Dynamic 3D Model Construction using Architectural House Plans

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***Abstract*—The paper presents a complete approach to a dynamic 3D model construction from 2D house plans. This tool assembles 3D models and overlays virtual model on the real 2D blueprint of a house (architectural or hand-drawn). Key content of this research covers three dimensions which are; Wall detection and Wall modeling, Roof detection and Roof modeling and Template matching of Doors/Windows. The end result will be mainly based on Image Processing and Augmented Reality technologies. This tool lets users easily manipulate 3D models in real time through their smartphones and to showcase architecture models are in an entirely new way.**

Keywords*— *Image Processing; Augmented Reality; Dynamic 3D Modelling

I. INTRODUCTION

2D floor plans lack aesthetic appeal. So it is almost difficult for an ordinary person to imagine a new design of a house and visualize in their mind. Architects may hire CAD programmers for this purpose. However, the cost is high and consume a considerable amount of time. The major problem faced by the clients is “Unavailability of an app that is made for clients which can build the 3D model on top of a blueprint (house plan). Moreover, design the interior without an aid of an Interior Designer”.

Initial step of the research is to extract values from the architectural plan (blueprint) through image processing to detect walls. For this, we identify corners of the floor plan and plot them on a graph as a graphical representation. Then x and y coordinate values of all points are extracted and written to a text file. The roof of the house is detected using intersection points of lines by calculating the angle. Coordinate values are obtained from the points. Template matching algorithm detects doors and windows of the house plan. 3D modeling part is operated in "Unity" game engine using the coordinate values of the text file. Finally, the 3D model is augmented using several computer vision algorithms.

II. BACKGROUND

A prior study provided an in-depth investigation of product design in 3D modeling scenarios and how to enhance those using AR and design metaphors for augmenting drawing tools during modeling [1].

This research contains two major sections,

- Creating a 3D Model from a 2D House Plan.
- Visualization of the model in real time using Augmented Reality (AR) and Virtual Reality (VR) technologies.

Moreover, these technologies improve the visualization and interaction of a building or infrastructure design and construction process and also the communication and innovation within research [2].

The typical approaches to 3D modeling software packages include AutoCAD 360 Pro, Sketch Up Pro, Home Design3D and Floor Planner. Most of the time these methods are complex and has a long learning curve. In this paper we suggest a novel approach which creates 3D models in real time without complex tools or user training.

III. METHODOLOGY

Image Processing and Augmented Reality Technologies will be used to achieve primary goals of this project. Augmented Reality (AR) is a technology which 3-D virtual objects are integrated into a 3-D real environment in real time [3]. Recent advances in computer interface design, and the ever increasing power and miniaturization of computer hardware, have combined to make the use of augmented reality possible in demonstration testbeds for building construction, maintenance and renovation [4].

The research methodology is discussed under three components,

- Wall Detection and Modeling
- Roof Detection and Modeling
- Template Matching of Doors/Windows

As the initial step, clear images in elevations of the house plan should be captured from the camera and it is validated to avoid capturing a low-quality image. Once an image has been captured as shown in figure 1 is sent to the server, it is passed

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through a number of computer vision algorithms to extract information. First, a dilate operation is applied to remove finer details like text. This dilate operation can be performed multiple time to remove more unwanted details as shown in Figure 2.

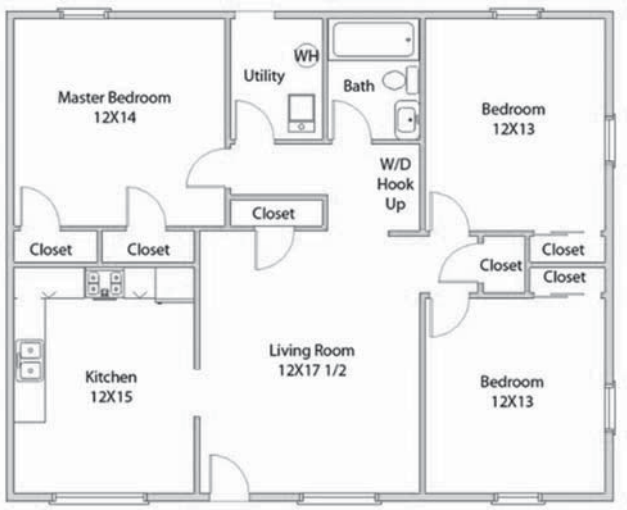

Fig. 1. A Captured floor plan

A. Wall Detection and Modeling

Image Processing technology and OpenCv 2.4.9 library in Python version 2.7 is used to detect walls. The Harris Corner edge detector is used to extract corners of line segments. Captured image of the floor plan is the input for this purpose. It runs the function cornerHarris to detect corners using the Harris-Stephens method. Every corner is depicted in red color points as shown in Figure 2 The intersection of two edges; it represents a point in which the directions of these two edges change. Hence, the gradient of the image (in both directions) have a high variation, which can be used to detect it [5].

All points of corners are extracted and graphically represented using a graph. After analyzing all coordinates, it was clear that four coordinates were received per one corner. However, we developed an algorithm to detect only the longest line segment pixel coordinates to remove all of the "double thickness" lines caused by detection of both the inside and outside of a wall. All extracted coordinate values are written to a text file to construct walls.

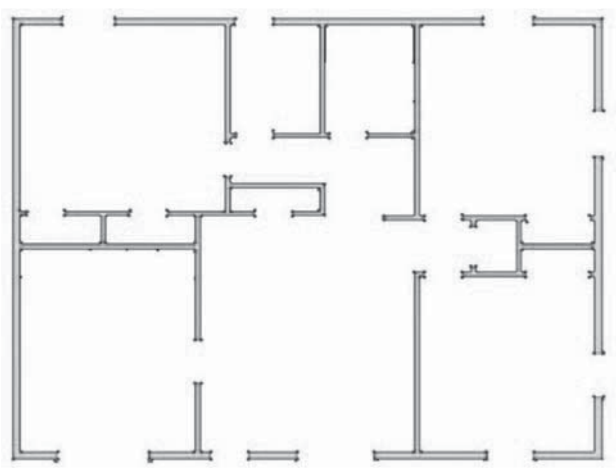

Fig. 2. Extracted features and detected corners from Harris Corner Edge Detector

Wall Modeling part is executed in Unity 3D to build a wall by extruding line segments upwards according to specific coordinates. Here we start this procedure by having a plane for the floor, manually setting the Y location so that wall prefabs fit well when they have a y position of 0. Since there would be no movement on the Y axis all, we are concerned with the X and Z locations of the walls. In this research component, we use an algorithm for building walls at runtime by reading coordinates detected through cornerHarris function. The development of this area was improved by applying Mobile augmented reality systems (MARS) provide this service without constraining the individual's whereabouts to an especially equipped area [6]. Augmented Reality is then used to overlay the virtual 3D structure on the real 2D diagram.

B. Roof Detection and Modeling

Image processing technology is used to detect the angle of roof, type of roof and size of the roof. Input image for this algorithm is captured images of front elevation and side elevation of the house plan. Captured images are first executed in Canny Edge detector to detect line segments. The Canny algorithm is an optimal edge detector algorithm that marks as many actual edges as possible and an edge is marked only once [7]. Then the binary image which is a result of the above algorithm is passed through Hough Transform Algorithm to extract information. It only returns an array of (rho, theta) values. \rho is measured in pixels and \theta is measured in radians. This algorithm is run over the detected features, and the length and angle of each line are calculated. Angles are restricted to between 0° and 180° to ease the matching step. Hough Transform Algorithm is used to detect the roof angle (rho, theta) and return detected multiple line segments with slightly different perspectives. Figure 3 shows the resulting image. Fourth argument is the threshold, which means minimum vote it should get for it to be considered as a line. Number of votes depend on upon the number of points on the line. So it represents the minimum length of line that should be detected [8].

Bitwise – OR operator is used to remove unwanted line segments, and it is passed through several logical algorithms to mask the image. To reduce the number of line segments further, additional passes of the algorithm can be run, with higher thresholds. It returns the specific line segments which include only the roof as shown in Figure 8. Finally, the main coordinates of the corners are detected and written to a text file.

Fig. 3. Detected angles of the roof

Roof modeling part is executed in Unity 3D by extruding angled roof segments in x, y, and z coordinates respectively. Roof angle and roof sizes are extracted from the text file coordinates passed from Image Processing algorithms according to desired elevations. After reading all values, computer vision algorithms are developed to build the roof in run time. This works for fairly basic roof structures, not complex types. Users can also view the interior structure of the house by removing roof option provided in our tool.

C. Template Matching of Doors/Windows

In this process, OpenCV template matching algorithm is used to extract doors and windows in captured floor plan images. This is a technique to find areas of a source image that are similar to a template image. Applications of the multiple match template technique range from tracking of multiple independent objects to several pose variations of a single object [9].

Template matching algorithm is used to detect various template images of Architectural notations for doors/windows. The shape context at a reference point captures the distribution of the remaining points relative to it, thus offering a globally discriminative characterization [10]. Then localize the location with higher matching probability and draw a rectangle with different colors around the area corresponding to the highest match. After detecting all the positions where doors and windows are placed, OpenCV color extraction algorithm is applied to extract door and window areas separately. In this color extraction algorithm, we provide the color range to detect doors and windows places. As a result, it provides two images as shown in Figure 4. Middle point coordinates are identified in order place the 3D models of doors/windows.

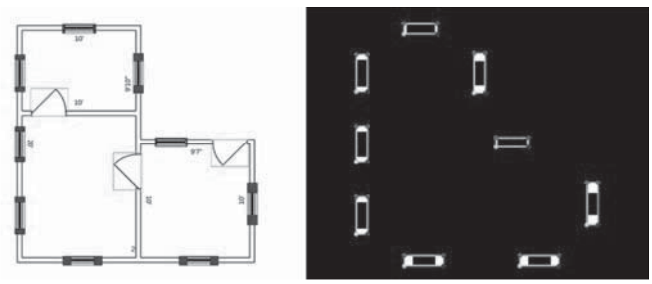

Fig. 4. Detected Doors/Windows and their Coordinates

Augmented Reality presents information in a correct real world context. To achieve this, the system needs to know where the user is and what the user is looking at. Normally, the user explores the environment through a display that portrays the image of the camera together with augmented information. Thus in practice, the system needs to determine the location and orientation of the camera. With a calibrated camera, the system is then able to render virtual objects in the correct place.

The term tracking means calculating the relative pose (location and orientation) of a camera in real time. It is one of the fundamental components of Augmented Reality [11]. Figure 5(left) shows a dynamically created virtual model on top of a tracker. Marker based Augmented Reality is used for this purpose Figure 5(right) shows the tracker used to augment the 3D model.

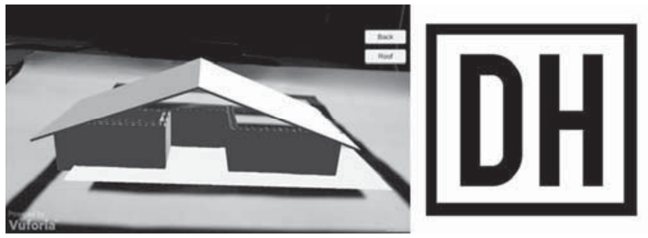

Fig. 5. Augmented virtual model on top of a tracker

IV. Results And Discussion

The main result of this research is generating a 3D model by extracting details from the architectural plan. This is an Android based mobile application. In the analysis, we used Vuforia library to augment the 3D model. Vuforia is an Augmented Reality Software Development Kit (SDK) for mobile devices that enable the creation of Augmented Reality applications [12]. Track planar images which best fit our requirements is the marker based tracking. Vuforia library uses Computer Vision technology to recognize and track planar images (Image Targets) and simple 3D objects, such as boxes, in real-time [13].

There were some problems when implementing this application. Issues in extracting elevation details arose when the environment did not have adequate lighting, or if the design space surface was reflective. This issue was minimized by laying low gloss white paper on the surface. Another hard task was capturing clear images from a camera. Images obtained from were not high-quality images. As the solution, our team had to purchase a Unity plugin which gives a higher resolution when capturing photos. There are obvious limitations in the tool such that it cannot detect some unusual complex features in the architectural blueprint, a higher computational time when detecting values and accuracy related problems. But the issues need to be modified to support a greater amount of features in the architectural plan. The roof algorithm is fairly basic, and it was beneficial to remove the roof to see the model internally. Furthermore, the user can also view the house using Virtual Reality technology by using a Virtual box or any other similar device. Our team used Google VR SDK for that purpose.

V. Research Findings

According to Wall Detection and Wall Modeling research components, it was revealed that Wall Detection can be effectively done using a new algorithm to detect only corners of the floor plan. It provides more accurate results than detecting the whole line. It was also noted that the detected coordinates should run through several computer vision algorithms in order to remove dilation between two consecutive points. This will lead the research to get more accurate results.

VI. FUTURE WORK

Other forms of implementation could be carried out during the 3D model development such as interaction with other data formats such as AutoCAD. Manipulate dynamic 3D models for multistore residences and buildings would enhance compatibility of the tool. We hope that this can be improved to achieve the maximum accuracy for complex building areas with some effort and reduce computational time for processing. Creation of more complex roof model extension to the current tool would be beneficial to the delivery of accurate and detailed models. We hope that this product will be more useful for Architecture and other design application areas.

VII. CONCLUSION

In this research paper we have presented a tool to extract values from 2D blueprint of a house (architectural or hand-drawn) and to create 3D models in real time. The main outcome of research is to create 3D models dynamically and give customers the ability to customize their prefabricated home interiors while maintaining the design of the exterior structure [14]. Augmented Reality offers a real visualization of the final product for customers, enabling clients to create their dream homes. This study proves that a 3D model can be generated dynamically from an architectural house plan, without human assistance to provide values manually.

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