A.L.V.I.N.N.

AUTONOMOUS LEARNING VEHICLE INTEGRATING NEURAL NETWORKS

PROJECT PLAN

Dec1709

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1 Introduction

1.1 PROJECT STATEMENT

This project is in collaboration with Rockwell Collins to use computer vision, machine learning, and neural networks to have a drone detect an airport runway or objects in the air. This will require the team to identify the software and hardware requirements capable of performing these tasks. Computer vision tools can then be used to detect objects within a picture or video stream. Machine learning and neural networks will then be incorporated to perform teaching operations for identifying different objects or distinguishing between similar objects. Furthermore, part of the project will consist of determining which machine learning algorithms are particularly suitable for our object recognition task. Since this problem is interdisciplinary in nature, we will also have to investigate to what extent traditional computer vision techniques could be incorporated into our solution.

1.2 PURPOSE

Rockwell Collins is an aviation electronics company dealing with military and commercial aircraft. Rockwell Collins could use this technology to introduce new products that could have multiple uses for their customers. Although we are starting simple with basic object detection this could develop into technology that the military could use to survey an area before sending troops in, detect enemy forces, identify bombing locations, or drop locations for aid packages. Commercial uses could be finding hotspots in forest fires, locating remote wreckage sites, finding lost hikers, or finding survivors of some disaster.

1.3 GOALS

Rockwell Collins primary goal of this project is to detect objects on the ground such as a landing strip or objects in their air such as other drones. To accomplish these goals, we need to set some smaller goals to help us succeed. First, we have an educational goal. This goal is to learn about the topics covered in this project from computer vision to neural networks. Upon acquisition of this knowledge, we can then accomplish our next goal of deciding what software, technology stack, and equipment to use. Once we have decided on the software to use we can start working with it learning how to use it to proceed to the goal of object detection. Teaching the system to distinguish between objects is the next goal. With these goals achieved we can work towards our final goal of implementing all of this with neural networks.

If time allows we could then look at detecting landing strips versus other paved features such as large parking lots or roadways. Detect another drone which could lead to detecting its movements and setting autopilot to follow it. Auto Course correction when detecting objects when flying to avoid collisions. Object identification confidence, projecting the system's confidence on what it perceives an identified object to be.

2 Deliverables

- Phase I: Detect ‘X’ in an image
- Phase II: Detect ‘X’ with background noise in an image
- Phase III A: Detect multiple objects within an image Possibly incorporate GPS or Google Maps to help facilitate object detection based on what stationary objects/landmarks may be in the area (airport, lake, specific buildings, etc.).
- Phase III B: Identify objects even if objects have several different appearances.
- Phase IV: After detecting an object, report to control possible object identifications with associated confidence levels.
- Phase V: Identify an object that may present itself is several different positions
- Phase VI: After successfully being able to identify objects, begin feeding the system back to back images building up to real-time image capture and video feed
- Phase VII: Tracking movements of identified objects
- Phase VIII: Beyond tracking movements, track fellow system in air and follow the system via autopilot.
- Possible Bonus Features
  - Course Correction: Identify objects in the system’s path and communicate with control. Control can advise whether to continue the pre-selected course or course correct. Possibly incorporate GPS or Google Maps to help facilitate this feature.
  - 360º View: Like Nissan’s 360º view technology around their vehicles, have a 360º view of what is around the system laterally and what is above and/or below the system.
  - Feature Recognition: Ability to recognize various features present on objects (colors, symbols, unique traits, etc.)
  - Thermal Imaging or Night Vision: Object detection and identification through thermal imaging or night vision cameras.

3 Design

3.1 PREVIOUS WORK/LITERATURE

Below are several resources/research that has previously been done on our topic. Besides those listed below, machine learning work has been done before on image detection and movement and Google has Google Draw Neural Network. We are currently still in our education state and learning about these resources.

- Nielsen, Michael. *Neural Networks and Deep Learning*
  - http://neuralnetworksanddeeplearning.com
  - More of a tutorial than research. This is an online book explaining neural networks and solving a common classification problem.
- Lecunn, Y., Bottou, L., Bengio, Y., Haffner, P. (1998) Gradient Based Learning Applied to Document Recognition
  - http://yann.lecun.com/exdb/publis/pdf/lecun-01a.pdf
  - One of the first papers demonstrating the idea of Convolutional Neural Networks
- Krizhevsky, A., Sutskever, I., Hinton, G. E., (2012) ImageNet Classification with Deep Convolutional Neural Networks
  - http://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks.pdf
  - Recent paper on image classification using convolutional neural networks (CNN)

The above references are incredibly advantageous as they will be able to provide the team an understanding of neural networks and machine learning, since this is a new topic for the team. While it is mostly advantageous, a shortcoming that they do have is the level of abstraction in terms of their discussion on machine learning/neural networks. As the team is still new to the concept of machine learning, certain advanced algorithms for very specialized neural networks and such should be considered carefully as to not get bogged down with details.

3.2 PROPOSED SYSTEM BLOCK DIAGRAM

Below is a block diagram for our system. Once we have more educational background in the technologies we plan to use in our project, we will be able to construct a technical block diagram of how the system parts work together.

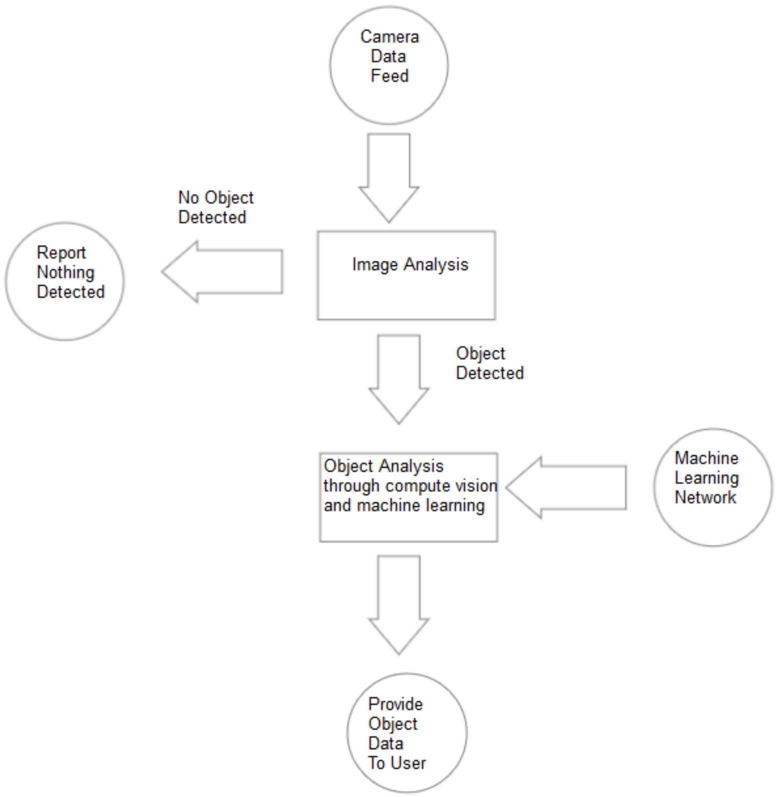

Figure 1: A.L.V.I.N.N Block Diagram

3.3 ASSESSMENT OF PROPOSED METHODS

With the primary objective being dealing with neural networks and computer vision; there are several different approaches for how to proceed. The 3 different approaches to the current problem are as follows:

- MATLAB: Use it to prototype out models for the application quickly to be able to get an understanding of the bigger picture
- OpenCV: Use it towards computer vision as well as object detection
- Tensorflow, and other Machine Learning frameworks: Use it to be able to use machine learning to be able to do detection in a fast manner via usage of a neural network.

For the ALVINN team, the primary approach that will be followed is to build off the TensorFlow framework and integrate it with tools such as OpenCV to incorporate machine learning with computer vision to be able to detect objects.

3.4 VALIDATION

For the variety of tasks that the application should be able to perform, there will be a series of test suites to be able to validate whether they adhere to the client's specification. The following is a listing of a few validation tests to be used for the application

- Provide the application with a series of images of aircraft/other objects with a cluttered background and test whether the system can reliably detect the target image.
- Provide the application with a video of an object moving with a cluttered background behind it and test whether the system can reliably detect the moving object.

For the above validation tests and many more, the success of the tests will be based on how consistently accurately the application can detect an object (either moving or stationary) through a large amount of trials.

4 Project Requirements/Specifications

4.1 FUNCTIONAL

The project is proposed to have the minimum function requirements:

1. Drone/System must be able to process a single picture, string of pictures, and/or continuously moving video.
2. Drone must be able to detect stationary objects apart from the background.
3. Drone must be able to detect moving objects apart from the background and from other objects.

4.2 NON-FUNCTIONAL

The project is proposed to have the minimum non-function requirements:

1. Time nonfunctional requirement for data processing; i.e. we want to run within a certain time limit such that it doesn't take 5 minutes to process an image and figure out an image was spotted 5 minutes ago.
2. Space/Memory nonfunctional requirement. Since the client would like to have this application run on a drone which is an embedded system with limited memory/storage, a non-functional requirement would be to be able to implement this without any large memory/space requirements
3. Output information format. I.e. what is the format in which an end user will see the data from our application. Thus, a non-functional requirement would be to have the data be outputted in an elastic way such that future users could easily integrate and use the data in other systems.
4. Arguably, our bonus features could be considered as non-functional potentially. Hard to say based on lack of knowledge on scale of bonus features but for example it could be argued that having a GUI for example would be a non-functional req.
5. It should be able to identify certain objects within a certain threshold of accuracy. I.e. we may say that we want to have the application detect an airplane 80 percent of the time for example.

4.3 STANDARDS

When working on this project, the team will be adhering to several standards. First, all code that will be written will standardized and documented, making it easy to maintain, understand, and debug if necessary. Some IEEE standards which will be more applicable than others would be the IEEE floating point standardization, test methodology standardization, as well as code standardization. For testing and coding, these standards are incredibly important. Since our application will be using a lot of floating point precision and arithmetic, it is important that the IEEE standard for floating points is adhered to, such that it will be able to be transferred to the client’s system easier. In the project, there will not be any practices which would be considered as unethical by organizations such as IEEE or ABET.

5 Challenges

The immediately observable challenges we face in this project are knowledge or theory related. The machine learning field is unfamiliar territory to most of us, since ISU does not offer its machine learning class as an elective to computer engineers. The vastness of this field and the open-endedness of our client's expectations means we need to be careful before investing a lot of time in a technique or method that may not be scalable. Expanding on this, we also need to be aware of potential pitfalls since there is no "one-size-fits-all" approach to an image recognition problem. Consequently, clear and consistent communication with our project stakeholders (who are more knowledgeable on the machine learning field) is of utmost importance.

Another issue we are challenged by (particularly in the early planning stage) is organization. Our project consists of fifteen people total; two teams of six, two advisers, and one client. We have four different mailing lists and already experienced that our advisers may have conflicting expectations or visions.

6 Timeline

This is our absolute aggressive goal. We know that we will have to scale this back dramatically. We are currently working with our advisors to establish a more realistic vision for 491/492.

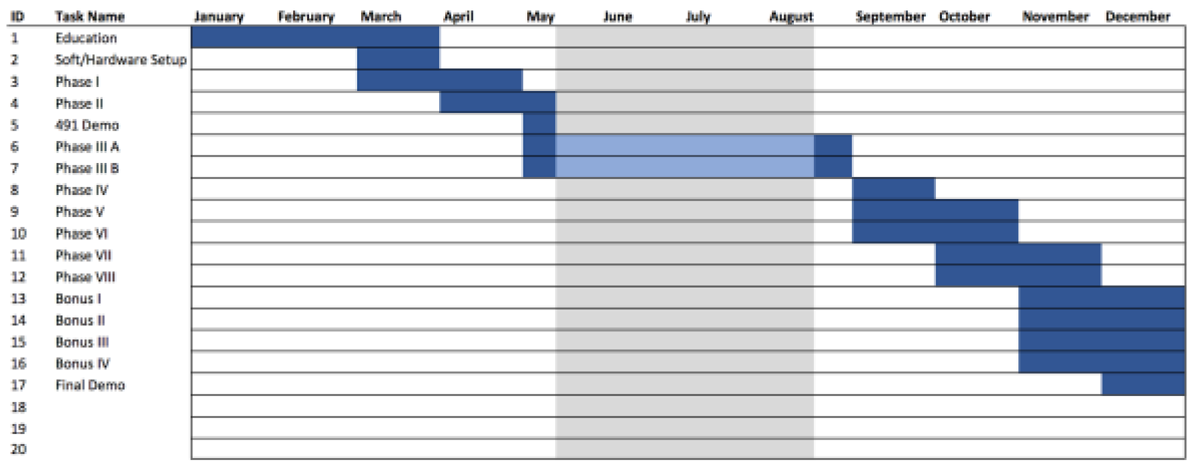

Figure 2: Proposed Timeline

6.1 FIRST SEMESTER

The proposed project breakdown for the first semester of senior design can be seen below. At this time, we are still deep in the education stage and are not sure how we would currently assign tasks.

Week Beginning/Ending			Tasks	Assignment	Deliverables
February	13	19	Education		
	20	26			
March	27	5			
	6	12	Begin Setup & Coding		Design Document 1
	13	19	Begin Phase I		[Spring Break]
	20	26			
	27	2			Project Plan 2
April	3	9	Begin Phase II		Phase I
	10	16			
	17	23			Design Document 2 & Project Plan 3
	24	30			Phase II 491 Demo
May	1	7	Begin Phase III A & B		

Figure 3: First Semester Project Breakdown

6.2 SECOND SEMESTER

The proposed project breakdown for the second semester of senior design can be seen below. At this time, we are still deep in the education stage and are not sure how we would currently assign tasks.

Week Beginning/Ending			Tasks	Assignment	Deliverables
August	21	27	Phase III A & B		
September	28	3	Begin Phase IV		
	4	10	Begin Phase V		Phase III
	11	17			
	18	24	Begin Phase VI		
	25	1			Phase IV & V
October	2	8	Begin Phase VII		
	9	15			Phase VI
	16	22	Begin Phase VIII		
	23	29			Phase VII
November	30	5	Begin Perfecting Code		
	6	12			Phase VIII
	13	19	Bonus Features		
	20	26			[Thanksgiving Break]
	27	3			492 Final Demo
December	4	10			

Figure 4: Second Semester Project Breakdown

Note: This is our absolute aggressive goal. We know that we will have to scale this back dramatically. We are currently working with our advisors to establish a more realistic vision for 491/492. We also are not 100% sure what else we need to do for 492 deadlines (e.g. project plan revision, etc.).

7 Conclusions

First and foremost, the primary objective of our project is to appreciate what it is like to work on a larger project with a multidisciplinary engineering team. Usually, it is advisable to under promise and over deliver. However, we believe that setting aggressive goals for such an exciting project is beneficial and will be a self-fulfilling prophecy - higher morale yields higher productivity! We still want our goals to be realistic, and we are working with our advisers to discuss the feasibility of phases 3 and beyond in more detail. Considering that estimation work (at best) is required for a visual object recognition task we are trying to approach this project from a research perspective. Thus, to optimally achieve our goals, we will be in close contact with our advisers to evaluate what steps are likely to lead to success. Time is also going to play a pivotal role in the success of our project. Therefore, we will try to run heavily computation tasks overnight remotely on machines with specialized performance-critical hardware. Our goal is to complete phases I and II before the summer, and use the remaining time before the next semester to have the next set of goals pinned down for the next phases.

8 References

Machine Learning

- http://diydrones.com/profiles/blogs/using-tensorflow-to-allow-a-robot-to-identify-objects
- http://theopenacademy.com/content/machine-learning
- https://491dec1709.slack.com/files/daschott/F46274YA1/learning.zip
- Good lightweight article to read for not treating machine learning like magic:
    - http://www.pyimagesearch.com/2014/06/09/get-deep-learning-bandwagon-get-perspective/

Neural Networks

- Chapter 26 of the free online book. Good overview of using the simplest of Neural Networks. One can download a pdf of each chapter.
    - http://www.dspguide.com/pdfbook.htm

Computer Vision

- Slide 2 and 3 of the attached PDF gives a high-level overview of that Traditional Computer Vision pipe-line that is heavy on the Feature Extraction stage and light on the pre-processing and Classification stage.
    - https://491dec1709.slack.com/files/tlavan/F49KXLFH8/rcl_021317_murad.pdf
- Somewhat light article that shows a nice example of combining "Traditional" with Deep Learning Computer vision techies. (cool demo near the end: using the Jimmy Fallon show as an input))
    - https://medium.com/@ageitgey/machine-learning-is-fun-part-4-modern-face-recognition-with-deep-learning-c3cffc121d78#.7732t9p7a
- Slide 9: gives a nice overview of a generic classical Computer Vision pipeline
    - http://developer.amd.com/wordpress/media/2013/06/2162_final.pdf
- I would to keep an eye on this intro series (still in progress). Read at least part 1, which gives an overview of traditional approaches for Computer Vision:
    - http://www.learnopencv.com/image-recognition-and-object-detection-part1/
- Near the end of this slide set, gives the topics covered which does a reasonable job of covering topics useful for doing computer vision.
    - http://www.cs.cmu.edu/~16385/spring15/lectures/Lecture1.pdf

Technologies

- TensorFlow Video
    - https://www.youtube.com/watch?v=APmF6qE3Vjc
- Intro to Matlab
    - https://491dec1709.slack.com/files/tlavan/F4663EHSR/ee225_matlabintro_2015.pdf
- OpenCV
    - http://www.learnopencv.com/

Standards

- *http://standards.ieee.org/cgi-bin/lp_index?status=active&pg=40&type=standard&coll=15*