Individual Contribution Report and Literature Review for the Proposed Task: How to Autonomously and Cost-effectively Achieve the Task of Making Multiple Small Unmanned Aircrafts Face the Same Side of a Building Using Structure from Motion

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1. Abstract

1.1 Overall Objectives

The first objective of this paper is to make sure that my team members understand the significance of achieving the proposed task stated above within the context of the U.S. Army Unmanned Aircraft Systems (UAS) Roadmap 2010-2035 [1] and the mission of the Naval Air Systems Command (NAVAIR) as seen in [2]. Secondly, it is to make sure that they understand the key terms from the research and the literature review, particularly because my teammates and I have varied backgrounds, and lastly, that they understand the comparative analysis and can select the sub-tasks that are suitable to their skills and abilities to plan for and achieve a final deliverable of the proposed task.

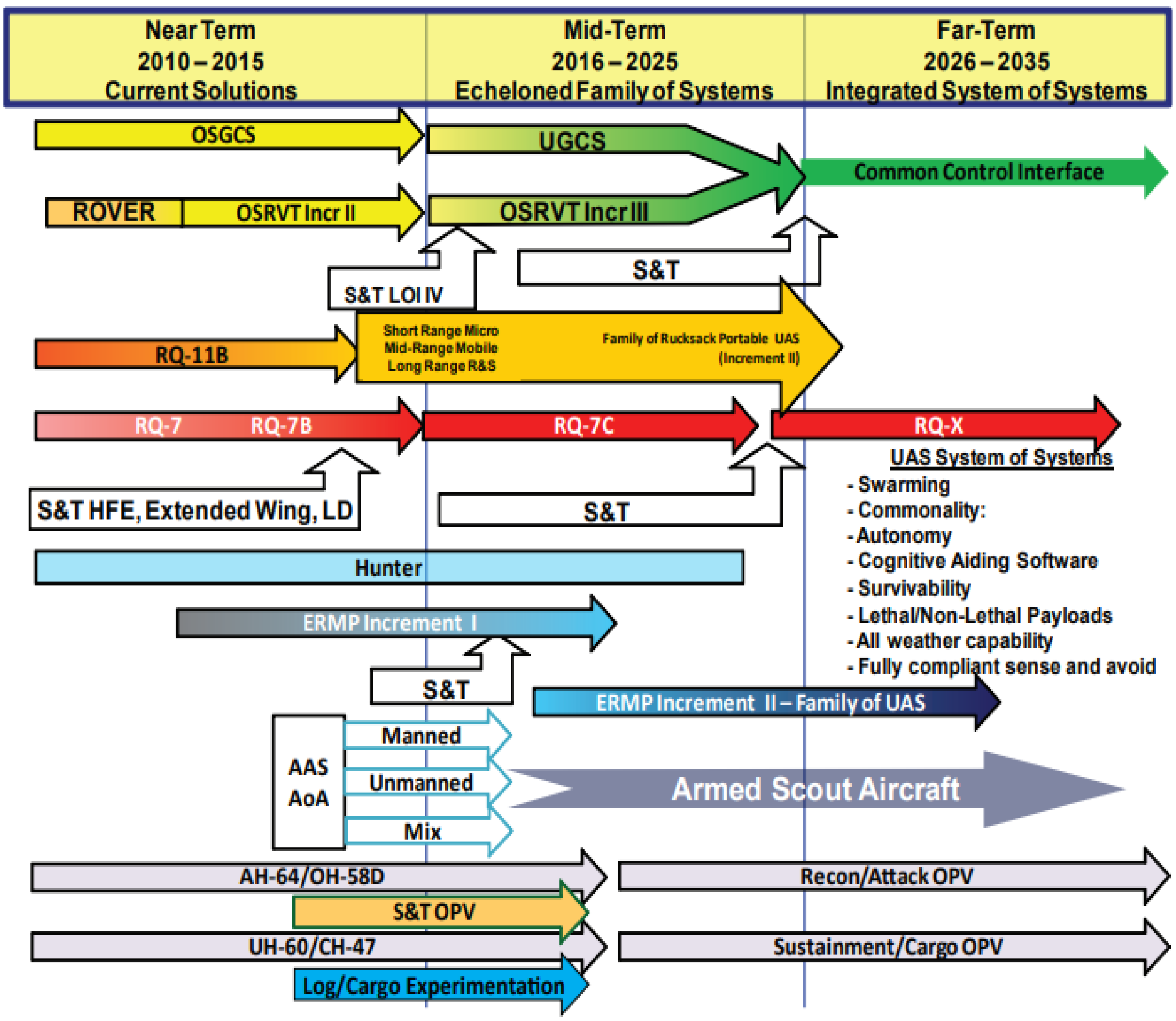

Figure 1. An overview of planned capability improvements depicted in Army UAS Capability Timeline from U.S. UAS Roadmap 2010 – 2035 [1]

1.2 Context

The idea that Unmanned Aircraft Systems are "unmanned" is a misnomer because Army UAS are operated and maintained by trained and professional soldiers [1]. Conceptually, the U.S. Army Roadmap for UAS 2010–2035's far-term description says that "UAS are fully integrated into unmanned ground systems as an unmanned systems team providing new UMS synergy and capabilities to the Commander" [1]. Naval Air Systems Command (NAVAIR)'s mission is aligned with that far-term description: "Deliver integrated air warfare capabilities to enable the fleet to compete, deter and win—tonight, tomorrow and in the future [2]." Small Unmanned Aircrafts (UAs) may prove to be affordable solutions to many problems, on and off the battlefield, that would be more expensive with larger and more advanced equipment [3], and they show great potential for uses in intelligence, inspection and surveillance, search and rescue, and reconnaissance.

1.3 Conclusion: Plan for Showcase

Because [4] – [7] support the premise that the effective use of Structure from Motion (SfM) can offer a reduced-cost option compared to using the Simultaneous Localization and Motion (SLAM) while SfM (*see 3.1.4*) can perform at least as well as SLAM, I propose that SfM should be used to achieve the task of making multiple small Unmanned Aircrafts face the same side of a building. Also, because my team members including myself cannot afford expensive hardware such as a LiDAR sensor, hi-definition camera lenses, and/ or small UAVs, and NAVAR likely cannot loan us any small UAVs or other equipment for physical simulation, it is strongly suggested that a virtual simulation using open-source software *(see **Appendix B**)* should be a good option to deliver a final product that my team can showcase.

1.4. Overview

In section 2, my expected contributions, team organization, and detailed background are covered. In section 3, how my strategies for literature review and research questions have evolved over time is explained before the literature review. My literature review starts in section 4 with a summary of the U.S. Army Roadmap for UAS 2010 – 2035: *Eyes of the Army*, which is relevant to the proposed task: how to autonomously and cost-effectively make multiple small Unmanned Aircrafts face the same side of a building using Structure from Motion (SfM). This will show how the proposed task aligns with the planned capability improvements in the mid-term (2016 – 2025) and the far-term (2026 – 2035) in [1], which is directly connected to the significance of achieving the proposed task. In my literature review, I have reviewed more than ten published pieces and publications. Lastly, in section 5, my detailed Individual Contribution Plan from this semester, fall 2022, till the end of the year is displayed.

2. About the Student's Expected Contributions, Team Organization, Detailed Background

2.1 Student's Expected Contributions to the Senior Project

2.1.1 Communicator

I will work as the main point of contact for my student team members. I obtained a certificate in Effective Communication, Team building & Business Writing from the University of California, Riverside Extension in 2014, and I will utilize the communication, team building, and writing skills I learned there to help my team succeed.

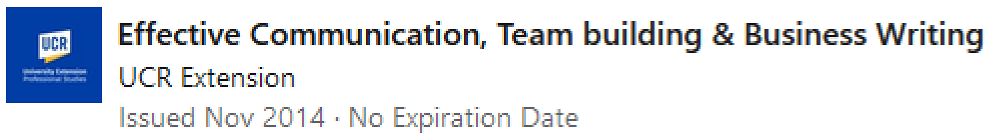

Figure 2. To view my other certifications and employment history on LinkedIn, please connect with me via: www.linkedin.com/in/yeana-l-bond/.

2.1.2 Explorer and Documenter

I will suggest possible solutions by researching peer-reviewed papers, relevant academic books, and other various resources about Artificial Intelligence, Machine Learning, Computer Vision, and related topics to ensure my team's work is informed and up to date so that we can achieve the goal of the proposed project as well as a final deliverable.

2.1.3 Peer Educator

As a post-baccalaureate student with teaching experience in both the private and public education sectors, I can also work as a peer leader by learning and then teaching my team members about new concepts, algorithms, and models found in my ongoing research as well as by searching for opportunities to attend conferences during the Fall 2022 and Spring 2023 semesters.

2.2. Student's Team Organization of |YES| and Detailed Background Relevant to the Expected Contributions to the Senior Project

California State University, Bakersfield (CSUB)		**Naval Air Warfare Center Aircraft Division (NAWCAD)**
| Faculty Members - - - - - - - - - - - - - |	| |YES| - - - - |	| NAVAIR Scientists |
Mr. Woods, Associate Professor of Management, Faculty Director of CSUB Center for Entrepreneurship & Innovation Dr. Cruz, Associate Professor and Associate Chair	Yeana Bond Esme Orsornio Spencer Ledwell	Dr. Estabridis, Director of Autonomy Research Arena Dr. Reitz, Aerospace Engineer

Figure 3. Yeana's team, CSUB faculty, and NAVAIR scientist members are, in total, 7 people which translated to that there are 21 communication paths [8]. To effectively communicate with CSUB faculty members and NAVAIR scientists, it is ideal for the student team to have a main point of student contact among the three members of the student team |YES|.

2.2.1 Active Leader in Communication

After working more than six years in education, customer service, and technology, I have developed a professional skill set in communication, from writing business emails to giving a pitch to recruit new members for our Software Engineering club. As a senior at CSUB, I have volunteered to be an active point of contact among my student team members to write emails, request meetings, and manage our schedule as a group. Through this experience, I want to learn how to network outside of school and seek out other women engineers because our representation in STEM is still lacking. I look forward to learning how I can effectively share ideas with team members, CSUB faculty, and NAVAIR scientists.

2.2.2 Motivated and Curious Student Researcher

I first found that I genuinely enjoyed learning more about Artificial Intelligence and various machine learning models as well as research itself when I took CSUB's Artificial Intelligence course offered by Dr. Cruz in 2021. With his encouragement, I applied for and was awarded the 2022 CSUB Spring Pandemic Research Grant last semester. I proposed a research topic in which I explored various Neural Network models and collected raw video data and captured images using OpenCV for my individual research with Dr. Cruz acting as my faculty mentor. Through my research *(visit my public website, https://www.cs.csub.edu/~ybond/4800/fer_research.php)* and studying LSTM (Long-Short Term Memory network), CNN (Convolutional Neural Network), and other deep learning models, I proposed the development of an A.I.-based application to help telepsychologists by providing them with real-time facial emotion recognition data as an additional means of reading their patients' emotional states. The experience of exploring previously proposed ideas and solutions via peer-reviewed research papers in Artificial Intelligence and Machine Learning, and what Python can do in Computer Vision, was intriguing enough for me to consider pursuing a graduate degree in the future. Without Dr. Cruz's input and guidance in CMPS 3240 Artificial Intelligence and CMPS 4800 Undergraduate Research in 2021, I could not have taken this research route for my senior project.

2.2.3 Instructional Assistant

Unofficially, I acted as a private tutor for my younger sister in Mathematics, English, and other subjects when we were growing up. I am experienced working as a teacher or an in-class assistant in private, public, and adaptive (special education) educational settings. This has included working in places such as an English Immersion camp, an English Lab School, a Special Education school, and a middle school. This semester, I am an in-class lab assistant for Professor Gordon Griesel in his CMPS 2240 Computer Architecture I: Assembly Language lab sessions. This is my first on-campus position working for a professor, and I bring to it my ability to help students debug their codes logically and efficiently. This reflects my previous debugging experience in various computer science courses at CSUB and Bakersfield College. Through my assistant work for Dr. Chengwei Lei, I also presented the main concepts of supervised, unsupervised, and reinforcement learning models to members of a PhD student group and professors at the Keck School of Medicine at the University of South California. This presentation was used to determine what the best machine learning model is for their dataset. These experiences have given me the ability to share what I find in the process of my research and help my team understand any Computer Vision algorithms that they are not familiar with.

2.3 Summary of myself: Well-rounded undergraduate researcher and developer

If I had to choose one area to work in aside from research, I would choose to develop back-end work. This is probably because many Computer Science majors on the traditional track, including myself, start learning a language that is more geared toward calculation or processing input data in the back such as the C family languages or Python. This does not mean, however, that I would not be able to work as a front-end developer. I have taken COMP B42 Web Design: HTML & CSS in which I had several projects for front-end, and I was able to apply what I learned to Financing for Dummies, where I led UI design and visualization of data being created, read, updated, and deleted in CMPS 3420 Database Systems. Also, I recently started a new position as an Intern Automation Specialist in which I transform data for analysis and develop, test, and maintain data pipelines. A table of my courses, and course/ internship projects can be found in ***Appendix A***.

3. Strategies and Research Questions for Literature Review

3.1 Changes in Research Strategies before the First Meeting with NAVAIR on 21st in October 2022 and after

I started out with three areas of Computer Vision: Image Segmentation, Stereo Vision, and Structure from Motion. After surveying the three areas by researching mostly secondary and primary resources and comparing the costs of different types of sensors and/or camera lenses in the three areas, Structure from Motion stood out since the cost that SfM requires is much less than, for example, a LIDAR sensor [4] – [7]. My team members are unable to afford a UAV that has a LIDAR sensor, and we do not know if we can create our own data (images) from a very basic physical simulation next semester yet. Also, to borrow any equipment from NAVAIR, a formal request must go through a process of approval internally, so getting a piece of equipment might not be an option in case such a request is denied. Therefore, running a simulation in a virtual space to test our work is suggested.

After my team received feedback from NAVAIR scientists in our first meeting with them, I started conducting more research to find primary and secondary source focusing on SfM. Soon, I realized that knowing key terms and concepts was necessary. I will briefly provide a definition of each term or concept that is pertinent to the topic and central task of this project.

3.1.1 Drone

A drone is an UAV. This term is probably more familiar than Unmanned Aerial Vehicles (UAVs). These can be remotely or autonomously controlled [9]. The term, “drone” is not found either in [10] or in [11], so it will not be used in this paper either.

3.1.2 Photogrammetry

Structure from Motion is a technological descendent of photogrammetry, which started in the mid-1800s [12] when photogrammetrists took analog aerial images and used triangulation and bundle adjustments to manually build 3D maps [13].

3.1.3 Lidar (LiDAR or LIDAR)

Lidar, which stands for “light detection and ranging,” sends laser (Light Amplification by Stimulated Emission of Radiation) pulses out to the ground and reads the light’s rate of reflection and intensity to detect and recreate in image form 3D maps of a scanned area [14]. It has been engineered in recent years and made small enough to be mounted to UAVs. Aerial Lidar is an aircraft-mounted, remote sensing technology, whereas SfM “uses optical remote sensing imagery to extract surface elevation information via traditional photogrammetry [15].”

3.1.4 Structure from Motion (SfM or SFM)

Structure from Motion is a photogrammetric method that can be used by UAVs to match feature points after extracting 3D information about the environment from the motion of tis projection onto a 2D surface [16] – [17]. An alternative term for SfM is “multi-view photogrammetry (MVP)” [18].

SfM can produce high quality and dense 3D point cloud at low cost. It can consist of several algorithms as a technique aimed to achieve a certain goal, and this technique combined with Multi-View Stereo (MVS) algorithms, so they together are referred to as SfM-MVS [19].

3.1.5 Point cloud

Point clouds are considered the baseline for the production of 3D models to reconstruct surfaces under a defined coordinate system [20].

3.1.6 Photorealisticity

"Photogrammetry offers photorealistic mapping results in the form of orthomosaics, point clouds and textured mesh. A true, life-like digital twin [14]." SfM, then, would seem superior to Lidar since it can produce more accurate images that contain not only elevation and height information, but also texture, shape, and color for every point on the map [14]. Photogrammetry is a more cost-effective and accurate means of recreating detailed, realistic 3D representations of a building, object, or space.

3.1.7 Cost Comparison of Structure from Motion (SfM) and Simultaneous Localization and Motion (SLAM)

In my tertiary search, I already noticed that it is likely that a sensor that SLAM requires is more expensive than a camera that SfM would need. Thus, I will include what I found in an article that provides a clear comparison of two systems which gave my research direction more affirmation.

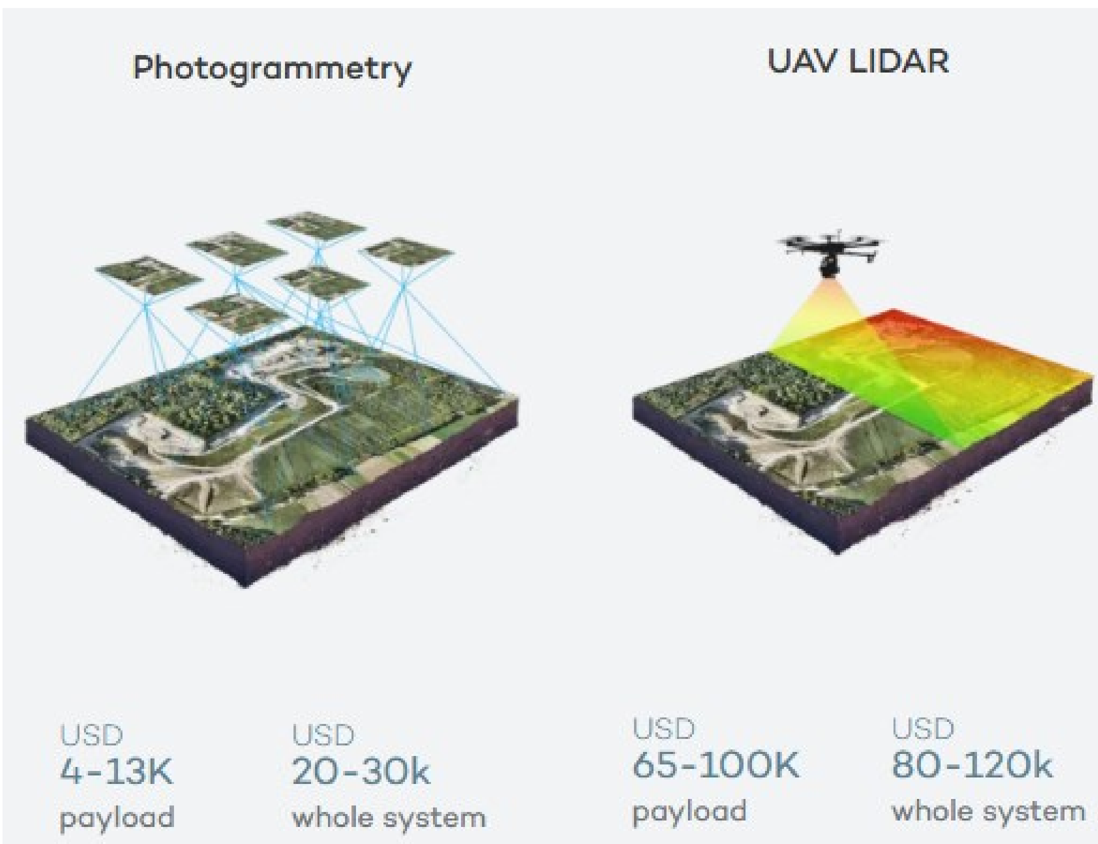

Figure 4. An entire high-end photogrammetry system costs between $20,000 and $30,000 which is still less than the UAV LIDAR's payload cost range. Note that all above prices are in US dollars [14].

3.2 Research Questions via User Stories

An effective and flexible team should keep the end user in mind as it works, paying attention to the user story which can provide guidance and ensure that the end deliverable meets the expectations, wants, and needs of the end user [21].

"The purpose of a user story is to articulate how a piece of work will deliver a particular value back to the customer. 'Customers' do not have to be external end users in the traditional sense, they can also be internal customers or colleagues within your organization who depend on your team" [21]. In my team's case, they could be student team members, CSUB faculty members, or NAVAIR scientists *(see **Figure 3** in 2.2)*. A user story is centered on the result and the benefit, whereas use cases can be more granular and describe how your system will act [22]. In an agile framework, "a user story is the smallest unit of work, which is an end goal, not a feature, expressed from the software user's perspective" [21]. My user stories below are created provided that a small UAV can successfully face toward a wall of a building in a simulated setting after identifying an object (a building's wall).

3.2.1 User Story 1

Can one of the small UAs measure the height, width, and length of the targeted building and report to the front-end operator while the rest of the peer small UAs try to face toward the same side of the targeted building?

This user story assumes that the information of measured height, width, and length of the targeted building and other detailed information such as position of objects, for example, perimeter walls, or buildings can be shared with the front-end UA operator who monitors multiple small UAs' status or can be shared with the other peer small UAs with which it is flying.

3.2.2 User Story 2

A user of a final product of this research wants to input a certain number to define how many numbers of UAs work together in a simulation of achieving the proposed task.

3.2.3 User Story 3

Can three small UAs fly to the targeted building together while maintaining a triangular shape?

If a certain number of multiple small UAs can maintain certain positions calculated relative to one another, it may be easier to make them face toward the same side of a building in some cases because they fly already maintaining a shape which translates to a plane mathematically. These ideas of User story 2 and 3 are created provided that the algorithm for maintaining a certain shape is implemented.

3.3 More Research Questions Related to Achieving the Proposed Task via Brainstorming

3.3.1 What is the definition of "the same side a building" in the context of the proposed task?

3.3.2 What algorithms are under the Computer Vision for 3D-mapping?

3.3.3 What are new concepts and terms I should become familiar with first?

3.3.4 What are the advantages and disadvantages of using SfM in achieving the proposed task?

3.3.5 What if the number of small UAs becomes equal or greater than two?

3.3.6 Is there any way to physically simulate and test the developed algorithm at the end?

3.3.7 What conclusions can I draw after comparing SfM with SLAM in terms of conducting a simulation?

3.3.8 Can NAVAIR provide such a physical simulation environment? If the answer is positive, is the physical simulation environment outdoor or indoor? If not, what is the alternative plan to physically test a final deliverable?

3.3.9 What SfM software are available, and are any of them open source?

4. Literature Review

4.1 Introduction

Use of Unmanned Aircraft (UA) for governmental and military purpose continues to increase [3]. How to autonomously and cost-effectively achieve the task of making multiple small Unmanned Aircrafts face the same side of a building using Structure from Motion is the proposed task to achieve as an immediate goal for one UA in this paper. The successful achievement of this task can be incorporated with SWARM trajectory planning algorithms. However, the scope of my literature review here is focused on SfM or studies that used SfM to achieve a similar goal to the proposed task.

I will refer to the U.S. Army's plans and uses for UAs to ground my literature review since they are almost universally identical to those of other branches of the armed forces. According to [3], the definition of "UAV" (or UA) is "a powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload. Ballistic or semi ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles." Use of this equipment has also expanded to surveillance, reconnaissance, and search and rescue [3].

4.2 Summary of U.S. ARMY UAS ROADMAP 2010 – 2035: *Eyes of the Army*

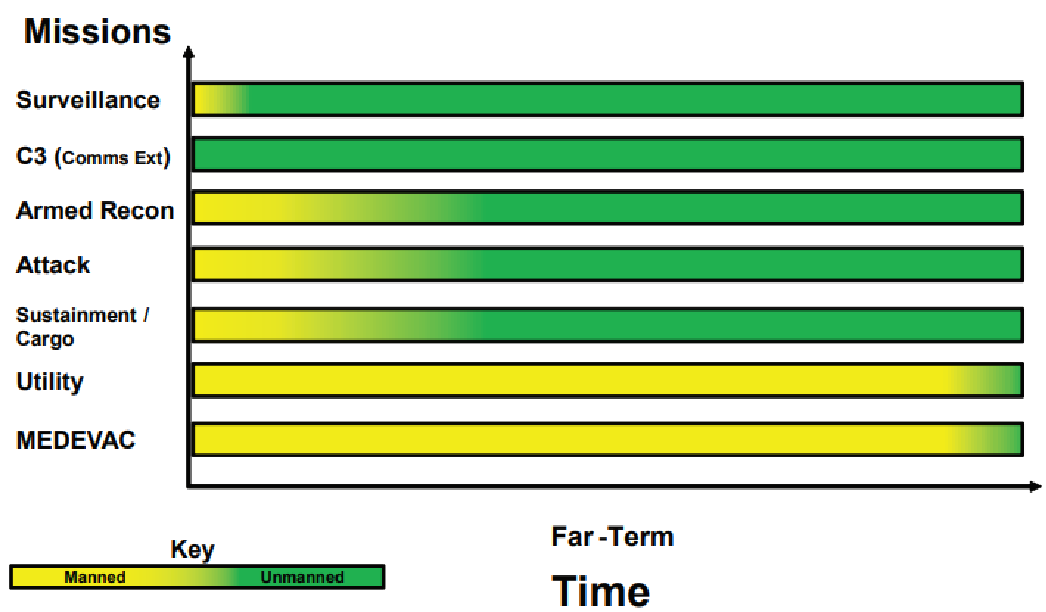

Figure 5. The far-term manned-unmanned roles transition from 2026 to 2035 [1]

The army currently uses over 4,000 UAs that are fully integrated into its missions, and they are making advances in UA technology in the mid-term (2016 – 2025) that may result in the autonomous operation of many of those units [1]. The long-term for the Army's work in researching and developing capabilities in UAVs extends to 2035 for achievable advances in Artificial Intelligence (A.I.) and units' abilities to function with minimal to no operator interface. Achieving our project task, which can lead to enabling multiple small UAVs to face the same side of a building using Structure from Motion (SfM) while operating autonomously, aligns with the Army's missions [1] and can be used in other military branches like the Air Force, Navy, and Coast Guard.

Currently, UAs rely on human control to complete their missions. Remote operational and tele-operational modes require personnel controlling the units either with direct visual of the unit (remote) or through sensor-communicated information that allows the user to operate the UAs outside of their field of vision. A semi-autonomous approach allows the operating system to take on some control tasks, relieving human operators of some control [1]. Fully operational autonomy, a noted goal of the Army's plan, gives greater "decision making" ability to the UAs while maintaining mission intent as defined by human operators whose direct control of the system is limited to programming mission data and monitoring progress. The UAs, in such a mode, will be able to function through A.I. and sensory systems in a way that frees up human operators to monitor multiple units or work on other time-sensitive, mission-related tasks [1]. This is essentially "shifting even more sensing, perception and decision-making to the robot… while the robot remains a slave to the human and subject to the limits of design and mission constraints [1]." Our team's task, as mentioned, would contribute to the implementation of operational autonomy by providing the SfM-applied ability for small UAVs to all face the same side of a building or an object.

Figure 6. The far-term's final portfolio step which leverages a shift in air warfare that redefines the human role in it by achieving a fully autonomous capability and SWARM (Smart Warfighting Array of Reconfigurable Modules) [1].

By 2025, it is projected that "UAS Nanos will collaborate with one another to create swarms of Nanos that can cover large outdoor and indoor areas. The swarms will have a level of autonomy and selfawareness that will allow them to shift formations in order to maximize coverage and cover down on dead spots [1].” Also, this means that small UAs like Nanos will be equipped with the ability to navigate confined spaces between buildings, which explains the reason why achieving our team’s proposed task is critical to having small UAVs like Nanos collaborate safely and effectively, especially considering that Nanos will possess the ability not only to fly but also eventually land and crawl on a surface [1].

4.3 3D UAV Registration of Large Scale Environment Using Structure From Motion Based Approach [17]

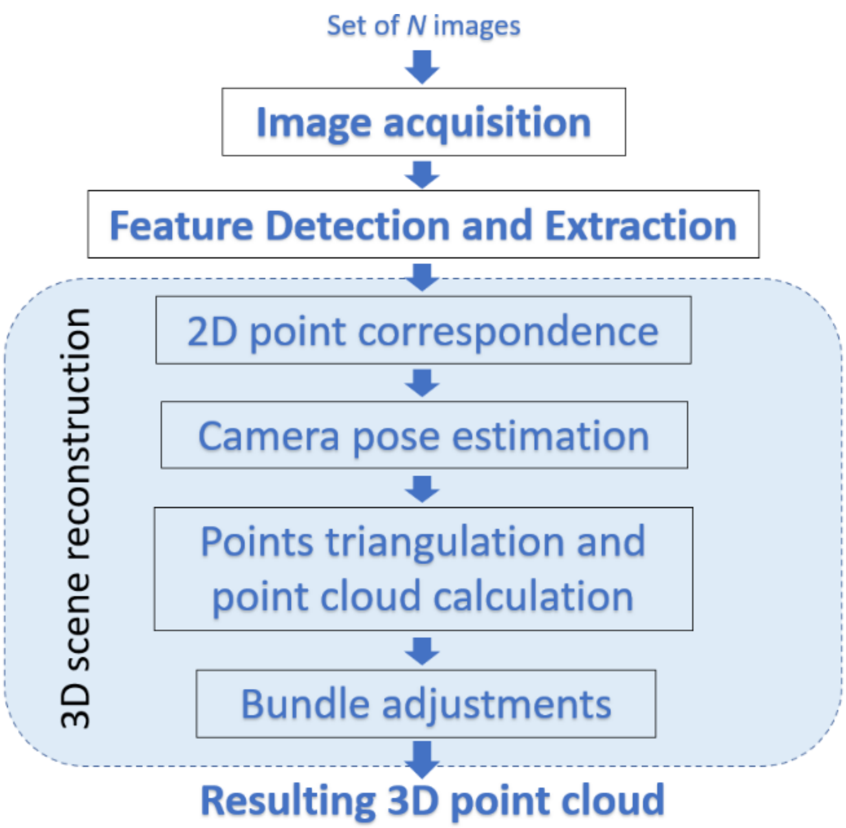

Figure 7. An example of Structure from Motion (SfM) pipeline [17]

This paper taught me how satellite and traditional aerial photos are often unable to provide data with real-time constraints like, for example, cloudy weather, and that even though it is costly, the quality is not guaranteed to be enough to provide a detailed operational photographic data. Also, UAVs can be used to perform search and rescue in disaster areas using SfM while they reduce the operational costs in offering a rapid, accurate 3D mapping of the environments.

In fact, satellite and traditional aerial manned aircraft is generally in the range of twenty to fifty centimeters per pixel, while the resolution which the UAV based photogrammetric mapping approach can obtain up to a one to two centimeters per pixel.

In this paper, feature detection, bundle block adjustment and 3D model generation are listed as three basic steps of SfM. I learned that the SIFT feature descriptor and matcher algorithms are most well-known method which image matching is based on, and each is matched with its corresponding ones. A great takeaway was for me to first understand a pipeline of the Structure form Motion as the figure above shows an SfM pipeline from the step of image acquisition.

4.4 Comparison of UAV-based LiDAR and Digital Aerial Photogrammetry for Measuring Crown-level Canopy Height in the Urban Environment [5]

This study compares the performance of UAV-LiDAR and UAV-DAP (Digital Aerial Photogrammetry) in measuring crown-level Forest Canopy Height (FCH) in urban environment across topographical slope and non-ground coverage. Even though UAV-LiDAR sensor can measure FCH accurately, its cost makes its applications over large areas difficult. Therefore, UAV-DAP is used. It is mentioned that it can be hardly used to see ground under dense cover or near buildings, so it is not thoroughly reliable when one needs to generate an accurate Digital Terrain Model (DTM). However, the combination of using UAV-DAP for non-ground coverage areas and using UAV-LiDAR for flat areas was able to reduce the overall cost while the UAV-DAP approach and the LiDAR-DTM replacement can work together on mitigating the negative effect of high non-ground coverage. While this joint solution is not something that my team is looking for, this was a good paper that taught me how Lidar and photogrammetry differ.

4.5 2015 Gorkha Post-Earthquake Reconnaissance of a Historic Village with Micro Unmanned Aerial Systems [6]

The aerial images taken by the cameras of two Unmanned Aerial System (UAS) platforms were used to reconstruct a detailed three-dimensional (3D) point cloud model of the village called Bungamati in Nepal after a disaster. SfM is described as a time-efficient, cost-effective, and safe way to collect the 3D point cloud and imagery. It covers a greater area and gives a greater level of detail than Lidar, and some Lidar use is combined with SfM to minimize Lidar's weaknesses. This application of ground-based Lidar and SfM can aid in search and rescue efforts after a disaster or other destructive event.

4.6 SfM/MVS-based Three-Dimensional Structural Diagnosis System for Damaged Houses [7]

This paper also suggests an SfM/MVS-based 3D Structural Diagnosis System as a low-cost system for taking images of damaged houses without having to enter a disaster area. SfM/MVS (Structure from Motion/Multi View Stereo) uses collected images of the exterior of the houses while sensor data such as acceleration and GPS location information are obtained to evaluate the degree of the damage by implementing a function that captures the images "only when the synthetic acceleration is almost the same as the gravitational acceleration." Multi-view images are analyzed by SfM to estimate the shooting position and posture for each image and to create 3D model.

Figure 8. An example of a three-dimensional (3D) model [7]

Scale Invariant Feature Transformation (SIFT) is used to detect feature points for each image [23] and is considered as one of the most well-known methods of completing such a task [17]. It is also explained that the small number of feature points by SfM is the reason why MVS is used along with Patch-based Multi-View Stereo (PMVS) to make a 3D model by filling gaps between feature points to make a planar surface. Meshroom *(see **Appendix B**)* "analyzes the multi-view images and outputs the 3D location and the rotation matrix of the direction of the camera estimated by SfM in JSON" (JavaScript Object Notation). Then, it creates a 3D model that consists of a dense point cloud in the PMVS in ply (Polygon File Format).

Another takeaway of this paper is that the 3D RANSAC (Random Sample Consensus) algorithm can be used to repeatedly take 3 points from the cloud in the 3D model to repeatedly apply the plane equation and estimate the size of the walls and identify them.

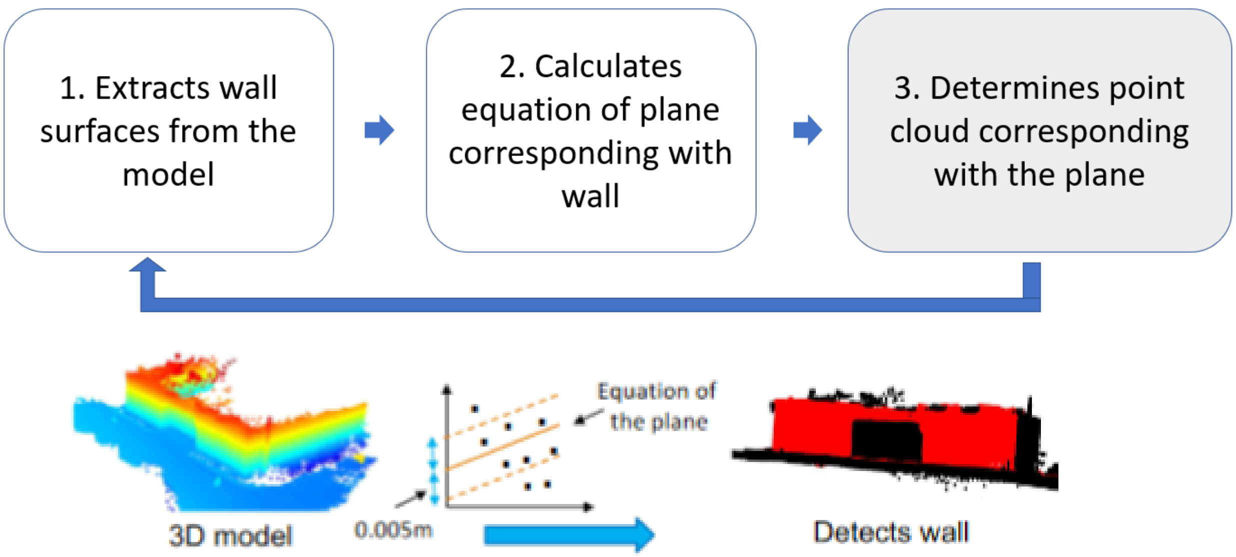

Figure 9. 3D RANSAC Procedure for identifying the point cloud corresponding with the wall surface [7]

From this paper, since I acquired a very important keyword, "wall extraction", and a name of an algorithm called 3D "RANSAC", I started using them in my researching and found the following paper.

4.7 An Improvement Method of Wall Points Extraction Process from Mobile Mapping System Data by Localization Method of Space Division [24]

An extraction method for the wall points of an individual building from a Mobile Mapping System data is more focused in this paper. Because this wall points extraction method can extract undesirable planes which are not part of the target building, and it requires a lot of time to extract small planes by using RANSAC, the idea of localizing the extracting target from the influence factors which are far away from the target is proposed to generate 3D polygon model of a building automatically.

This paper explains that what RANSAC extracts is the largest plane from the whole space as the truth, which makes the number of points on the small wall plane less than the plane which RANSAC estimates from the whole space without considering the building's structure. This is where the idea of evaluating wall planes of a local space becomes strong. I learned that RANSAC has been used in extracting planes (plane detection), so I am going to perform more research especially on RANSAC and its variant algorithms.

4.8 Reconstructing 3D Scenes from UAV Images Using a Structure-from-Motion Pipeline [25]

This paper is the first paper that uses Grid-based Motion Statistics (GSM) I have found so far, and it is interesting to see a different method to work with large datasets of images. It points out that the RANSAC algorithm can be used to discard the mismatches by finding the transformation matrix of features points, but it is a difficult and time-consuming process to the right transformation matrix when there are a lot of mismatches in the data space, which is very common with image datasets in reality. GMS strategy is utilized as a pre-processing of RANSAC because it helps decide which are true or false feature matches with taking the number of neighboring matches into account. Overall, by mitigating drift (accumulated error) effects, it improves the completeness and accuracy. The relevant open source I found on Github is reposited here: https://github.com/JiawangBian/GMS-Feature-Matcher.

4.9 Three papers from AFIT (Air Force Institute of Technology)

4.9.1 Determination of Structure from Motion Using Aerial Imagery [26]

With this paper, I realized that some assumption I had are very similar with the assumptions and limitations this paper has. They are as follows:

4.9.1.1 Location of a camera

In relation to the Global Positioning System (GPS) receiver, the location of the camera on the UAV is assumed to known. This assumption might not be needed, though, since our project will prioritize a simulation in a virtual space.

4.9.1.2 Direction of a camera

The pointing direction of the camera with respect to the Internal Navigation System (INS) is also assumed to be known. This is more likely to be assumed in our project as well because it might contribute to confirming that multiple UAVs are looking at the same side of a building using the information of the pointing direction.

4.9.1.3 Lambertian property

It is naturally assumed in achieving the proposed task that a building that a camera looks at in a virtual space does not change its appearance while it is being viewed in the scene.

It is mentioned in this paper that these assumptions simplify the detection and tracking of features, which is an important step in the pipeline.

4.9.2 Assessment of structure from motion for reconnaissance augmentation and bandwidth usage reduction [27]

In this paper, the writer proposes a method of transmitting reduced-size 3D models. The steps in that method are Imagery Collection, sparse Reconstruction, Dense Reconstruction, Mesh/Surface Generation, and Mesh/Surface Texturing. After reconstructions are compressed, the reduced size 3D models are transmitted using a freely available resource, 7-Zip, using less bandwidth. While a spiral flight path is chosen to collect images in this paper, the next paper that is going to be reviewed selects a simpler flight path around a central object (building) at a constant altitude in the similar virtual world used in this paper while pursing the idea of reducing the bandwidth usage.

4.9.3 High Resolution Low-Bandwidth Real-Time Reconnaissance using Structure from Motion with Planar Homography Estimation [28], [32]

Any two images of the same planar surface in space are said that they are related by homography [29] which is an isomorphism of projective spaces in projective geometry [30]. Homography is also called projectivity, projective transformation, and projective collineation [30]. In this paper, by combining SfM and Planar Homography transforms [31], 2D urban environment images are transformed into 3D simplified models of buildings. This paper's virtual simulation is very similar to what my team aims to achieve: one virtual UAV flies around a building while collecting images to detect a target wall. While this is only a proof-of-concept, this technique could be useful in the future to aid in navigation of UAVs either autonomously or with the guidance of a human operator.

To make the calculation efficient in detecting and matching features, all features line up with the same row of pixels. They are then used to create a 3D point cloud called a sparse reconstruction that creates an approximate rendering close in size and shape to the original. Everything up to this point has been done previously by others researching Structure from Motion, so this is where their algorithm deviates significantly. Normally, the 3D points are considered as a whole where each point is connected to its neighbor to create a complex mesh. Instead, the geometry of the scene with large, generalized planes is approximated. A plane can be defined by any three points in space and drawing a triangle between them and by expanding the borders of the triangle infinitely in all directions to create a plane. To find planes within each feature matching sets, their algorithm randomly takes three starting points and counts how many points fit along that plane. The plane with the most points is considered the dominant plane. To create a texture, the dominant plane is mapped to the corresponding original image, and using a process called thermography transformation, their algorithm warps the image such that the dominant plane is entirely flat to the viewer's perspective. Then, the image is cropped and applied as a texture for the dominant plane. As the algorithm iterates through each match in real-time, a texture plane is rendered in the virtual world. For instances where two planes might conflict with each other, the algorithm dynamically adjusts the final reconstruction choosing the plane which again has the most detected points that lie within it.

They also collect data from three different models as part of their experiment with each one representing different conditions the algorithm might perform under, which differs from what our team plans to do. Still, it is very interesting to see how their algorithm works, especially in a simulation setting (*Watch the YouTube video cited in [32]*) which is very close to what our team aims to accomplish in.

5. Detailed Individual Contribution Plan for 2022

My team plans to use various algorithms to compare and achieve one goal in a virtual setting, but various algorithms might require different SfM software, which might bring some challenges regarding how much time we have to spend to analyze an algorithm's requirements, the environment it should be run under, and how to fairly compare it with the results from different algorithms. While I am acting as a leader of literature review and survey, I plan to spend time in searching Github and finding various SfM software to determine which software is a good candidate to assist my team members for implementing and testing.

Ideally before the last week this semester's final term, our team finishes Literature Survey to submit to 3rd Annual Computer Science Conference for CSUB Undergraduates while by 9th in December, we submit the draft of it, which replaces the assignment of group final report for our Senior Project I. In the next semester, our team plans to visit the NAVAIR scientists and the site of their physical simulation environment. In the meantime, the following table shows the timeline along with each item of my individual contributions to our project.

Table 1. Yeana's detailed individual contribution plan for the fall semester in 2022

Start Date	Item of Individual Contribution to Project	Due Date
9/1/2022	Acting as a Main Point of Communication and Team Leader *(see section 2)*	Yeana's default job
11/1/2022	Preparation and Submission of Abstract and Application for 2023 Annual Conference, Explaining Algorithm Options to Team Members and Getting Them Familiarized with Literature Survey Format and IEEE Reference Guide via Group Meetings	11/30/2022
11/10/2022	Literature Survey for Third Annual Computer Science Conference for CSU Undergraduates	11/30/2022
11/10/2022	Beginning of Trial of Applying *Super-leadership model* for Team Management	11/30/2022
11/15/2022	Literature Review and Submission for Group Paper	12/9/2022
11/18/2022	Group Meetings before Holidays and Keeping Reading Literature Pieces	11/30/2022
11/30/2022	Preparation for Progress Report and Presentation	12/9/2022
12/13/2022	Submission of Literature Survey for Third Annual Computer Science Conference for CSU Undergraduates	12/28/2022
12/19/2022	Assisting Implementation and Testing	12/29/2022

5.1 Super-leadership model

I first learned this model as a competitive swimmer to enter Korea National Sport University. As the team leader of |YES|, I project this whole experience of being in a team for a shared goal to lead them to conducting an effective leadership and, in fact, both my team members, Spencer Ledwell and Esmeralda Osornio have past or current leadership role experiences in school or at work as I do, so I have recently suggested a model of "super-leadership" to them.

"Super-leadership is often described as 'Leading others to lead themselves' and is based on individual self-leadership" [33]. It is a management style that emphasizes individual autonomy [33]. According to Charles Manz and Henry Sims, "super-leaders" are expected to exemplify both strong self-leadership with their strength coming from the abilities of those who surround them rather than solely themselves [33]. Super-leadership helps the individual members take initiative and self-lead [34] as opposed to a traditional leadership style in which direction from a leader is continuous. Super-leadership's key outcomes are: "developing environments that promote positive attitudes, enabling employees to set personal goals, encouraging observation and comment amongst subordinates, and encouraging members of a group to support and motivate one another" [33]. I believe that implementing this model will help our group achieve greater organizational effectiveness [34].

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Appendices

Appendix A. A Table of Summarized Course Projects Taken by the Senior Student

Name of Course (COMP – Bakersfield College, CMPS – CSUB)	**Area**	**Descriptions of Course Projects / Topics**	**Language**
COMP B42 Web Design: HTML & CSS	Front-end	Designed and created a 5-page website for a fictitious business that takes orders online	HTML/CSS
COMP B10 Introduction to Programming Methodologies using Python	Back-end	Practiced object-oriented programming and created a program that simulates a radio channel switch knob and other controls	Python
CMPS 3120 Discrete Structure	Back-end	Created a bot that determines areas of possible paths of a coin collecting robot by showing the total maximum number of coins that the robot can collect while it is passing each optimal route	Python
CMPS 3500 Programming Languages	Back-end	Created functions to inspect data to load, identify a square matrix, calculate a value of determinant and cofactor, inverse, nth power, addition, subtraction, and multiplication of matrix	Python, Ruby
CMPS 3560 Artificial Intelligence	Back-end	Developed a program that fills an array with as many ones (1s) as possible using a Genetic Algorithm, a fitness function, and genetic operator	Python
CMPS 3420 Database Systems	Front-end & Back-end	Designed navigation of home, user roles, and contact pages where end users can create, read, update, and delete financial transactions of their spending and saving information	MySQL, HTML/CSS
CMPS 4800 Undergraduate Research	Research & Back-end	Proposed an A.I.-based application that assists telepsychologists by evaluating a patient's facial emotion detected during a remote therapy session	Python
CMPS 3390 Application Development	Front-end & Back-end	Automated creating problems and scoring answers for a math quiz game application with recording feature for students to explain and justify answers to the teacher	Java, CSS

CMPS 3350 Software Engineering (in progress)	Front-end & Back-end	Adding a variety of visual and audio elements to a 2D game and creating game features using OpenGL and OpenAL Developing mobile applications using Android Studio	C++, Java
CMPS 4890 Experiential Prior Learning (internship in progress)	Back-end	Transforming image data to hexadecimal values then to floating point values in SQL as Intern Automation Specialist (Sep 2022 – Present) and verifying and updating raw data after comparing one attribute with another as an Intern Data Engineering Technician (Jun – Sep 2022)	Python, MySQL

Appendix B. A List of Currently Available SfM Resource for Implementation and Testing

Name, Platform, Cost (F = Free, NF = Not Free)			**Relevant webpage(s)**
3DF Zephyr	Windows	F	https://3dflow.net/3df-zephyr-free
ARC3D	Web-based	F	https://www.youtube.com/watch?v=56wuxAKBhME https://www.youtube.com/watch?v=zXcHjk3Ax2o http://what-when-how.com/digital-imaging-for-cultural-heritage-preservation/arc3d-a-public-web-service-that-turns-photos-into-3d-models-digital-imaging-part-1
Bundler – SfM for Unordered Image Collections	Linux	F	https://www.cs.cornell.edu/~snavely/bundler https://github.com/snavely/bundler_sfm
DroneMapper	Web-based	F	https://dronemapper.com/about/ https://dronemapper.com/sample_data/
RealityCapture	Windows	NF	https://www.capturingreality.com/realitycapture https://www.youtube.com/watch?v=OFktGsFkYPY
VisualSFM	Windows, Linux, macOS	NF	http://ccwu.me/vsfm/index.html https://www.youtube.com/watch?v=5ceiOd8Yx3g
Linearis3D	Windows	NF	https://www.linearis3d.de/standard-photogrammetrie.html https://www.linearis3d.de/sdk.html
Agisoft Metashape	Windows, Linux, macOS	NF	https://www.agisoft.com/pdf/metashape_presentation.pdf https://www.agisoft.com/features/professional-edition
OpenCV	Windows, Linux, macOS, Android, iOS	F	https://ducha-aiki.github.io/wide-baseline-stereo-blog/2021/05/17/OpenCV-New-RANSACs.html https://opencv.org/evaluating-opencvs-new-ransacs https://pypi.org/project/pydegensac https://learnopencv.com/image-alignment-feature-based-using-opencv-c-python
MATLAB & Simulink	Windows, macOS, and Linux	F	https://www.mathworks.com/discovery/ransac.html https://www.mathworks.com/support/requirements/platform-road-map.html
OpenSfM	Windows, Linux, macOS, Web-based	F	https://opensfm.org https://readthedocs.org/projects/opensfm/downloads/pdf/latest
COLMAP – SfM and Multi-View Stereo	Windows, Linux, macOS	F	https://github.com/colmap/colmap https://www.youtube.com/watch?v=Lcp5osRGUrs
Meshroom – 3D Reconstruction Software	Windows x64, Linux, macOS (some work required)	F	https://meshroom-manual.readthedocs.io https://alicevision.org https://github.com/alicevision/Meshroom https://github.com/alicevision/MeshroomMaya