Aerial Video Processing in Support of Disaster Relief Proposal

Prepared for: George Mason University, SYST 699

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Problem Statement

The problem we are trying to solve is how to process large amounts of video data to identify structural damage and thermal blooms.

The United States Air Force (USAF) currently lacks the capability to quickly process large quantities of video data in support of disaster relief. Unmanned Aerial Vehicles (UAVs) fly over terrain following natural disasters such as hurricanes, earthquakes, tornados, and floods to gather up to 12 hours of video in a single flight. Human analysts must watch this video continuously for the duration of the footage to spot area of interest. The problem that exists is this laborious task of watching 12 straight hours of video is known as “death by video” for the analysts. This is not only expensive to have the man hours required, but it also delays the disaster relief efforts.

Problem Contribution

The contribution to the problem we will make is integrating a series of components to take video data in, fuse it with additional information as needed, process the data to identify anomalies and display the anomalies in a more useable form. It will do this through researching existing mechanisms for processing video and imaging data and suggesting how these techniques can be used to transform the information inputs into useable output for the analysts who would otherwise be watching the video. This project is focused on identifying and integrating image and video processing techniques to meet the needs for disaster relief.

Background

In 1965, the cofounder of Intel, Gordon Moore, predicted that the number of transistors on integrated circuits would double approximately every two years, which in fact turned out to be approximately every 18 months. During this same period of time, the space per unit cost of hard drive memory doubled even faster at every 14 months. The price of one Gigabyte of storage shrank from $300,000 in 1971, to $.10 in 2010. In the 20th century, the pace of Gordon's law has contributed the two necessary ingredients, processor speed and cheap data storage, for what will be the 21st century's primary technological horizon – Big Data.

The pace of development in the sensory industry has reflected the pace of technology in general; and with the burgeoning demand for data that these systems can deliver presents the daunting task of how to handle it. The struggle to process, analyze, and most importantly glean an enhanced insight from massive amounts of "Big Data" is a commonality between many diverse industries in developed countries around the world. Every day, 2.5 quintillion bytes of data is accumulated from everywhere; climate sensors, posts to social media, digital media, purchase transaction records, cell phone GPS coordinates just to name a few. In fact, 90% of the data that exists today has been created in the last two years alone. This leads us to the conclusion that optimal "Big Data" analytics will be one of the primary obstacles that humanity will try to overcome in the 21st century.

Currently, UAVs gather video up to 12 hours in length, which is downloaded in pieces to a Remotely Operated Video Enhancement Receiver (ROVER) system, and is downloaded and processed in total to ground control stations. Human analysts watch the video for significant events or findings, and either communicate their findings as the video continues to run, or make notes for later reporting.. . When required, the human analyst follows government protocols to declassify the video segment and then sends the video through channels to those that need it such as the Red Cross and the Federal Emergency Management Agency (FEMA). The main part of our project's endeavor is to examine a couple ways to make the AF's current practice more efficient, by designing a versatile video system designed to process up to 12 hours of video feed, automate identification of anomalies at near real-time, and rapidly transfer video down to human analysts on the ground for more precise and thorough analysis of system identified anomalies.

Assumptions

This project will operate under several assumptions. These assumptions are designed to provide boundaries and guidance for the concept of operations and the analysis of alternatives. The first assumption is that all videos incoming will be of a known format and standard. This means the system will not need to account for any type of video format or quality. We will assume that we are processing twelve hours of data at a given time. This assumption means that the video is being loaded after it has been collected and that in loading the video, users can provide additional inputs to the system to provide more information on the video itself. It also means sometimes the videos will be reviewed after-the-time of collection, which is often nicknamed "forensic analysis."

We will also assume that humans will be viewing the results of the video processing software and will validate or negate automatically identified video anomalies. It is not currently planned that analysts will rewatch the videos to catch any anomalies that the software has missed. We will also assume the technology exists for the software components and algorithms to function as intended.

Scope

This project will focus on defining a concept of operations (CONOPS) for a software system to process and analyze twelve hours of video for the purpose of disaster relief. The main deliverable for the project will be a CONOPS document and a minimum of 2 alternatives to recommend for executing the task. The project is only concerned with defining how the software system should work. No recommendations for hardware solutions, network nodes, communication link, or video sensors will be provided under the project scope. The project team plans to deliver a robust CONOPS document to document how the system will function at a high-level. This will allow the team to come up with two feasible alternatives which will go into more details about the flow of data and potential algorithms. The alternatives will be evaluated using a predetermined and sponsor approved criteria model and the best recommendation will be provided.

Stakeholders

The primary stakeholders will be the Secretary of the Air Force's Acquisition (SAF/AQ) department. Mrs. Dorotha Biernesser is the program monitor element for this department and has expressed the interest for the team to complete the project. Mrs. Biernesser plans to share the analysis with the A2C department, which oversees short range planning for Air Force intelligence analysis. . A system that automates video processing benefits the Air Force by speeding up the time to process video data and freeing up analysts to work on more pressing work. Both of these parties have a vested interest in the details and satisfactory completion of the project.

Additionally, disaster response and disaster relief groups such as the Red Cross, The Department of Homeland Security, and the Federal Emergency Management agency are stakeholders in the project. These individuals will depend on the information provided by the final system when it is deployed to provide accurate and timely processing of video footage to develop disaster response and relief strategies.

The Systems Engineering and Operations Research (SEOR) department at George Mason University (GMU) is a stakeholder in the project because they act like the umbrella corporation overseeing our small team's project. GMU has a fine tradition of delivering quality engineering products to customers and project sponsors alike. Their stake in the project will be to ensure reliable and intelligent systems engineering practices have been executed on the project to provide a feasible and well thought out solution for the sponsor to uphold the reputation of the department and university.

High-level Requirements

The following are the high-level requirements for our system:

- The system shall accept digital video.
- The system shall be able to accept video feeds containing 30 frames per second resolution.
- The system shall be able to accept video feeds of 2048 by 2048 pixel view (200 meters by 48 meters).
- The system must be able to process up to 12 hours of video.
- The system shall accept electro optical (EO) and infrared (IR) video feeds.
- The system shall be able to detect anomalies in video footage.
- The system shall be capable of alerting the user of anomalies found in video footage.

Project Definition

This project will investigate an ideal system of software that can facilitate the retrieval and gathering of data. We will introduce some methods to automate the processing of large amounts of this structured and unstructured data from various forms of onboard video and photographic sensors in addition to other forms of pertinent data from off-the-shelf vendors. By doing so, this project intends to accelerate the information processing cycle to free up time for the analysts to analyze the anomalies vice identifying them. Additionally, this project will aim to provide disaster relief organizations such as the Red Cross and the FEMA information a to support their relief efforts by identifying where damage has occurred, what type of damage has occurred, and when damage has occurred. This can improve planning and utilization of resources by identifying areas that have the greatest need for specific resources.

Literature Review

There are two key problems in regards to our problem. The first is, how can we process the information that we are given to identify those points of information that are most relevant to our interest. The second problem is that, given that we have processed this information, how do we present the results of the processing. There has already been work done for identifying disaster damage as well as for categorizing video information. The RADATT tool is one example of such a damage detection system; it maintains pre disaster data and imagery through GIS technology. When a disaster occurs, post-disaster imagery can be loaded into the system and the data can be compared against the pre-disaster information to identify areas of damage.

Earthquake damage assessment has successfully done through using pre-disaster and post-disaster satellite imagery. The images were processed using a change detection algorithm, and areas of change were highlighted. For this particular case, the key inputs required for the assessment was the area of damage as well as the temporal information associated with the imagery. However, this could possibly be applied on a different scale with video data and integrating with historical imagery. Another case developed algorithms for preliminary damage detection. There has alternatively been an algorithm specifically designed for UAV video that uses video image matching to merge video into geo-registered video, which provides coordinates for the imagery.

Additionally, there have been a number of papers integrating captured video information with GIS to manage data collected for disaster relief. By integrating video into GIS, data can be managed both temporally and spatially. This allows people to revisit locations through video. Additional work has also been done to automate UAV video categorization through using multisensor fusion to generate metadata on UAV videos. This work has also investigated mechanisms of indexing and retrieving information based on this meta-data, which is an alternative way of mapping the events of interest in the case of our project.

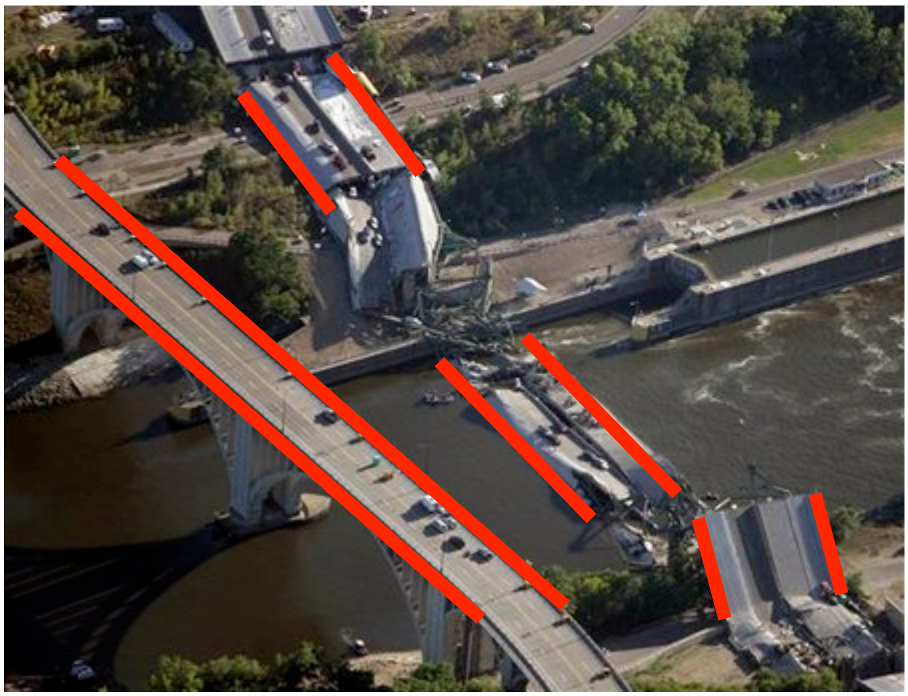


Figure 1: UAV Image of collapsed bridge showing break in line segments

Approach

We began our project by meeting with our sponsor, Mrs. Biernesser and Captain Johnson, to determine the scope of the task assigned to us. They revealed that the USAF (United States Air Force) is facing a problem with the processing time to analyze aerial video data. Mrs. Biernesser said the "[USAF] have been flying around the forest of this problem and keep getting smacked in the face with branches," which implies that their research to improve their video processing capability has been unsuccessful and there is a need to expand their field-of-view. We solicited information from our sponsor to better clarify the restrictions and constraints of our project, which also helped us understand the bound of our system's capabilities. The restrictions correspond to:

- Damage detection - detects man-made structural damages (e.g. collapsed building and washed-out bridge)
- Alert system - notifying operator of damages (e.g. flashing border or time-stamp)

The constraints correspond to:

- Video format - EO and IR
- Frame rate, resolution, duration of video, mean altitude of video footage

At the writing of this Proposal, we are gathering requirements from our sponsor and translating that to top-level requirements of our system. We will continue to refine our system assumptions as our sponsor provides us with more information. From that, we will work with our sponsor to develop a clear set of final deliverables due at the end of the semester

Going forward we intend to perform extensive research on the technology currently in the market for video/image processing. One of the most important aspects of this research is to determine the various algorithms employed in identifying areas-of-interest in a given video. The areas-of-interest is defined as an area of significant anomaly in the video footage. These algorithms are considered to be the system logic that identifies conspicuous color gradient, temperature spike, and/or a break in line patterns. These technologies are currently employed in the fields of fingerprints recognition, facial recognition, airport thermal scanner, as well as various military surveillance applications. Another approach that we intend to do extensive literature research on is crowd-sourcing. By splitting a 12-hour video into smaller segments, e.g. 30 seconds, these smaller video clips can then be inspected by a large amount of viewers to identify whether any areas-of-interest exist.

With respect to the alert subsystem, we will examine known algorithms to output an alert to the operator. This may include a flashing border around the screen, a circle around the areas-of-interest, time-stamps, and so on.

Ultimately, we hope to answer at least these few questions:

1. What are the video processing capabilities used to analyze electrical-optical (EO) and infrared (IR) video-format data?
2. Are the software capable of distinguishing the differences in color gradient, temperature, or even non-linear pattern?
3. How fast and accurate can the algorithm detects these areas-of-interest?
4. Will the alert comprise of an audio signal, a time-stamp, and/or geographical coordinates?

For our data analysis process, we will identify at least two effective alternatives in processing aerial video for disaster relief. Given a set of known parameters (video format, frame-per-second, resolution, area of coverage, and so on), we will pay close attention to how accurate and quickly can the system identify the area-of-interest in a 12-hour video footage. Some criteria may include recognizing a temperature spike within a midst of cold debris, a charcolored structure from an aftermath of a fire, and/or a structural anomaly of a collapsed building.

We will divide our system into four stages to perform in-depth research:

1. **Input stage**: when the system receives aerial video footage and the system gathers image/video data from other sources corresponding the geographical areas being assessed.
2. **Processing stage**: when the system analyzes the data collected.
3. **Pairing meta-data stage**: when the system pairs the meta-data corresponding to what the processing stage outputs as the areas-of-interest.
4. **Alert stage**: when the system alerts an operator of the areas-of-interest.

Project Risks

Due to the nature of this project, the project team faces two main areas of risk. The other areas of risk surrounding the project will be documented in the Concept of Operations (CONOPS) document and will include a risk mitigation plan. The first main risk facing the project group is the limitation of available video processing literature. Different military branches and government agencies such as the Central Intelligence Agency (CIA) have been operating drone fleets for years now. There is certainly video processing knowledge in the industry and lessons learned. However these documents are likely classified and thus unobtainable by the project group. This places a great amount of risk on the group in not being able to obtain a feasible solution that is optimal with what the industry is currently practicing. For this reason, great emphasis has been placed and resource hours have been allocated to allow the group to research the methods and algorithms necessary to carry out the video processing task. The second biggest area of risk is the time limitation for the semester. Only having 16 weeks to develop a robust solution poses a serious risk to any engineering development cycle. The team will be limited in the amount of trade studies and analyses that are able to be performed. This has the possibility to risk the quality of the overall recommendation at the end. A brief synopsis of the risk table to be included in the CONOPS can be seen below.

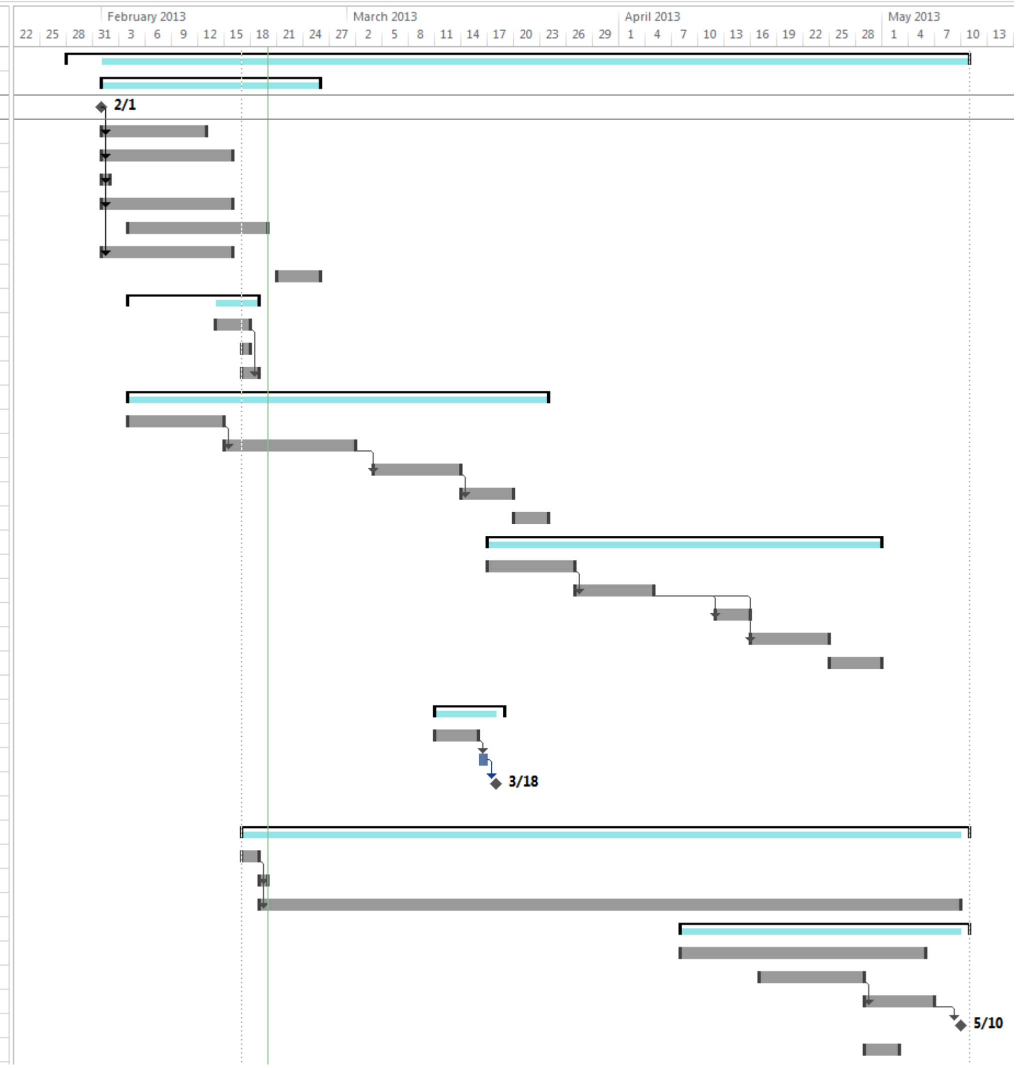
Table 1: High Level Risk Table

Risk	Mitigation Strategy	Likelihood	Impact
Short duration of the performance period in the event the schedule slips	Redefine scope as needed to account for period of performance	Low	Medium
Availability of sponsor for feedback on deliverables	Utilize both sponsors to review deliverables	Low	Low
Availability of desired software packages for developing deliverables	Identify additional software with similar capabilities that are more readily available as well as utilize SEOR labs if available and loaded with desired software	Low	Low
Availability of SMEs to provide information on	Work early with Sponsor to leverage any contacts that are available; identify SMEs needed early on	Medium	Medium

Schedule/GANTT Chart

GANTT CHART

	Task Name	Start	Finish
1	**1 Complete SYST699 Project**	**Mon 1/28/13**	**Fri 5/10/13**
2	**1.1 Write Proposal**	**Fri 2/1/13**	**Mon 2/25/13**
3	1.1.1 Meet With sponsor	Fri 2/1/13	Fri 2/1/13
4	1.1.2 Gather Requirements	Fri 2/1/13	Tue 2/12/13
5	1.1.3 Define Project Scope	Fri 2/1/13	Fri 2/15/13
6	1.1.4 Study Current Operations	Fri 2/1/13	Fri 2/1/13
7	1.1.5 Define Necessary Deliverables	Fri 2/1/13	Fri 2/15/13
8	1.1.6 Complete Team Meetings	Mon 2/4/13	Tue 2/19/13
9	1.1.7 Define Stakeholders	Fri 2/1/13	Fri 2/15/13
10	1.1.8 Review with Sponsor	Thu 2/21/13	Mon 2/25/13
11	**1.2 Create Proposal Presentation**	**Mon 2/4/13**	**Mon 2/18/13**
12	1.2.1 Create Slides	Thu 2/14/13	Sun 2/17/13
13	1.2.2 Complete Team Meeting	Sun 2/17/13	Sun 2/17/13
14	1.2.3 Rehearse Presentation	Sun 2/17/13	Mon 2/18/13
15	**1.3 Complete CONOPS**	**Mon 2/4/13**	**Sat 3/23/13**
16	1.3.1 Brainstorm New Methods of Operation	Mon 2/4/13	Thu 2/14/13
17	1.3.2 Define Operational Scenarios	Fri 2/15/13	Fri 3/1/13
18	1.3.3 Define Architectures	Mon 3/4/13	Wed 3/13/13
19	1.3.4 Develop CONOP illustrations	Thu 3/14/13	Tue 3/19/13
20	1.3.5 Sponsor Review	Wed 3/20/13	Sat 3/23/13
21	**1.4 Complete AoA**	**Sun 3/17/13**	**Tue 4/30/13**
22	1.4.1 Research design alternatives	Sun 3/17/13	Tue 3/26/13
23	1.4.2 Develop System Logic For All Options	Wed 3/27/13	Thu 4/4/13
24	1.4.3 Risk Analysis	Fri 4/12/13	Mon 4/15/13
25	1.4.4 Effectiveness Analysis	Tue 4/16/13	Wed 4/24/13
26	1.4.5 Lessons Learned	Thu 4/25/13	Tue 4/30/13
27	1.4.6 Sponsor Review		
28	**1.5 Interim Progress Report (IPR)**	**Mon 3/11/13**	**Mon 3/18/13**
29	1.5.1 Create Slides	Mon 3/11/13	Fri 3/15/13
30	1.5.2 Rehearse Presentation	Sat 3/16/13	Sat 3/16/13
31	1.5.3 Give Presentation	Mon 3/18/13	Mon 3/18/13
32	1.5.4 Meeting with Instructor		
33	**1.6 Create Website**	**Sun 2/17/13**	**Fri 5/10/13**
34	1.6.1 Write Code	Sun 2/17/13	Mon 2/18/13
35	1.6.2 Add Team Bio Information	Tue 2/19/13	Tue 2/19/13
36	1.6.3 Add Periodic Updates	Tue 2/19/13	Thu 5/9/13
37	**1.7 Prepare Final Report**	**Mon 4/8/13**	**Fri 5/10/13**
38	1.7.1 Write Report	Mon 4/8/13	Sun 5/5/13
39	1.7.2 Prepare Final Presentation Slides	Wed 4/17/13	Sun 4/28/13
40	1.7.3 Rehearse Presentation	Mon 4/29/13	Mon 5/6/13
41	1.7.4 Give Presentation	Fri 5/10/13	Fri 5/10/13
42	1.7.5 Sponsor Review	Mon 4/29/13	Thu 5/2/13



Work Breakdown Structure (WBS)

The following figures illustrate the Work Breakdown Structure (WBS) for the project. The main project activity with be to complete the aerial video processing project. The subtasks are comprised of the 7 top activities that will be required to complete the project. Each subsequent figure has the sub-tasks broken down into sub-sub-tasks for visibility into the lowest level tasks to be completed.

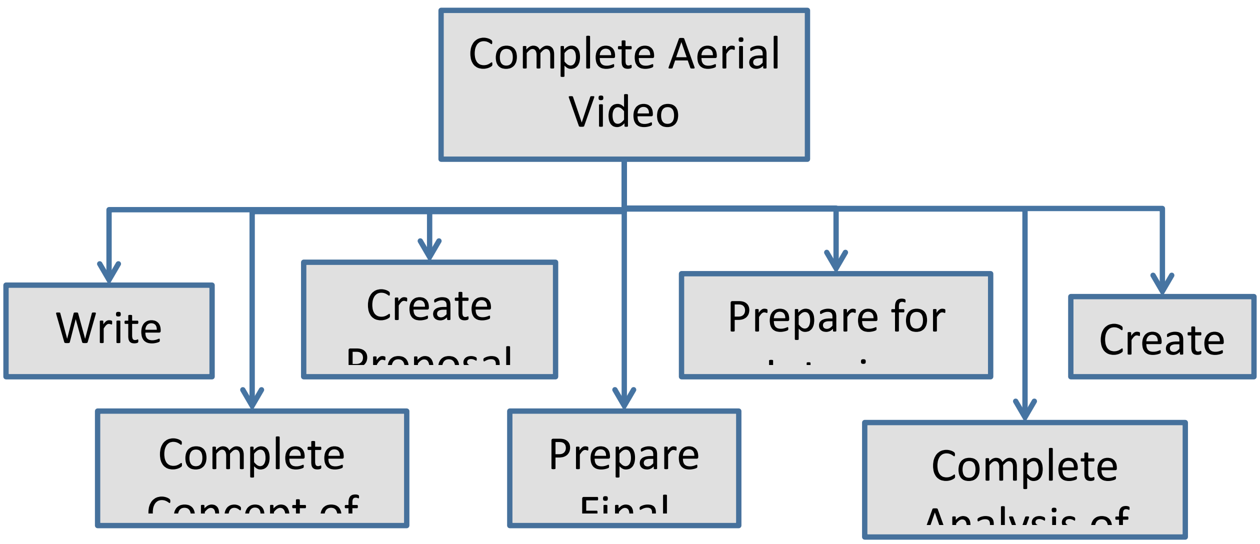


Figure 2: Top Level WBS

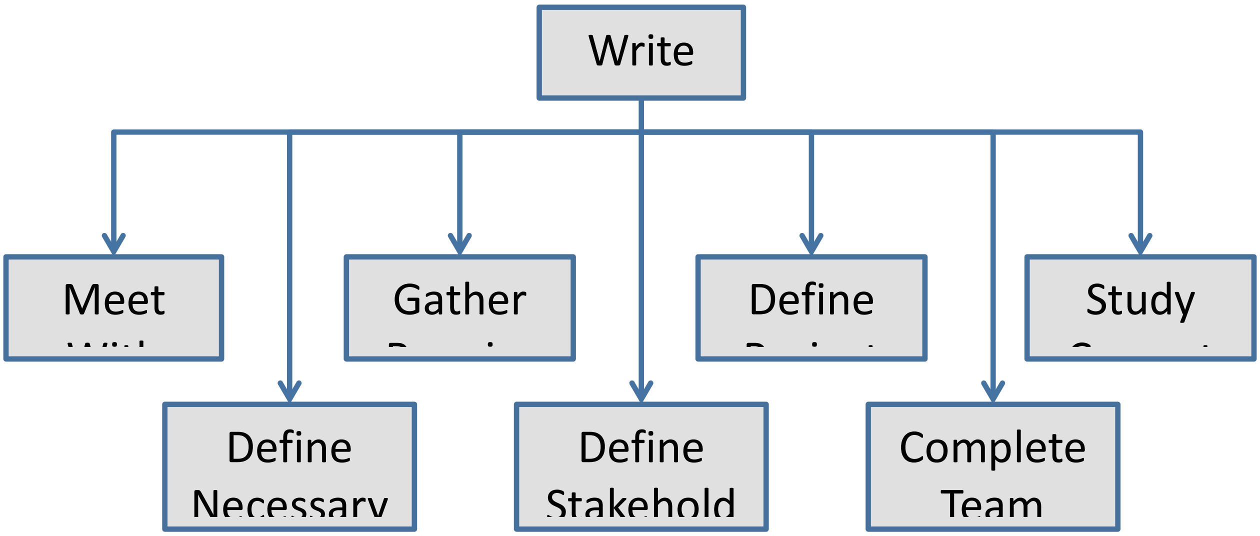


Figure 3: 'Write Proposal' Sub-Task

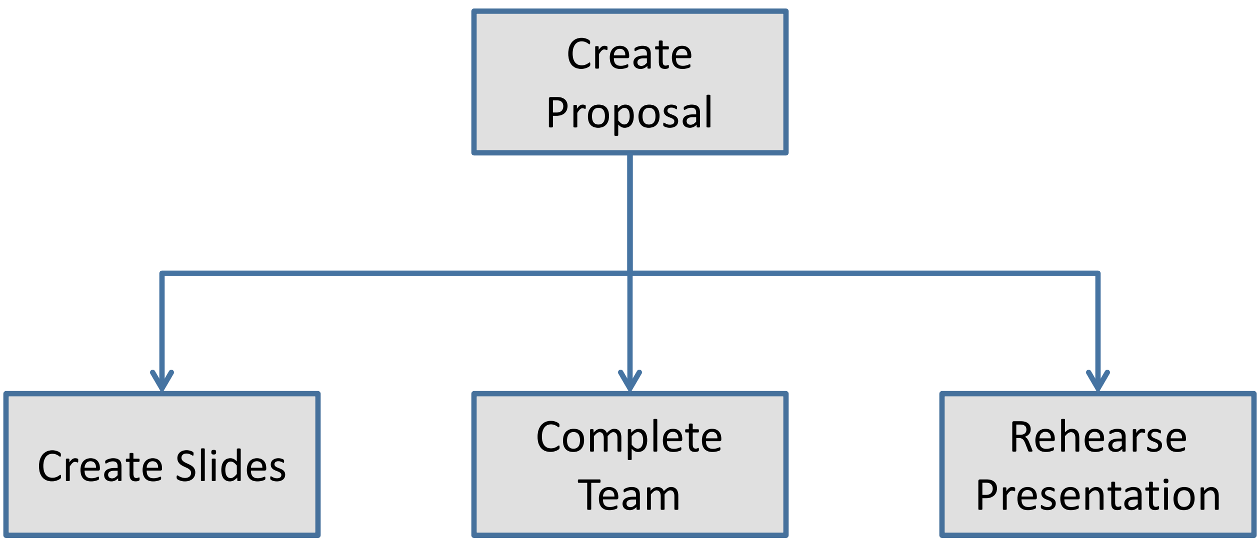


Figure 4: 'Create Proposal Presentation' Sub-Task

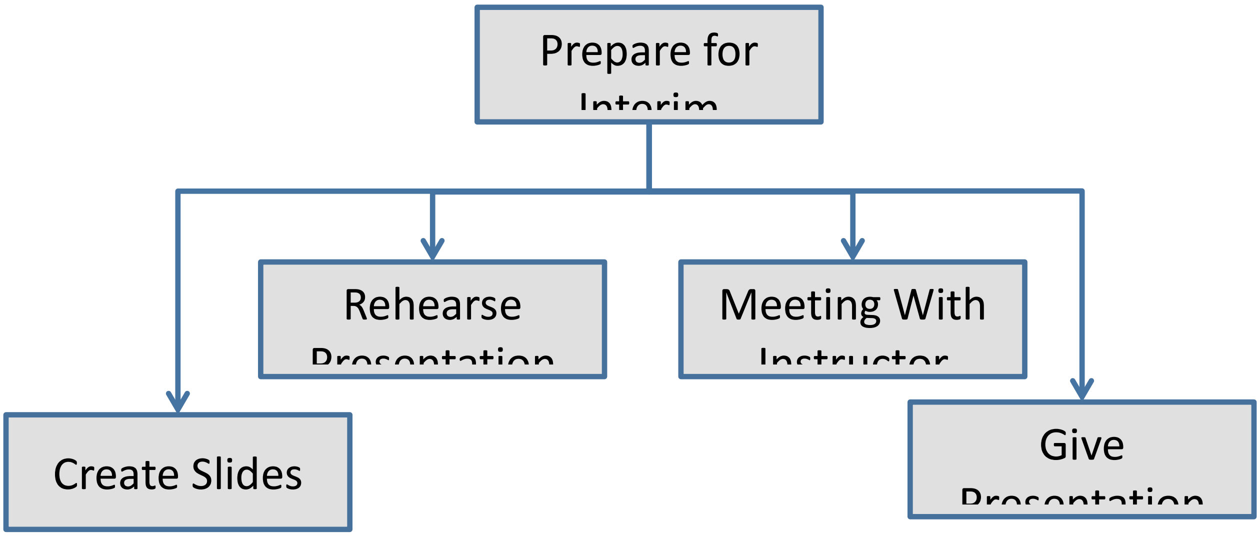


Figure 5: 'Prepare for Interim Progress Report' Sub-Task

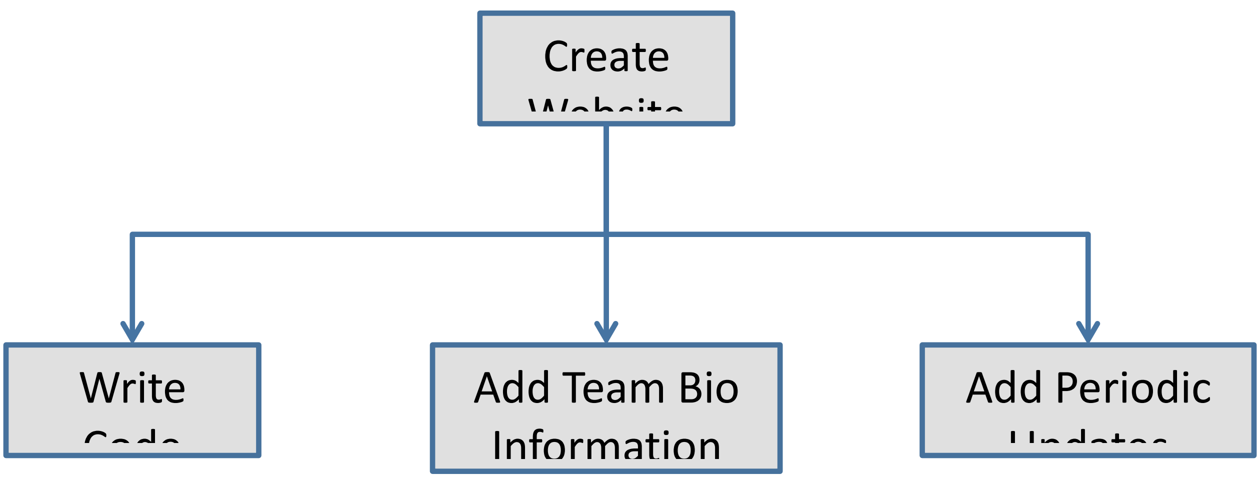


Figure 6: 'Create Website' Sub-Task

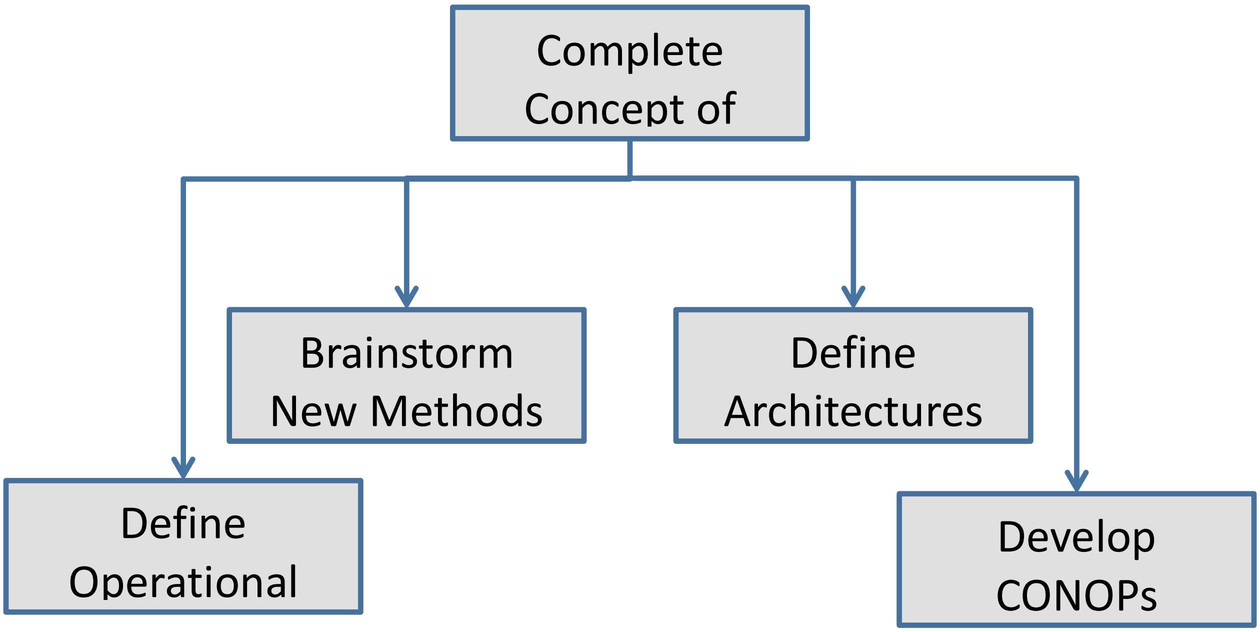


Figure 7: 'Complete CONOPS' Sub-Task

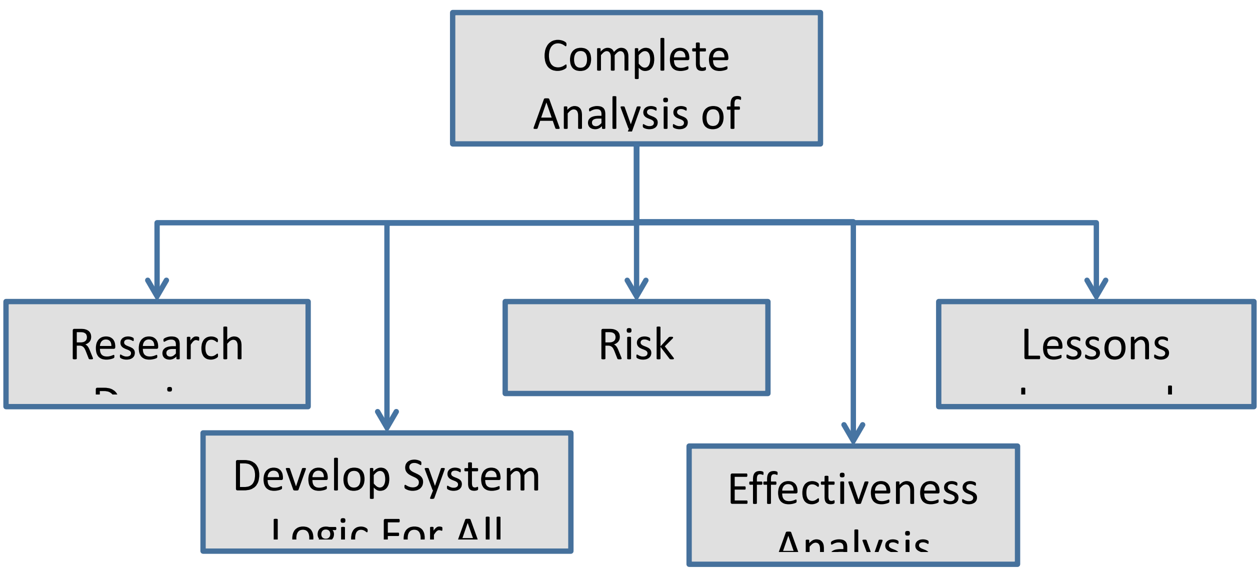


Figure 8: 'Complete AoA' Sub-Task

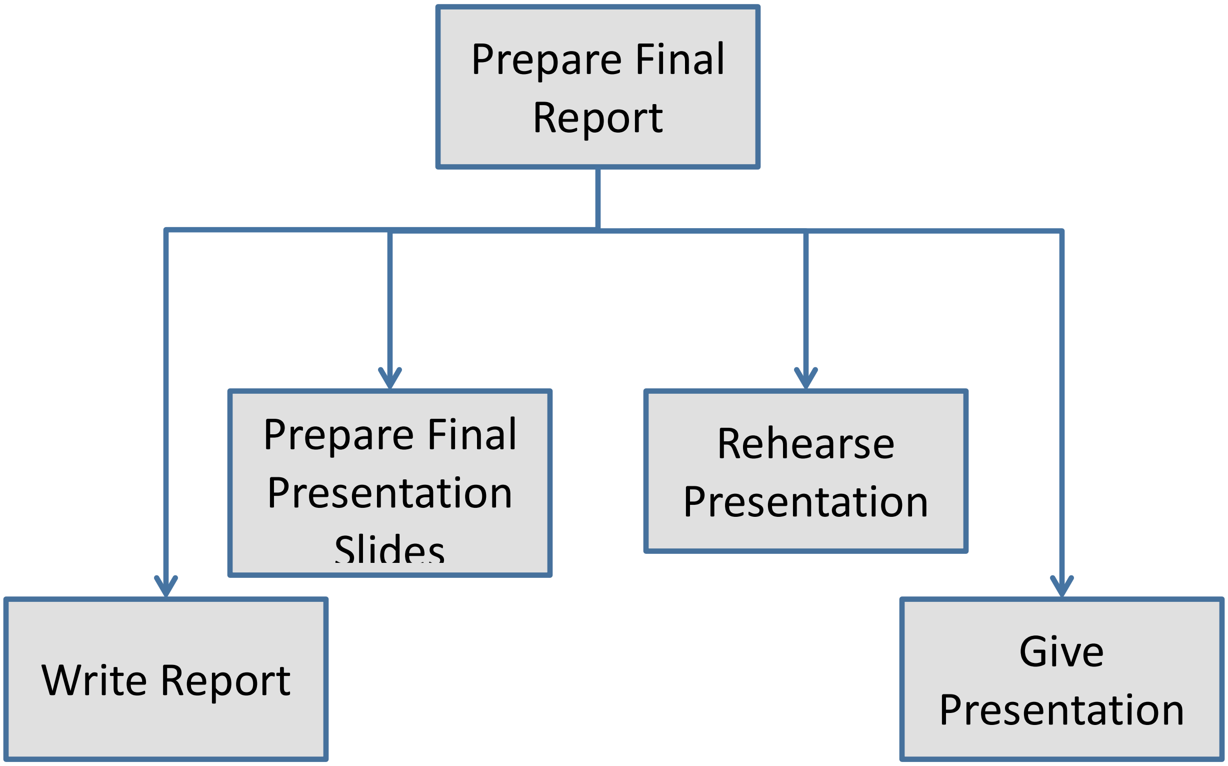


Figure 9; 'Prepare Final Report' Sub-Task

Deliverables

The following deliverables will be provided as part of the project:

- Interim progress report - This report will document the interim progress made through the period of performance. This will provide a chance for sponsors and stakeholders to verify that the project is proceeding in a timely manner and that
- Project website - The project website shall be updated through the development of the project as an outreach to external parties interested.
- Concept of Operations (CONOPS) Document - This deliverable will form the core of our project. Its purpose is to develop how aerial videos can be automatically processed. It will define the system flow, use cases, and how the system would function operationally. It will also identify the system inputs and outputs as well as how the system should function.

- Analysis of Alternatives (AoA) - This document will cover the exploration of multiple alternatives with respect to the "how" the system will process aerial video. The AoA will detail the specific processes of each option and the specific information generated by each. The AoA will also assess the critical technology and compares the performances of each alternative.
- Final Report - The final report will document the entire process of developing the concept of operations and analysis of alternatives as well as include sections on how the system would work, next steps, impacts of such a system and conclusions.
- Final Presentation - The final presentation will be provided to the major project stakeholders as a chance to present the process and conclusions of the project and offer a forum for discussion as to the validity of the approach taken and the applicability of such a system.

Our plan for vetting deliverables with the sponsor is by providing them 3-5 days prior to the deadline to ask for and receive feedback and comments. This will ensure we are on the same page. This will occur on the following dates: Concept of Operations (3/20), Analysis of Alternatives (4/25), Final Report (4/29)

Success Criteria

This project will be successful if the following can be accomplished:

- Sponsor accepts the in-depth CONOPS based on the criteria that it meets all the baseline requirements and provides the information needed.
    - Identify at least two viable alternatives how the system processes aerial video data.
    - Identify at least two methods how the system alerts an operator.
- Sponsor accepts the AoA comparing the at least two viable alternatives.
- Dr. Barry and/or Dr. Loerch accept the Final Report.
- Dr. Barry and/or Dr.Loerch accept the Final Presentation.
- The website is accessible and contains the details of this project.