Notable outcomes of any mid-project review, evaluations

* More research driven, ex of minimizing to audio
* Review oral notes with each other
* Discuss team dynamics

Project execution overview:

One of the key decisions that we made in the project was choosing our method of object detection. In many ways this could be valued as the single most important technical decision we made. This is because the ramifications of this decision reach into many different facets of our project. Early on we did as much research as we could on methods for object detection, which is the primary challenge our algorithm and so our solution faces. We need to be able to detect cars reliably. We found that most modern, state-of-the-art object detection algorithms are based on appearance-based object detection. The specific method we were interested in early on was histogram of gradients. This type of detection uses a specific histogram of gradients feature that must be calculated before being run against a classifier of our choosing. We originally paired this methodology with a linear support vector machine classifier.

In developing and prototyping this algorithm we realized early on that it was extremely processor intensive. This method must calculate the features of interest, in this case histogram of gradients, in a brute force way everywhere in the picture and also at various scales. Then it compares all of different calculated features against the support vector machine. It is quickly apparent that this type of heavy, exhaustive calculation was not an elegant solution that would fit well within an embedded system without a great deal hardware acceleration. Given that the algorithm itself is something that does not reasonably run on modern desktop computers, we were beginning to realize the infeasibility of this algorithmic choice in the given timeline for the Cornell Cup. The algorithm was state-of-the-art, difficult to implement, and ultimately slow enough that it increased our workload manifold.

For these reasons we began reevaluating our other researched solutions. The solution with the most merit was one developed by Nieto […]. It utilized a classical morphological approach in order to detect cars. This is something that made our algorithm simpler to implement. Basic morphological steps are fairly quick to begin with, and many of them are already implemented in open source libraries like OpenCV. This choice had potential to both reduce the initial work implementing our algorithm, as well as the tail-end work we would have improving our final speed of execution. It is worth mentioning that morphological approaches tend to be less robust. In this way we view appearance-based object detection as an overall better quality solution. However, given our real world constraints the decision was clear that we needed to move to an algorithm similar to that of Nieto […].

This decision was paramount to the success of our project. We struggled to make it for many reasons, but the primary was that it would push our timeline back further. This decision was made in early January, and which was getting very close to a point of no return in terms of our algorithm. This made the decision both urgent and difficult to make. We focused on the reality of the situation, and what our research and analysis told us. We believe that this decision was essential to success and that it was a risk that we had to take.

Given that the core of our algorithm changed, it was clear that our timeline would be significantly affected. As we worked to modify it we began to understand that we were going to be on very strict schedule. For this reason we decided to reevaluate exactly what our scope was, and what we could realistically accomplish in the given deadline. In the beginning of our project we held hope that as we made progress we would have time to accomplish various tasks that were within the scope of our solution, but to some degree orthogonal to our core algorithm. These goals would include: a fully hardware accelerated project; the ability to detect and track objects at night and in rain; a solution that also works on bicycles; detecting objects with a greater field of view; and lastly some sort of video feedback to the user.

Another large part of the issue that pushed us towards a severe timeline was the nature of our work itself. Our solution is based on the idea that what we are doing is feasible today in embedded computers. However, the more we researched, and the further into development we reached, we began to better understand chaotic nature of research. While these solutions are absolutely feasible, they are at the point where they are still somewhat inchoate. This means that there is not necessarily a plethora of information regarding the research we pursue to emulate. This problem is exacerbated still due to the fact that the bulk of the research that we used to plan our project was not detailed enough to recreate in full.

Many steps were overshadowed, or not considered at all in any related publication. For example, there are some are some clear caveats to some of the solutions posed in the research we have reviewed. Many papers appear optimistic and seem to show their work’s efficacy in its best light. This is reasonable and even to be expected of research. However, it is something we had to learn. I made it very difficult to ascertain weaknesses and trouble spots before committing to replicating or building on published research. While we absolutely expect to have to innovate a solution, we were left trying to emulate modern frameworks that at times seemed incomplete to us.

We are capable students, and worked around these problems. The important conclusion from these difficulties is that it made it harder for us to straightforwardly plan our work. Our timeline became a more fluid document instead of something that we had hoped to keep as a static framework outlining our success. This resulted in much of our work taking longer than expected. We learned the algorithms, planned how long they should take, and executed their implementation. However, problems bubbled up that are difficult to predict until one has actually implemented the research.

We worked our best to predict how this would affect our timeline overall. We narrowed our project’s scope as much as we reasonably could. We tried to slightly overestimate how long tasks would take, and in general try to plan and provide for a more flexible timeline. We have reasonably achieved this. Still, looking back we would have greatly changed the way we originally planned our timeline given our insight into the dynamic and experimental process that is research based work.

Budgetary concerns:

We knew from the beginning our project would pose substantial cost. We already possessed many of the expensive resources we planned to need like a test car and motorcycle. However, there were many resources we did not have and did not have the finances to cover. Something as simple as travel from Oregon to Orlando posed an exorbitant cost – over $2000 just for our team of four students. This would completely consume our complete Cornell-funded budget.

Looking into the cost of our research and solution, we have a clear lead expense. The primary component cost of our budget was that of our cameras. They are at the heart of what we do, and so we were not able to sacrifice quality for cost to any degree. It was important to us to have a very high-quality, small, monochrome camera that had a resolution of about 640x480. We did not find many research cameras that fit our need that were not expensive. Since these cameras are specifically developed for the research market, which is lower volume, they are expensive. Regardless, we originally planned to purchase three of these research cameras in order to fully implement our solution.

Despite the high our cameras, we carefully made the choice so that the internal sensor was a specific CMOS one that is readily available at a very low price. We did this in order to prove the idea that at least our end solution could be very affordable. Each of our purchased cameras cost $290 with optics, while the sensor is available raw for less than $17 as of January of this year. We estimate that we could duplicate the research camera at a cost of less than $50 using these newer, affordable CMOS sensors.

Looking back at our overall budget, when our proposal was accepted we knew it would be difficult to ensure that we met all of our financial constraints. This made it clear we would need outside funding from our school in order to pursue our goal of participating in the Cornell Cup. We devised a strict but realistic budget based on our research needs. With these costs in mind we approached our advisors and our department chair with our budgetary proposal. Once it was conclusive that we were accepted into the competition we were able to arrange a budgetary meeting with the Dean of Engineering at our school. After reviewing our very clear and specific budget, he was able to grant us complete financial support. In this way we were able to procure a budget that fully met our needs. Our school has been very supportive, which has helped to ease most of the concerns we initially had about our budget.

Initially we expected to incur costs of $3478. After our financial meeting, our school made it clear that they would be able to cover travel costs outright, as it fit within the required criteria for such expenses. In a sense, this was a sort of out-of-band funding stream that we had not expected. This allowed us to focus our costs more on actual solution expenses. We had a final solution budget of $1266, mostly composed of three cameras costing $825. This left us with no gap in funding after Cornell funds were considered. Our budget was sound and we moved forward with the project.

In terms of unit cost for a prototype of our device, it is still relatively high. One prototype would cost an estimated $1032. In order of greatest to least cost, our unit cost is mostly decided by the cost of our development board, our camera, and our gimbal system. We know that these costs could be greatly brought down if we had more time and funding to do so. We will discuss this briefly.

The development board is quite expensive, at $555 without an academic discount. It has many bells and whistles that are not actually utilized at all. This includes many distinct peripherals, some which are even duplicated on both the Intel Atom and FPGA side. For example, VGA and gigabit Ethernet are duplicated, and neither would expected to be used in our end solution. We also do not fully utilize the SSD, nor do we use WiFi. These both represent expensive component costs that can be mitigated to some extent. In the cheapest form we can find, the supplier Digi-Key shows that the FPGA on the board costs at minimum $390 in individual units. This quickly moves upward to $644 for slight variants.

The point is clear. If we were to manufacture our own board, we could greatly reduce costs. For example, currently we operate in real time and do not utilize the FPGA solution at all. We could certainly reduce costs by not having this device or reducing its logic size in our end solution. In the same vein we could easily reduce the peripheral count manifold in order to drive costs down. This would obviously present an upfront cost we would have to amortize in the long run.

As stated above, our final camera solution would be expected to be relatively cheap as well. This was by design as we chose a newer CMOS sensor that does not sacrifice quality, and yet is very affordable. We also believe that gimbal costs could greatly be reduced. Quality motors can be quite expensive, but we only need one. Originally we thought we would need a 2-axis gimbal, which is the type we bought. However, further experience and knowledge about our algorithm showed that what we do can be done better with only one motor.

Overall we are very comfortable with our prototype unit bill of materials. It represents an absolute maximum starting point cost. From this high cost, we can begin customization and in-house manufacturing. These tasks will useful in twofold ways: our devices would be designed for and so better suited to our application, and they would be much cheaper. We see this as the logical next step in constraining our costs of goods sold were this to ultimately be a real product.