Predicting Floor Plans Using Images

Project Sponsor: Prem Radhakrishnan, Co-founder and CEO of geoConvergence

Team Members

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Project Description and Scope

The team was initially given two options from the project sponsor, Office Space Management and Predicting Floor Plans. After deliberation, the team decided to pursue Predicting Floor Plans Using Images.

The following is the description provided by the sponsor:

The purpose of this challenge is to predict the internal configuration of structures such as buildings by only using external satellite photographs of the building taken from various angles. Using the shape, size, and external characteristics of the building (such as the number and spacing of windows), the desired methodology should be able to produce a model of the building to include basic structure system (frame vs. load-bearing systems), the construction materials and likely material properties, structural detailing, and any other feature

> *responsible for the overall structural strength of the building. A machine learning model trained with a sufficient database of known buildings, along with constraints to represent current construction processes, could potentially yield a machine learning model that can use a minimal amount of external visual clues and then automatically produce a digital file of the most likely structural design of the building. The prediction of the number of configurations of non-load bearing partition walls would also be a benefit and should be regarded as an additional secondary challenge.*

This project can benefit first responders and firefighters. With this model, a fire fighter could take an image of a building and see the modeled floor plan of a building before entering to help them with rescue efforts. The project sponsor also highlighted other projects where this work can fit in, such as the IU Crisis Technology Information Lab First Responder Smart Tracking Challenge.[1] Other companies that have not yet been identified may also find this information useful.

Project Goals

Team members were motivated to create reasonable and actionable goals for the current semester based on their own experiences and judgement. The team successfully utilized their technical skills (e.g. web scraping) and personal skills (e.g. we reached out to another team for useful datasets). During the whole process, the project sponsor has been very helpful and proactive. After selecting the particular project and consulting with the sponsor, we were able to settle on the following goals:

1. Determine what would be the targets in the dataset. Because “internal structure configuration” is a high-level concept, we need to specify what would be the exact 'labels' for the configuration. For example, 'single-family residential' and 'office' could be some of the categories used. For this task, we will need to consult with a structural engineer or an architect.

The team decided on using exterior images of buildings in Monroe County, IN. From there,

[1] *First Responder Smart Tracking Challenge.* (2021). Indiana University Crisis Technologies Innovation Lab. https://ctil.iu.edu/frst/challenge-details.html

targets such as number of floors, square footage, number of rooms, and types of rooms were selected after reviewing multiple sets which contained information.

2. Determine what buildings/structures will be used as samples in the dataset. While sponsors may be able to provide some blueprints of some structures from their clients, it may also be feasible to use some public databases. We will again need to consult with structure engineers and/or architects to transfer the blueprints to labels.

The group decided on including all buildings in Monroe County in the database. This allows an opportunity for the next group to make a determination

3. Collect image data for the buildings. We will be using public data, e.g. NASA satellite images, Google street view, etc. However, it is normally not free to use an API for this kind of service.

The team decided on using the Elevate database from Schneider Geospatial[2], which was suggested by the project sponsor. The data for Monroe County, which included images and target variables, was scraped and stored in a database.

4. (Optional) Extract features from the images. While it is possible to build neural network models for images directly, it may also be of interest to extract features from the images to build machine learning models, such as number and spacing of windows, building size, etc.

No machine learning was performed for this project. However, lots of discussions went into what is necessary for this project. This information can be used by the next team to pick up where we left off.

[2] *Elevate by Schneider Geospatial* (2021). Schneider Geospatial. https://www.schneidergis.com/elevate

Data Availability and Documentation Repository

Data collection was done by web scraping content from elevatemaps.io using a script written in Python. The script utilized Selenium Webdriver[3] and Beautiful Soup[4] packages by navigating to the page of a specific property by its parcel number, waiting for data content to load, and recording the content into a Pandas DataFrame. Selenium Webdriver automates the control of a real web browser which was required to load dynamic content from elevatemaps' property pages, something that a basic http 'get' request cannot do. Selenium's functionality to wait until certain page content to be loaded was used to account for this requirement. Other Python packages such as Requests or Urllib were insufficient tools because they were incapable of waiting for elevatemaps' database content to be populated. Without the Selenium Webdriver, a 'get' request would return a useless empty template html file. After page content was loaded with Selenium, it was passed to Beautiful Soup to extract every possible property data feature available as listed in the table below. Data for about 52,000 properties in Monroe County, IN, were collected in total which took about 12 hours of script runtime.

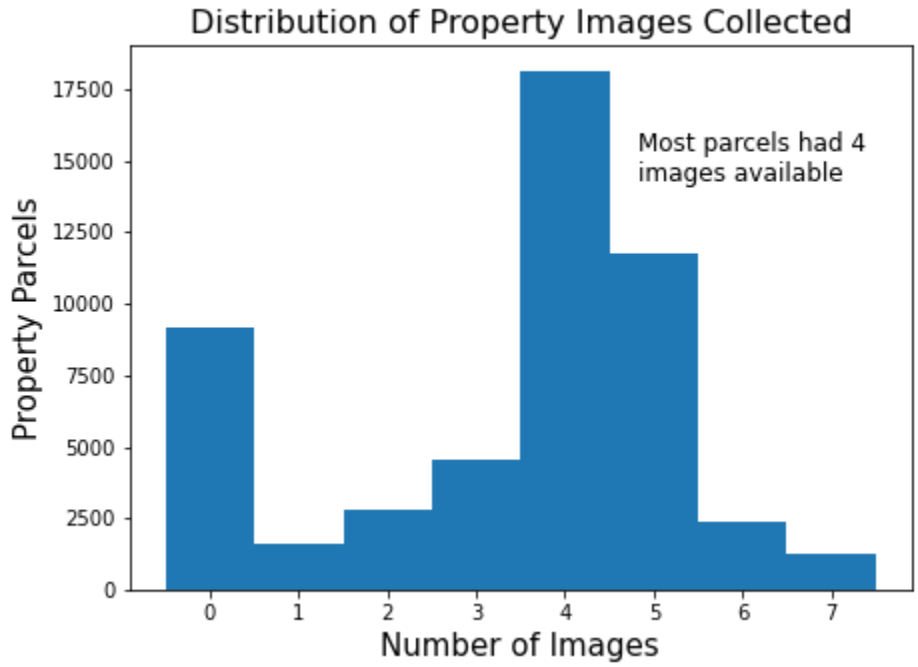
Features collected from ElevateMaps

ownerNamePRC	ownerAddressPRC	parcelNumber	altParcelNumber
propAddress	propClassCode	propClass	neighborhood
legalDescription1	township	corporation	taxingDistrict
taxingDistrictNumber	water	sewer	gas
electricity	allUtilites	parcelNumberTax	taxId
ownerName	ownerAddress	legalDescription	ov1pin
totalAcreageLanduseAndSoil	totalADJAcreageLanduseAndSoil	ov2pin	totalAcreageLanduse
totalADJAcreageLanduse	image_links	floors	bedRooms
finishedRooms	fullBaths	fullBathsFixtures	halfBaths

[3] *WebDriver* (2021, December 7). Selenium. https://www.selenium.dev/documentation/webdriver/
[4] *Beautiful Soup Documentation* (2020). Crummy. https://www.crummy.com/software/BeautifulSoup/bs4/doc/#

halfBathsFixtures	kitchenSinks	heatType	fireplaces
attachedGarages	commFixtures	commExtraFixtures	waterCoolerRefrig

Many of the properties contained multiple images, typically a few images of the exterior of the property and then a sketch of the floorplan. Below is the distribution of the number of images per property:



Additional data was obtained from the Indiana Department of Local Government Finance (DLGF) office. This consisted of the 2020 Assessor's data for parcels in Monroe County. This was obtained from discussions with the Floodplains DSIP group, who received the data from Marianne Cardwell, Director of Geoinformatics at The Polis Center. This set is a database of six tables describing all the parcels in Monroe County. It contains much of the information scraped from Elevate. It can be used to supplement the Elevate scrape.

Joining the two data sources was attempted. However, the DLGF parcel information contains a slightly different ID schema. Furthermore, the parcel data can contain duplicates for

addresses as multiple dwellings can be associated with a single parcel. If joining of the sets are needed, careful studying of the DLGF data is required.

All of our data and the web scraper are archived on the Space Management Basecamp Docs & Files section. Further documentation is archived in the message boards of Basecamp. The web scraper and further documentation were provided to the sponsor for his own archive in Bitbucket.

Results, Observations, and Findings

Since this was a new project, the majority of our efforts went into researching the domain space and deep learning techniques for image identification.

Computer Vision Research

Computer vision will be required to obtain the goal of this project. This section will be designated to tools and information that could provide assistance in the data preparation, image classification, and object detection of the project. Data preparation allows for efficient analysis and modeling. Without data preprocessing, applying machine learning models to unclean and noisy data would result in poor quality results.

Upon web scraping thousands of images, poor quality and even irrelevant photos are bound to enter the dataset. In our case, we have too many images associated with a property. Data cleaning will need to be done on these images. A possible method to resolve this inconsistency in the data is to build a preprocessing model that is able to detect and remove low quality and extraneous data. Next, data curation will be implemented to organize and manage the data. Two popular formats for organizing data for object detection are Pascal VOC[5] and Microsoft COCO[6]. The next step is to label objects in the images so that the machine learning model can properly identify and label these objects upon testing.

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[5] *The PASCAL Visual Object Classes Homepage*. (2014). University of Oxford. http://host.robots.ox.ac.uk/pascal/VOC/

[6] *COCO Common Objects in Context*. (2021). COCO Dataset. https://cocodataset.org/#home

There are many tools available to carry out the data preparation for this project. One open-source tool is FIFTYONE.[7] This is a software tool used for building high-quality datasets and computer vision models. Some of its main features include: curating datasets, visualizing complex annotations, evaluating models, working with geolocation, removing redundant images, and finding annotation errors. FIFTYONE is also easily integrated with popular coding tools such as PyTorch, Jupyter, TensorFlow, and Google Colab.

Target Variables

A good amount of discussion went into decisions about which target variables seem appropriate for this project. At the end of the process, a rough sketch of the floorplan of the building should be created. Thinking about which variables would help create this was a tricky situation.

Variables we obtained from the scraped data can be used. Numbers of floors is a vital target for this process as that will allow us to know how many floor plan sketches to create for each image. Square footage is also useful because that can help create the dimensions of the floor plan. Other items like attached garage and number of rooms can begin to fill in the sketch.

However, there are items that need to be detected that are not derived from scraped data. This is where image detection can be useful. A process for locating and counting the number of windows and doors can help to find where interior walls can be.

Our group did not have any expertise in architecture. So, deciding on target variables was a challenge. Our sponsor, Prem, helped greatly in this realm to get us motivated and in the right direction. It may be useful for the next project team to consult with an architect to develop more ideas.

Project Strengths and Weaknesses

Although it may seem like not much was accomplished, the team was able to collaboratively work to create a potential dataset. This sets up the next DSIP group for preprocessing and training. Despite our lack of knowledge in the domain space, we were able to research how to create a training set for image detection. When there were unknowns or

[7] *FiftyOne*. (2021). Voxel51. https://voxel51.com/docs/fiftyone/

questions, we were able to consult with the sponsor, Prem, and we reached out to a domain expert, Dr. David Crandall. For the future, we recommend that a student with knowledge in computer vision be placed on this project.

In terms of the project sponsor, Prem is a great client to work with, he is extremely helpful, and he understands the limitations which the students might have. Furthermore, he does research on available sources of information and shares the same to the students, which are very helpful for the students. One of the main things which we (students) could have done better is to narrow down the scope earlier. Since the project has an open scope, it became challenging for the students to finalize and plan the scope effectively. However, in the later half, we were able to set and accomplish achievable goals. Hence, one of the key takeaways for the team working in next semester would be to finalize SMART goals as early as possible.

Project Opportunities and Threats

As stated in the description and scope, this is an emergent field in data science. There are many competitions created around this subject, including the Air Force Research Library Grand Challenge[8], which was mentioned in the sponsor's description. There are many applications to this type of research, so there are many potential opportunities.

However, this is a challenging space that requires lots of research and time. If other DSIP teams are interested in this project, they need to understand that they will be tackling a smaller portion of a larger problem.

Conclusion

Computer vision is a field many of us had little experience with. Furthermore, our experience was typically in an academic setting where curated datasets are already provided. Making a dataset for image identification is a challenging task that requires a lot of thought and consideration. The team was able to narrow down the scope to properties in Monroe County and pull images and target values. From there, a lot of conversation has gone into how the project should continue from here, including preprocessing, target variables, and additional

[8] *Machine Learning Prediction of Internal Building Structures Up to $1,000,000 (awarded in 3 phases)*. (2021, September 1). National Security Innovation Network. https://unum.nsin.us/afrl-challenge-5/info

image identification tasks. This group has set the groundwork for the next group to start running.

Recommendations

As much of the base layer of work and discussion was done during this semester, the team has a lot of recommendations in how this project should continue:

1. The incoming team should work with the project sponsor earlier on to set manageable goals for the semester. This is a complicated project with many moving parts. Things are not going to go as planned and that is okay. To handle all of these moving parts, the team should designate a dedicated project manager to keep tasks and research in order.
2. One of the items identified as a challenge is that there are multiple images for a single property in our scraped data. After consultation, it was agreed that the input images for the training set should be similar to those that would be taken in the field. As such, they should be clear front images of the building. The next team should discuss creating a preprocessing machine learning algorithm that detects a building. From there, it can output a confidence value for whether it is a building. This should be applied to the properties which have multiple images. The building with the highest confidence should then be selected for the training dataset.
3. After the preprocessing is complete, a recommendation from the sponsor was for the first layer to detect the type of building: residential, commercial, or industrial. Once that is determined, each type of building may need to be treated separately with their own processes to begin to create a floor plan.
4. More conversation should go into necessary target variables. This should be done after consultation with an architecture professional. Once there is a better understanding of what goes into creating a floor plan, the team should have an easier time deciding on target variables that will help construct a floor plan.