Structure from Motion with Plants

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ABSTRACT

The purpose of this research is to evaluate three widely used structure-from-motion (SfM) algorithms. These algorithms are often the first step in software pipelines used to build 3D models from a set of images that view the same scene from different perspectives. We collected images of four plants, with various sizes and color. The images were taken using a standard camera phone. In a first experiment, we controlled the number of images used for input and recorded the algorithms' number of output 3D points. The results supported our hypothesis that complex structures are more difficult to reconstruct. In a second experiment, we controlled the background color: white and pink. We will use these results in future work to improve feature detection and matching algorithms on challenging data for SfM algorithms.

Structure-from-Motion (SfM)

SfM consists of algorithms that computationally recover 3D geometry (set of points or a mesh) from a series of 2D images. In the natural world, the location of the eyes and brain circuitry solve variants of SfM in various ways.

Computational Steps in SfM

1. Feature Detection/Tracking

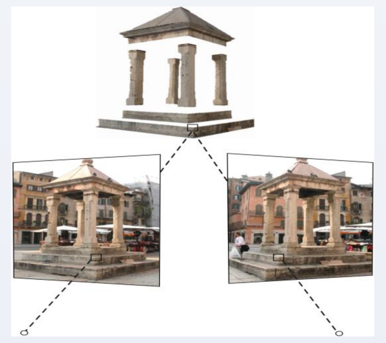
This process involves detecting and describing image features that contain useful local information (e.g., corners or high contrast edges).

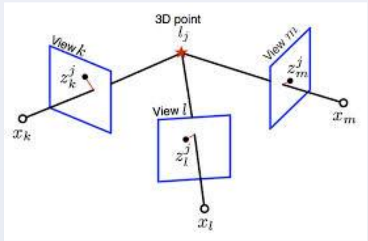
2. Correspondence Computation

This process involves matching the features between two or more images.

3. Bundle Adjustment

The final step is to jointly solve for camera locations and the corresponding 3D points in the world for the features detected in step 1.





Why is this problem important?

3D Model Reconstruction
3D Motion Matching, Camera Calibration
3D Vision, Perceptual Computer Interface
Robotics, 3D Coding of Image Sequences, Mosaics

What makes an algorithm good?

In this work, we use the resulting number of 3D points as a performance metric. We also relate the number of input images to the number of 3D points generated.

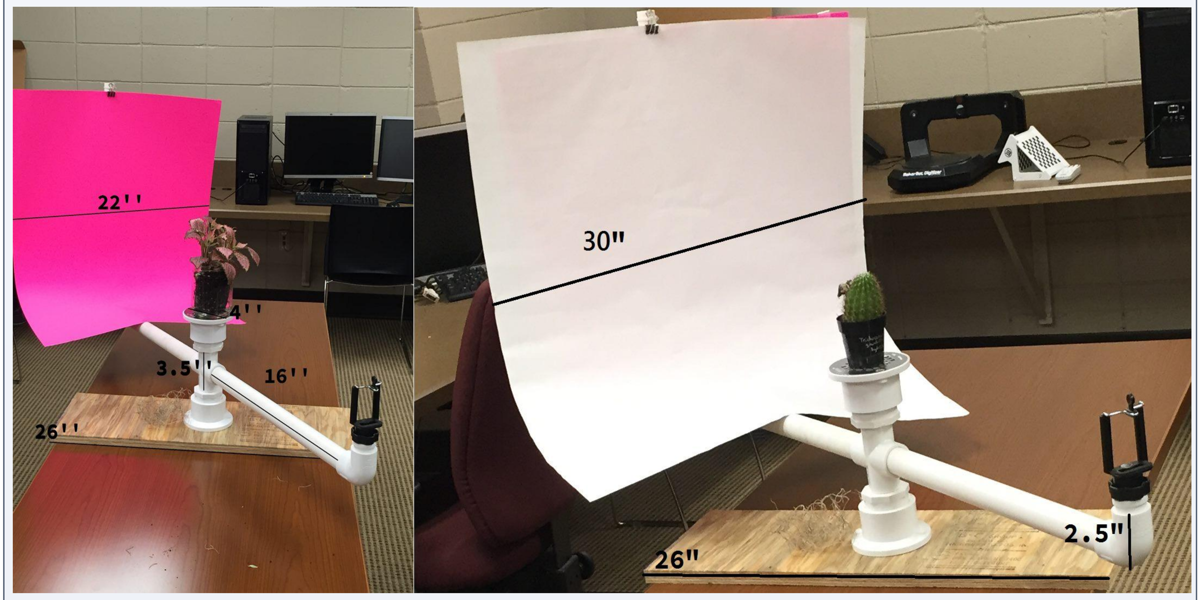
Existing SfM algorithms work well for man-made structures, where "good" features (e.g., corners, straight lines) are easily detected. In this research we focus applying SfM on plants and evaluate the performance of 3 existing algorithms.

Research Questions

1.How does the appearance and structure of a plant affect algorithm performance?

2.How does the background color of images affect performance?

Methodology



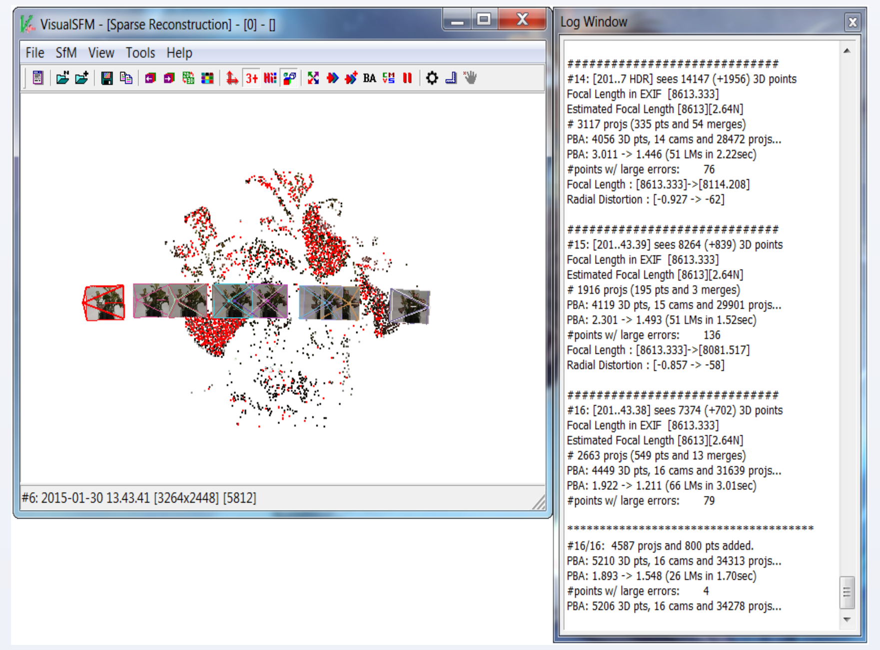
We created a rig that **holds a plant static relative to a rotating camera and backdrop**. We used two different background colors: white and hot pink.

We used four different plants to evaluate the three SfM algorithms. The choice of plants was motivated by **availability and difference in appearance**.

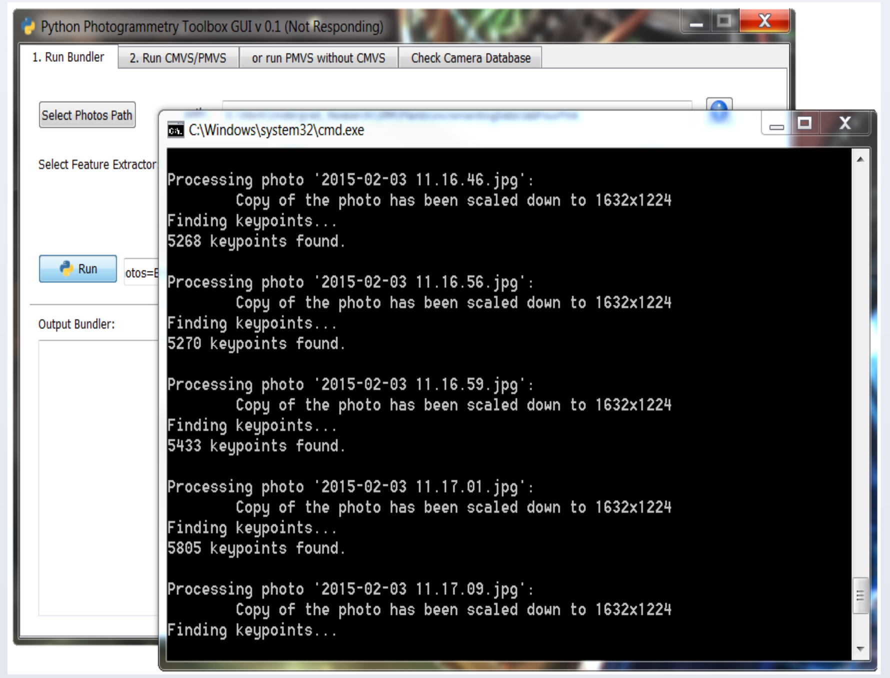
In the above image, we show sample sequences of images used as input to the SfM algorithms we evaluated.

SfM software

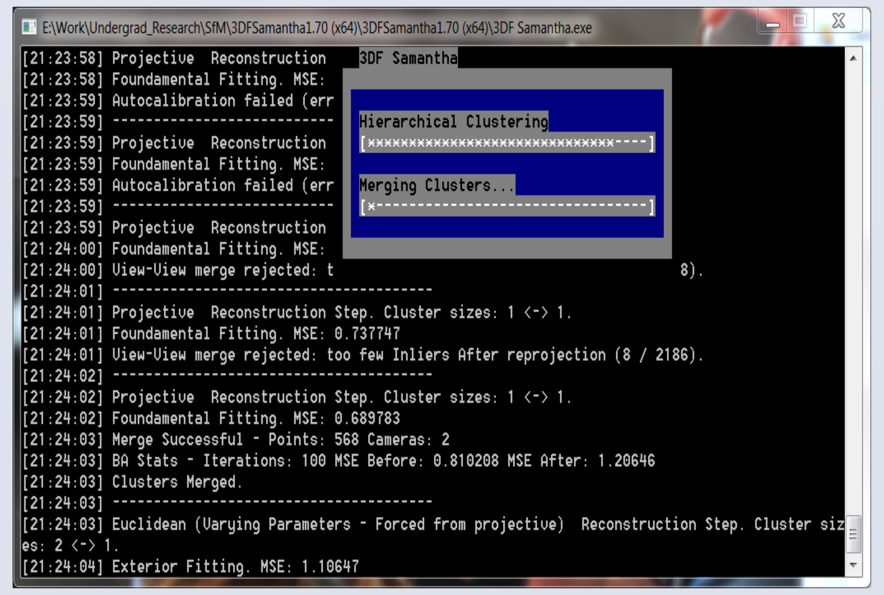
VisualSfM



Python Photogrammetry Toolbox - GUI

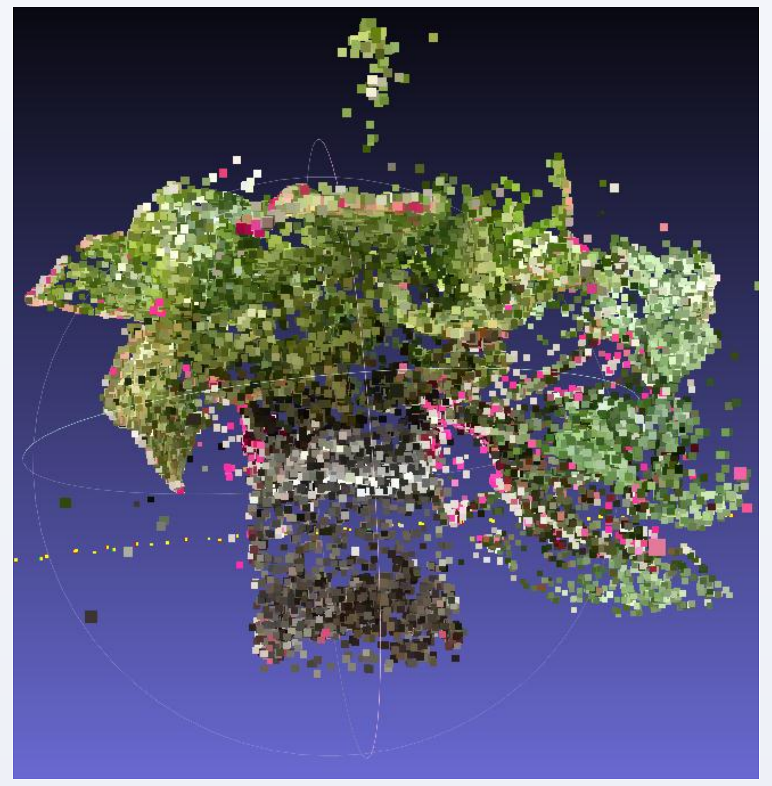


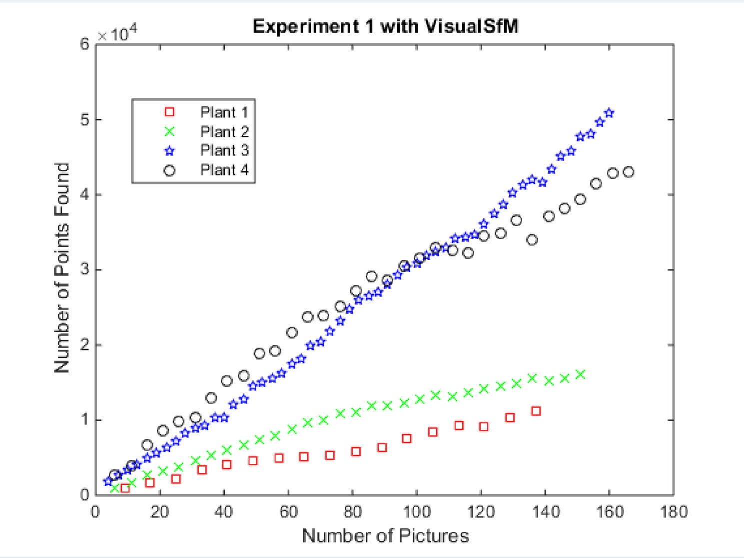
3DF Samantha



For each method, we controlled the number of input images as well as the color of the background.

Results

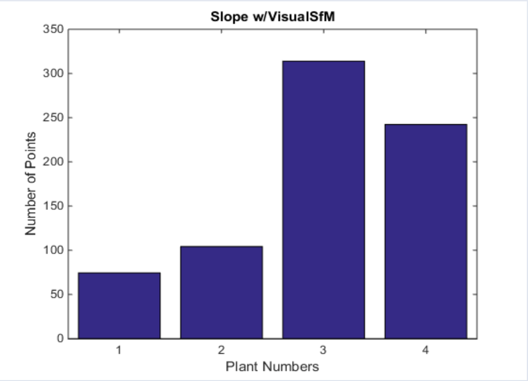


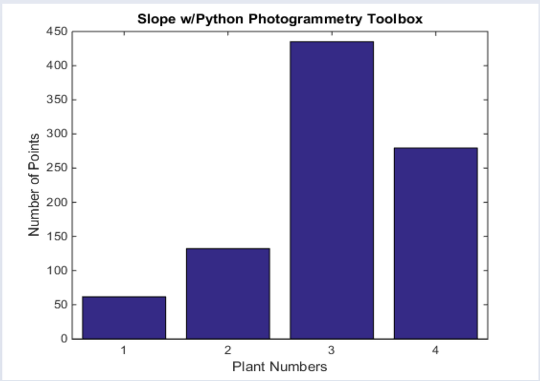


We observe a **linear relationship** between number of pictures and resulting points.

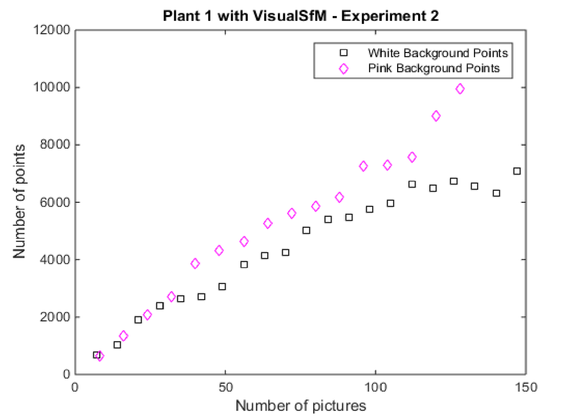
The **slope** of the line of best fit can be used as a predictor of plant "difficulty".

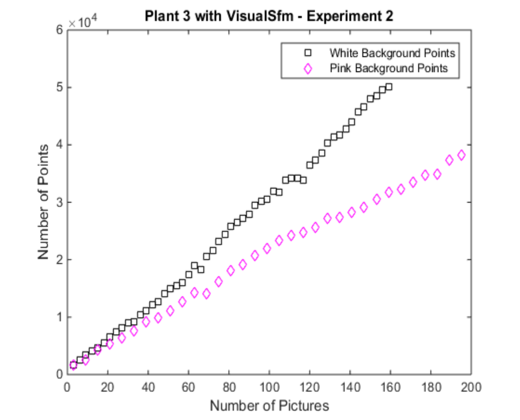
Different algorithms produce similar results.





Background color affects the performance of SfM algorithms.





Results

We found that the plant structure complexity is a good predictor for existing SfM algorithm performance. In other words, existing algorithms underperform on complex geometry.

We also show that background color is important. If the plant contains colors identical to the background, the color may blend into the background resulting in poor performance. If the plant colors contrast the background, the performance is increased.

Discussion

The three programs produced point clouds, but some were easier to install and use than others. VisualSfM was the easiest to install, because it had clean documentation. However, it was time consuming and takes a lot of processing power to use. 3DF Samantha also had a manual, but no GUI without a CUDA machine. It required coding knowledge. Python Photogrammetry Toolbox was the most difficult to install, but the easiest to work with. It produced incremental .ply files, which helps enormously on collecting data. For the other programs, you have to specify the input images manually, and run the program repeatedly, with a different number of inputs.

The geometry and color of the plant are important factors. We observed a linear relationship between number of pictures taken and the number of points. Background color is important. Plants that have the same color as the background decrease algorithm performance.

Conclusion

This research can lead to the improvement of future algorithms and interdisciplinary work with biologists. Further implementation could be used on larger plants or more complex plants, or scenes with multiple plants. More complex geometry presents challenges to the state-of-the-art, which suggests more work is needed in feature engineering for this challenging domain.

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