CATAN Resources Projection

Final project by

Tamir Blumberg & Amitay Regev

tamirblu@post.bgu.ac.il | amitayr@post.bgu.ac.il

Introduction

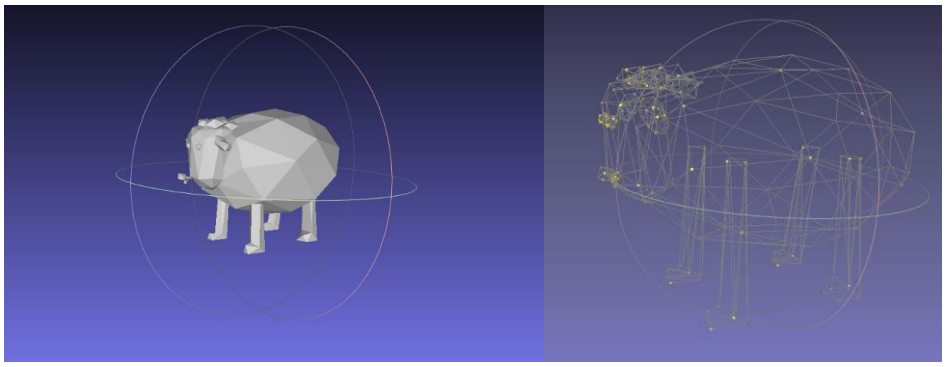
This project starts with a passion for the famous board game Settlers of Catan, aka CATAN. This game already has a nice appearance and even 3d objects in it like small buildings and plastic mini-roads. In addition to that, our project tries to take the 5 resources (Lumber, Brick, etc) presented on paper cards in the game, and screen them on top of the player's table. Putting more life and realistic feeling to the game.

Workflow

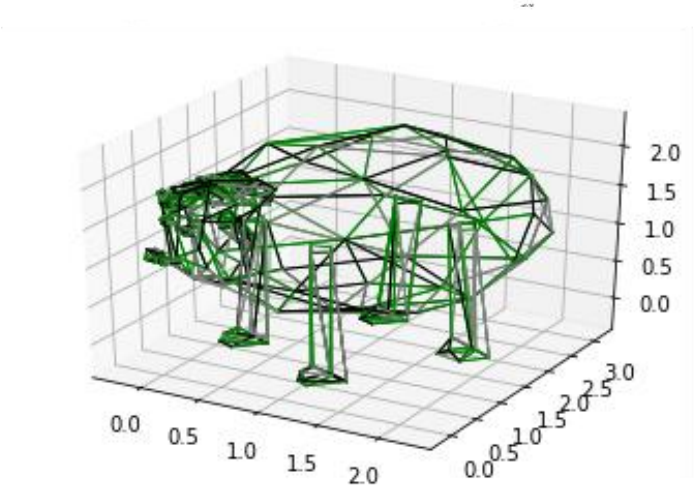
3D Models and Sampling

Initially, we began the process with 3D models of objects that represent the desired resources, in the process we searched the internet for most suited existing 3D models. Our goal was to represent these models in the form of a graph. To accomplish this, we utilized a sampling process based on MeshLAB which enabled us to convert the models into a discrete number of vertices and edges connecting them.

We encountered an issue during the process where the 3D models we were working with were overly complicated, containing hundreds of thousands of vertices and edges. This complexity resulted in Unnecessarily slow processing. We overcame this problem by utilizing sampling methods to suit the models to our specific needs. For example, we removed certain vertices based on a threshold; vertices with a proximity smaller than the threshold were reduced to a single vertex. Ultimately each model was reduced to around a thousand vertices, a significant improvement.



Another challenge we faced was ensuring that all resources were of a similar size. The models we came across during our search for suitable 3D models were highly variable in size. For example, our mortar model was based on real-sized construction building blocks, which were significantly larger than our Catan board. To address this, we centered, stretched, and squeezed the models to fit within a 3x3x3 3D box. This process made the models of similar size, resulting in the future more intuitive positioning and projection.



While the process we have described is complex and requires a significant amount of processing power and time, it only needs to be performed once. To improve the performance of the final application, we converted the final models' graphs into text information and then into a NumPy array in Python. This approach allows us to work with and plot the models more easily and efficiently.

Photo Shoot

We obtained an original game board of Catan and copy of chessboard printed on A4 paper. Then took over 40 photos of the board from various angles. To be even more precise, 20 pairs of photos (one pair shown below), when each pair first object shows the clean Catan board on a table, while the second one shows the exact same setup from the same angle, but with the addition of our A4 chessboard.

This photoshoot setup served two purposes. Firstly, it allowed us to perform camera calibration. Secondly, it enabled us to select a final product; a chosen environment-photo that will represent our game, onto which we will project the resources.

Camera Calibration

It is now time to extract the parameters of the exact camera used in a photo shoot. With the help of cv2.calibrateCamera just like in HW1, one can extract the camera matrix and external factors.

During the calibration process new challenge appeared, cause by man-made folds in the paper chessboard. These folds made it less smooth than it could be, making it un detected (For algorithms that recognize perfect flat and symmetric chessboard patterns). We found a bypass solution, using good old Paint software to manually cover the lower half of the board and get better results with more flat 5X8 chess pattern (as you can see below).

Projecting the resources

To project the sampling of 3D models onto specific photos, we combined the techniques we have described above. Using the camera matrix and external photo factors, we employed homogeneous coordinates to convert our 3D models into 2D projections on our selected images, utilizing the perspective projection in the homogeneous form method.

(As described below)

$$\begin{pmatrix} x_i \\ y_i \end{pmatrix} = \begin{bmatrix} \tilde{x}_i \\ \tilde{y}_i \\ \tilde{z}_i \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} x_p \\ y_p \\ z_p \\ 1 \end{bmatrix}$$

Cartesian point on the image

Homogeneous coordinates of the point on the image

Perspective projection matrix

3D Cartesian world point in homogeneous form

$$\begin{pmatrix} x_i \\ y_i \end{pmatrix} = \begin{pmatrix} \frac{f \cdot x_p}{z_p} \\ \frac{f \cdot y_p}{z_p} \end{pmatrix} = \begin{pmatrix} \frac{\tilde{x}_i}{\tilde{z}_i} \\ \frac{\tilde{y}_i}{\tilde{z}_i} \end{pmatrix} = \begin{bmatrix} \tilde{x}_i \\ \tilde{y}_i \\ \tilde{z}_i \end{bmatrix}$$

CONVERSION FROM HOMOGENEOUS TO CARTESIAN FORM

$$\begin{bmatrix} \tilde{x}_i \\ \tilde{y}_i \\ \tilde{z}_i \end{bmatrix} = \begin{bmatrix} f \cdot x_p \\ f \cdot y_p \\ z_p \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} x_p \\ y_p \\ z_p \\ 1 \end{bmatrix}$$

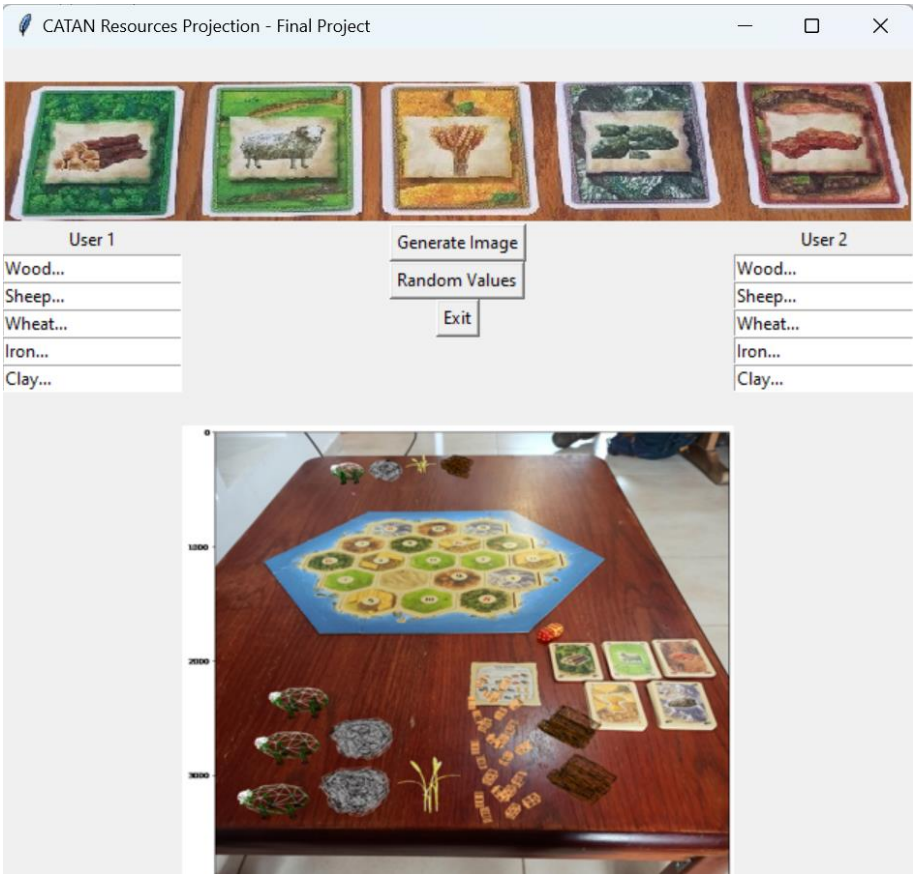
MATRIX MULTIPLICATION

This process involved projecting each point in the model (thousands of vertices) onto the 2D image plane and plotting the result using a suitable coloring method, resulting in this visually stunning projection.

User Friendly application using Tkinter

It's now time to take some more efforts and make POC user friendly interface that wrap everything together, hold and easy to use exe file that provide short running time. To make sure that preliminary calculation used to the max. 3D Models sampling and Camera calibration result were export to files.

Using TKinter, standard python library for interfaces, we create the software mentioned above. It gets user input 2X5 integers for 2 players and 5 resources each and output the photo of the table with projection of the resources top.



Conclusions

The results of the project have been met successfully; we have accomplished our primary objectives with great success. Even after undergoing the sampling process, the models retain detailed and clear, which are still preserved after projecting the objects.

Our user interface is a great example of the power of this technology. It's a proof of concept that we can use to enhance the gaming experience. For new users, using the existing code and photos of their table (for calibration) are all they need to bring their game setup to life.

Most importantly, our project has demonstrated the incredible potential of this technology. We've shown that we can create lifelike virtual figures without ever having to create physical ones. This opens a world of possibilities for gaming, education, and many other fields. We're excited to see where this technology will take us!

References

- Course Lectures and Practical Sessions
- Course Assignments