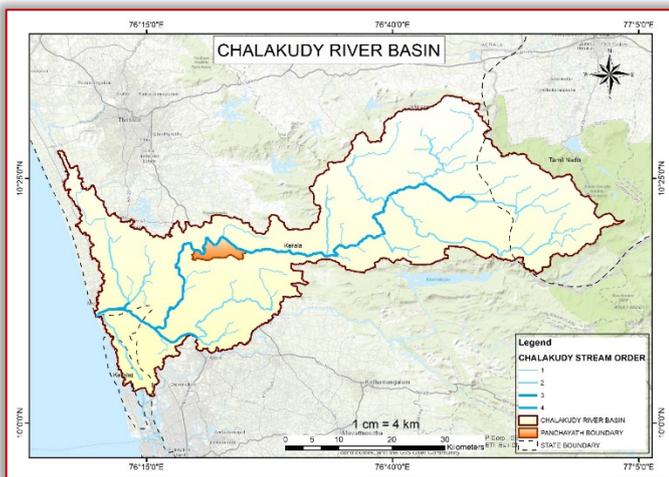
Figure 1. Study area map depicting streams and panchayat boundary

The study area is Meloor Panchayath, which is a small village in Chalakudy block. Meloor comes under the Thrissur district in Kerala State. Meloor lies on the banks of Chalakudy River, northern side boundary is completely facing Chalakudy River, which exactly measures 15.52 km². Geomorphologically, the stretch of Chalakudy river is characterized by a hilly area,

highly undulating terrain, moderately undulating terrain, low rolling terrain, transitional plain and floodplain (Figure 1).

METHODOLOGY
— Realistic 3D GIS Workflow
There is no GIS software with good quality 3D Visualisation ability. Vice-versa, there is software with good 3D visualization capabilities, but GIS abilities are not available. So for using the abilities of GIS software and 3D modeling software together, they should be interoperable. But currently, that is an issue, to solve this multiple software is used. While thinking about the basics, both GIS and 3D architectural designing is evolved from the CAD environment. So both software is good in CAD interoperability, CAD format can be converted to GIS formats or to 3D formats. Thus we selected AutoCAD as our CAD software and Sketch-up and Lumion as our 3D modeling and animation software. Then GIS layers in ArcGIS are converted to CAD and further procedure summarised below (Figure 2).

— GIS
≡ Data collection
Data used are SRTM DEM, Panchayat boundary, OSM River & building footprint polygon and flood inundated area as raster layer. SRTM DEM was downloaded from the NASA Earthdata website. Flood inundated area raster was used to check the flood heights.

≡ OSM Data Download
OSM Data is open source data hosted by an open street map. They are mainly crowd sourced data and now big multinational companies like Facebook are also funding them to create a quality map because they are also using OSM base maps in their services. OSM has roads, amenities, and Building polygons, placemarks, etc. All data is created either by crowdsourcing or by satellite image processing. Building footprints are created using satellite image processing. For this project, OSM data was downloaded using QGIS 3.4 plugin. The name of the plugin is "OSM downloader", where all data can be downloaded by drawing area of interest rectangle around our study area. The downloaded file will be in '.osm' format and it will be loaded in the QGIS interface, after downloaded from OSM servers. The downloaded file will contain lines, multiline strings, multi polygon, other relations and points.
Lines and multiline-strings include roads, river centrelines, transmission lines, etc., Multipolygons include building footprints, land use, water bodies, etc. So lines and multiline- strings are exported by right click and go to export, then select ESRI Shapefile as format and give the WGS1984 projection, then download. Building polygons and river polygons are separated using the attribute information and

separate feature class was created in ArcMap, Select by attribute and export tools were used for that purpose. Road data was also separated from transmission lines and river centrelines, and separate feature class was made.
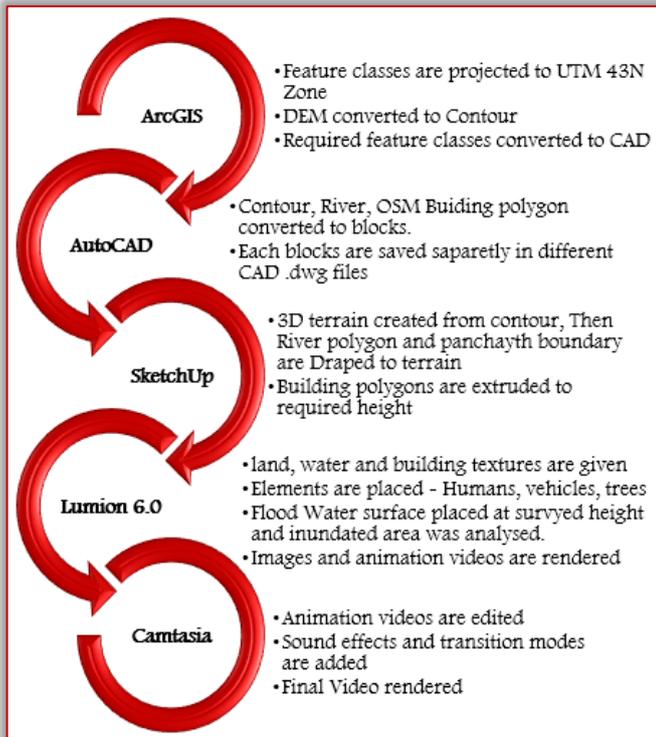
Figure 2. Workflow of 3D Flood animation

≡ **Data preparation**

OSM data was not enough, because some roads were not mapped. Road data was updated using base map services of ArcGIS and also field survey was also done. This digitized data need to be projected for every step ahead. So all the feature classes were projected to "UTM 43N Zone". AutoCAD software can handle all coordinate systems but Sketchup and Lumion are not capable of that. We need to convert the Coordinate to 2d coordinate in Meters, thus Lumion and sketch up will access the data by assuming it in the local coordinate system in the meter. The contour was created from SRTM DEM using the "Create contour" tool because DEM cannot be directly accessed in Sketchup. Required Feature classes were converted to CAD files using the "Export to CAD" tool in the conversion toolbox.

— **AutoCAD**

AutoCAD is a computer-aided designing and drafting software owned by Autodesk. It is mainly used in 2D drafting purposes. The native file format of AutoCAD is ".dwg" (drawing). The version used for this project was AutoCAD 2015. In AutoCAD, the separate .dwg files of individual feature classes were opened and it was converted into Blocks using the "blocks" command. This is done because when we import the .dwg files into Sketchup, they will behave like 'components'. Each component is meant to be in a union, without interfering with other components, so that component-wise editing is possible just like blocks in AutoCAD. The coordinates of AutoCAD space should be the same as the UTM coordinate values, cross-checking should be done.

— **SketchUp**

Sketchup, earlier known as Google Sketchup, when owned by Google, now it's acquired by Trimble inc., a mapping, and surveying the solution company. It is a 3D modeling computer program used for many drawings and 3D modeling purposes in architectural, interior designing, landscape designing, etc. We use Sketchup pro-2015, which is an advanced version with greater capabilities.

Sketchup is capable to import AutoCAD .dwg files directly using the "import" option in the File menu. Firstly, Contour was imported, which was imported and visualized as a component. Go inside the component and contour was used for the creation of Land-surface mesh or DSM. Sketchup has a "Sandbox" tool for that. So select the contours and run the "Sandbox" tool. Then, imported the river polygon and Panchayat boundary into Sketchup (Figure 3).
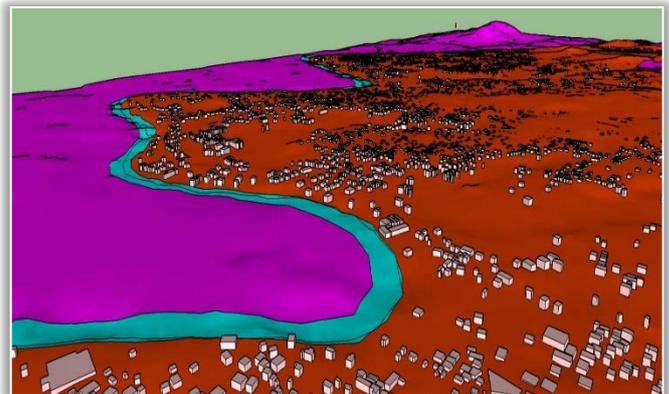
Figure 1. Sketchup 3D model

It was overlaid above the contours using the coordinates, thus it shows the GIS capability of layer overlay. Select Component of Panchayat boundary runs the "Drape" tool in the Sandbox toolset. Drape tool enables us to draw a polygon on Surface which can be differentiated by colors because, in Lumion, we can only give textures on the basis of unique colors. So Different colors were given to the river, Study area and outside study area portions. OSM Building Footprint was imported into Sketchup. Building polygon also overlaid above other layers using the coordinates, which was spatially referenced. This building polygon component was hollow polygons, so for extrusion for height, a face was needed. So Polygons are filled with face surface and all face are selected together and extruded upwards, intersecting the DSM surface, "Push/Pull" tool was used for extrusion. The extruded building polygons was having the same height, so in DSM with higher

altitude areas, building height seems to be less compared to the lower altitude region. This problem was solved by manually adjusting the height of each polygon using the "Push/Pull" tool. Colour was also given to buildings for giving textures in Lumion.

This Finished Sketchup file is saved as ".skb", which is not supported in Lumion. So it was exported to "COLLADA, .dae" file format. Sketchup was also able to create animation videos and good realistic rendering, but Lumion was added into workflow because of the better performance and availability of stock 3D elements like Trees, plants, vehicles, humans and specifically the perfect realistic water body rendering.

— Lumion

Lumion is a fast 3D rendering software with realistic outputs, they also have close to reality 3D library of many features like people, vehicles, trees, etc. It also has the sound effects and physical motion of each feature, like the movement of water waves, rain and trees leave in wind. Lumion is owned by Act 3D B.V. Lumion 6.0 was used in this project. Collada file created in Sketchup was imported into Lumion using the "import" tool in the "Objects" tab. The model will be placed in space according to the coordinate given, so it may face difficulty in moving to the coordinates which may far away from the origin, for avoiding that situation, the final stage of Sketchup file the entire 3D model should be moved close to the origin. Because in Lumion, coordinates don't matter, it is a visualization software. Textures for the ground, River, and Buildings are given from the library, it can be accessed from the "Material" tab. Categories of material textures available are nature, indoor, outdoor and custom. The colors given in Sketchup will act as the base for texture input, each color will act as a homogenous base while giving textures. Select each color and given the material color.

— Floodwater surface

The floodwater surface was created using the "Landscape" tool, where the "Water" tool is available. A Rectangle area of interest was drawn and the software renders water below that. So the water surface was drawn for the entire study area and it was raised up to the flood level. A particular reference location was selected and "Flood inundated raster" was checked for the flood height of that location. Then the surface height of that location from the origin in Lumion space is measured, there is no direct measurement tool available in Lumion, so an object was placed above the surface, which will show the height and that height was noted. Then, "Floodwater surface height = Surface height + Flood height" Thus flood water surface height was found out and previously created water surface was raised to that surface, assuming that water level is the same in all

inundated area. The water surface will cut through the terrain giving a visualization of the flooded area.

— Animation

The animation is created using movie maker tool in Lumion. Fly through using mouse and keyboard is perfect for creating the moving shots. Cinematic frames are possible to make using Lumion. The camera path was set using creating multiple snapshots that define the different camera positions. Weather effects were given from "New effects", then under the weather category, rain is available. So basically different clips were made using different weather conditions and flood levels. First, clear weather was used to create a clip for showing the conditions before the flood. Then slowly weather conditions are changed, like small rain events to thunderstorms and also temporal flood level rise also showed using the data obtained in the flood mapping section. The flood surface was raised according to the results obtained during the flood mapping. The camera focal length was adjusted to occupy maximum details. Sound effects were also added from the sound library, Thunderstorm sound and other background sounds are so realistic in Lumion environment. Each clip was rendered out of Lumion in the ".avi" format.

— Camtasia

Camtasia is primarily a screen recording software for creating video tutorials, it is owned by Techsmith. It also has video editing capabilities with good tools for inputting in video text and images. In this research, Camtasia Studio 8.4 was used. Camtasia editor has the industry-standard facility like the "timeline" interface, which enables drag and drops facilities for multiple tracks. Rendered clips were added into the timeline, then it was joined together using transitions for continuity.

RESULTS AND DISCUSSIONS

— 3D model

The 3D model is as shown in Figure 4 the buildings, river, and Topography are everything spatially accurate, it was created from the shapefile/Feature class from the GIS platform.

Figure 2. Final output of the 3D model

But Trees and all other elements are placed randomly to boost the visual appearance and to get the relative size comparison while flood happens, forgetting the impact of the flood.

The floodwater surface was the same as the flood inundated area found in the field.

Figure 3. Floodwater surface

Figure 4. Flood inundation visualization

— **Beneath a Flood**

Where flood mapping gives the 2D map and spatial variation of a flood, suppose we need to analyse the height aspect and feature submerged by water, a 3D model is a great tool. By placing elements like peoples and vehicles, we can compare and analyse the impact of the flood (Figure 5). All 3D elements in Lumion are in scale with the real environment, if the model from Sketchup is saved in meter, then every element placed in Lumion will be proportionate to the environment. .We are able to measure the flood height of every area as shown in Figure 6. This will help to understand the dangerous situation of floods. The elements placed like 3D human and Car will communicate the flood height and its impact, every element in Lumion are in standard size according to the unit selected in the SketchUp model. Flood underwater visualization can also be created using Lumion (figure 7). This visualization helps to communicate the impact of the flood on the masses. This visualization demonstrates the destruction happened. Weather condition, sun angle and cloud thickness, etc. can also be changed according to match the situations during flood events. The above images were rendered out of Lumion using an image rendering tool (figure 8).
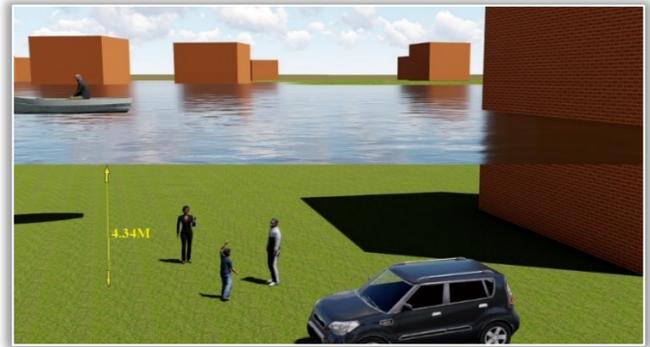
Figure 5. Analysis of features drowned by the flood

Figure 6. Flood inundation visualization

— **Animation**

Animation showing the temporal change of water level and flood inundated area was created using Lumion and Camtasia software. Rain effects and required sound effects where created in Lumion and Camtasia. Few frames of the animation are showed in figure 9 and figure 10.

Figure 9. 3D Visualization

Figure 10. Final Animation video

CONCLUSIONS

Using 3D GIS it was successful to recreate the flood and analyse the situation and losses during the flood. It was very helpful in analysing disaster events. Capable 3D GIS software was not available in the market and this workflow will help several enthusiasts for future research. In disaster preparedness, taking recent flood as a benchmark, planning for flood events was done. Relief camp location and Evacuation priority were calculated and according to that safest route avoiding flood was developed. This system can be used in future flood events for evacuation planning and it will help the disaster preparedness planning for Panchayat. This research found the flood inundated area and temporal change of flood, using that map was prepared. This map will facilitate future uses in disaster preparedness and land use planning for effectively using the flood plain

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