The Design and Construction of That Wooden Car

Olof Ekelund
University of Gothenburg,
olof.ekelund84@gmail.com

Carl Berglund
University of Gothenburg,
gusbercaal@student.gu.se

June 16, 2015

Contents

Acronyms

CC15 Carolo-Cup 2015

ESC Electronic Speed Controller

US UltraSonic (range finding sensor)

IR Infra Red (range finding sensor)

LCD Liquid Crystal Display

CRF Chalmers Robotics Facility

1 Carolo Cup

From autumn 2014 until February 2015, students from Chalmers University of Technology together with students from University of Gothenburg worked together on a project as part of a school course, with the goal of participating in the competition Carolo+Cup in Braunschweig, Germany. The purpose of the competition is for each team to develop a miniature autonomous vehicle. The team from Gothenburg ended up being quite large, initially 16 people and 15 of them went to the competition in Germany. At the start of the project it was decided to use an Agile-like method with weekly meetings to plan for the next sprint. In the first half there was only one large team with no leader or manager, but in November the decision was made to break the team in to smaller sub-teams with its own responsibility and responsible. There were three teams: integration and testing, lane following, and parking. The project included building a new car, as well as getting the car from the previous year, “Legendary”, running.

2 The Car

2.1 Motivation

The team for CC15 was originally of 16 team members, which was quite a lot. We had one car to work on, and we were weeks behind getting it to actually run on a track that was not yet designed or made. With the two primary tasks that were to be implemented for CC15, lane-following and parking, a distribution of labor was essential. By assigning two people to build a new car we would in a few weeks have a new platform to run tests on, and be able to distribute the two competitive elements between the cars. That was the motivation for building a new car.

This document will present the idea for the new car, its features and specifications, as well as how we built it. More than anything, we consider this a "what not to do" for future years that plan on building a new car for Carolo-Cup.

2.2 Idea

More than just enabling more people to work on several physical cars simultaneously, we saw this as clean slate in which we hoped to better the imperfections of the Legendary car. We considered the Legendary car to well built externally, but remove the hood and it was a hurdle of wires without color coding or labels. A maintenance nightmare, and we figured we could do it better.

What we did not know at the time, and had little ambition to find out, was how well configured the Legendary car actually was. It was weighted to have an even weight distribution, and its suspension equalized to able to run a perfect circle in various speeds, or so we were told later in the project. We think its safe to say neither had perceived the complexity of the Legendary car, or the complexity required to make a sound performing car. Without said understanding however, we set out to build our own car. What we considered being the major elements of success were the following:

Maintainability Everything from battery to range finding sensors accessible from the exterior of the car. See Subsection 3.1 in Section 3.

Clean wiring To avoid a hurdle of wires to every extent possible.

Logical labeling By keeping wires color coded and labeled, we could potentially save hours of unnecessary troubleshooting in the long run.

Less is more To always strive for an elegant solution that would make the car look more sleek.

2.3 Specification

General Specification:

Weight 3.1 kg

Length 20 cm

Wheel Base 25.9 cm

Wheel Diameter 65.4 mm

Power LI-Po battery, 10000 mAh

Hardware:

Ultrasonic 2 x SRF08

Infrared 3 x Sharp 2D120X ; range 3 - 20 cm

Infrared 1 x Sharp GP2Y0A2YK ; range 10 - 80 cm

Speed Pululu HALL-sensor

Optical uEye 1220

Motor Cheeta 60A

Steering Stock servo

Control/Processing:

Odroid U3 1.7GHz Quad-Core processor / 2GB RAM

Arduino MEGA 2560 16 MHz clockspeed / 256 KB flash memory

Arduino UNO 8 MHz clockspeed / 32 KB flash memory

2.4 How it performed

The car was used for testing the team's parallel parking sequence. It was quite sturdy on the track for most of the time, but due to lacking front wheel configuration it tend to drift slightly to the left when going forward. For testing parking this was not a major issue, and the car was used as to showcase parking for interested peers at the 2014 TEDx Gothenburg event, where it performed well for most of the time.

We brought the car to Germany but did not end up spending any time on it as we prioritized the better performing Legendary car.

3 Features

3.1 Modularity

3.1.1 Idea

The idea for a modular design stemmed from the difficulties on maintaining the Legendary car. For example, replacing the battery, if ever needed, was judged near impossible without spending hours tearing down the car and putting it back together again. Just charging the battery required one to unscrew the front "hood", admittedly not a major hassle but still tiresome in the long run. To make changes to any of the Arduino boards or the rear LCD required one to go through a hurdle of wires, with no labels or logical color coding to them at all. The idea was therefore to make various features on the new car as more or less independent components. For example, we did not know exactly what sensor layout the other teams preferred for the front ultrasonic range finders, and by making that component modular, it could be replaced in a "plug-and-play" fashion with no disassembly of itself or other components required. This concept was planned to include all LED's, range finding sensors and battery.

Some parts needed to be fixed on the car however. Typical components that could in no feasible way be made modular were items such as; motor, ESC, steering servo and radio.

3.1.2 Prototype

Early prototypes of this feature included a cardboard truck. LEDs were assembled to boxes that would fit on or inside the larger resemblance of a truck, see Figure 3.1. One side of the box was lined with pieces of aluminum foil, for power and ground, and the foil was connected to the LEDs through conventional wires. The same setup was applied to the car, just behind the place where the box would "sit" were strips of foil connected to an Arduino board. The boxes were held in place with fridge magnets.

At the time, we were thinking of taking this concept further by braking down systems of the car, such as blinking LEDs for indicator, and programming individual ATTiny chips for each such primitive function. This would allow for a cleaner, more maintainable main loop on whatever board the entire system would run. We bought chips and sockets, so that even the chips could be replaced if needed. Since we ultimately resorted to using the code from the Legendary car, we scrapped that idea.

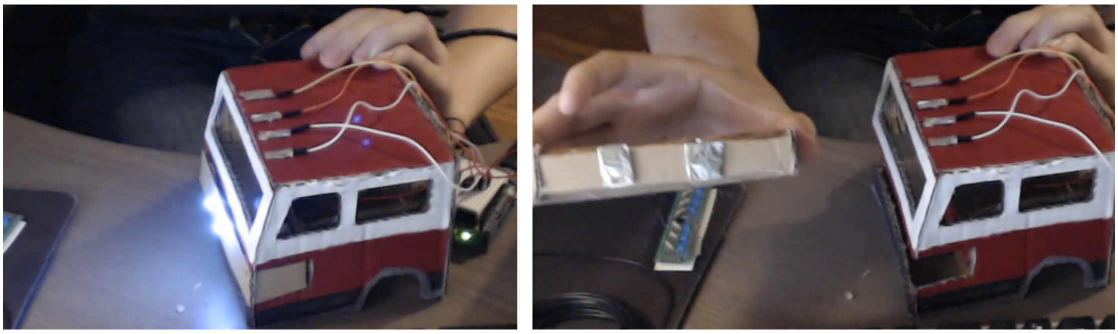

Figure 3.1: LED box connected with aluminum foil.

3.1.3 Result

The idea of modularity was pursued from the very beginning of building the new car, and quite a lot of our efforts was put into realizing this modular concept. When we started working on the car we did not yet have access to a laser cutter, and thus building for modularity was excessively time consuming and less reliable due to imperfections that were the results of our crafting abilities and our unmotivated confidence in said abilities.

We successfully made two components modular; a section for the front ultrasonic range finders, and a section for LEDs in the front. Essentially, the solution was simple in theory, but required some work. The aluminum foil had been replaced with conductive copper “springs” that would detract when pushed. In the case of the ultrasonic sensor, we had four of these springs in the back of the components box, one for each pin on the sensor board. when inserted in its designated slot, these springs could touch screws that were wired to their respective pin, be it signal, power or ground. The LED worked similarly, but with no signal cables and thus only a pair of springs, and works as seen in Figure 3.2.

The magnets were Neodymium disc magnets ordered from ebay, and really quite strong. In fact, the major challenge with these magnets was their strength as they would stay together and come off their respective panels when a modular component was removed. This was usually resolved by placing the magnets behind a wooden panel, fitted in a drilled hole, see Figure 3.3. While it was quite an elegant solution, drilling deep enough for the magnet to snug right in without drilling through the wood required some time and attention.

3.1.4 Reflections

As an idea, the concept was fun. Perhaps more fun than practical, and thus when we had implemented these two sections, we started to realize issues that made the concept impractical. Two such issues was time and weight. As the box that is the modular component required a designated slot where it would fit, almost twice the amount of wood was used to allow the box to rest in its slot. This meant a lot of work, crafting

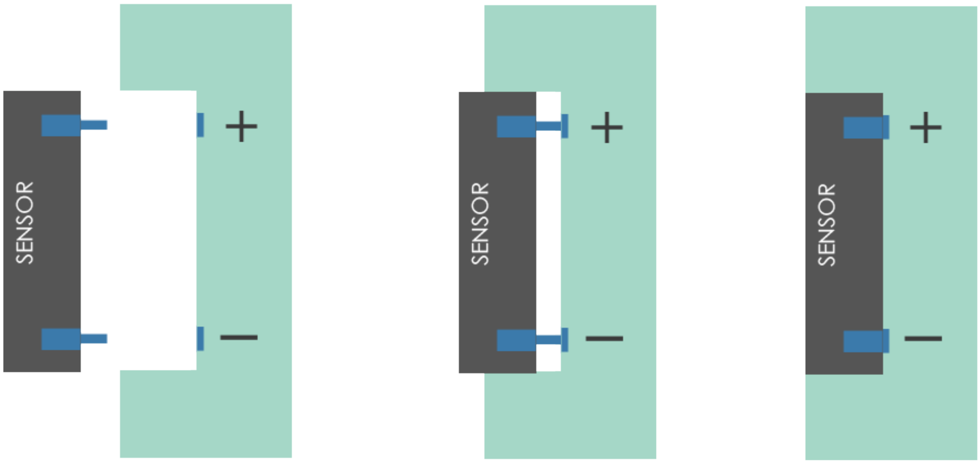

Figure 3.2: Component (gray) interfaces with system (green) with conductive springs.

the slot, or socket, as well as the box itself. Also, it became quite heavy. As we had little knowledge of mechanics or most of the things we were doing, we did not know if this was a problem, but we figure that at least for battery consumption - it could be. Hence, we gave up the idea with absolute modularity, but still had maintenance as a strong motivator when building the rest of the case, as is evident in the design of the battery compartment and motor compartment.

In retrospect, it was a fun concept but it can't really be motivated for any practical reasons. Sensor layout should be planned carefully before starting crafting a new car, rather than building for the possible change of heart.

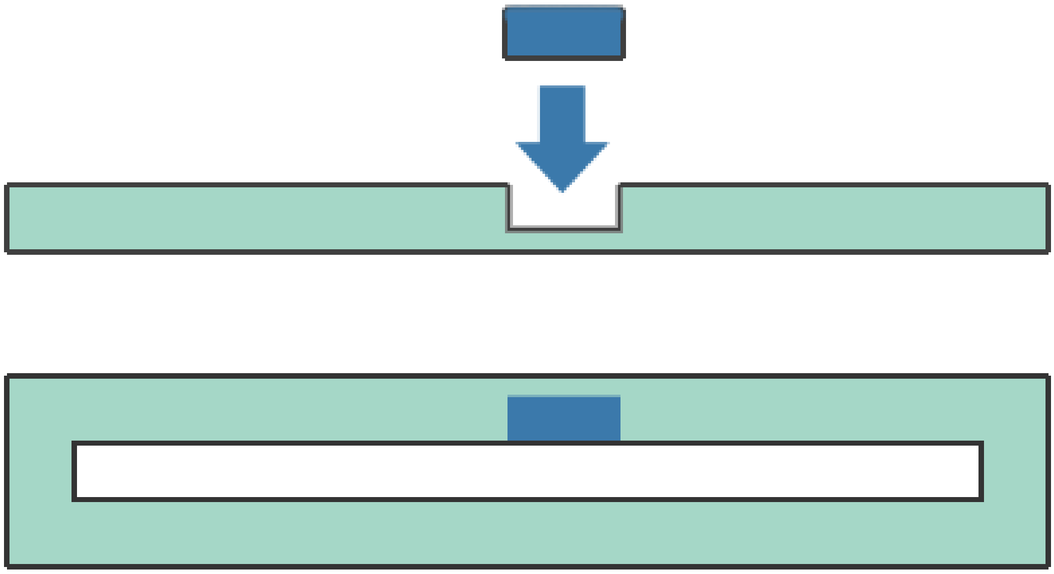

Figure 3.3: Component (lower) docks with socket (upper) through magnets.

4 How it's made

4.1 Construction

With our lack of experience with hardware it took us some time to figure out a suitable process to work with. We started out making designs with pen and paper, which was incredibly time consuming and error prone. This process involved drawing blueprints by hand which we then cut out in other materials. We made cardboard prototypes of some of the body parts. Especially the modular parts were prototyped in order to get a quick proof-of-concept and to see that the electronics would work as we intended them to. We kept working like this for a week or so, we did have access to a laser cutter which we realized within the first few sessions that we needed to use. But one of us needed to be trained by someone at CRF to be permitted to use it. This also meant the we needed a program to make CAD drawings. We ended up using Adobe Illustrator, which was a quite simple and effective option, it allowed us to design quite complex parts in just a few minutes. The downside, compared to using some 3d modeling software such as Catia was that we couldn't see in advance if the pieces we designed would fit together so this process was quite error prone as well. We did have the Catia files of the models the Legendary team made, these would have been very useful but after spending some hours just getting Catia up and running the files wouldn't open due to having been created with an earlier version of Catia. At that point we felt that we couldn't spend much more time on it. This was a month or two into construction so we had already made quite a lot of progress on our car.

The process we ended up with was to design in Illustrator and cut the pieces out with the laser cutter, while this was a bit too error prone it was a major improvement over the work flow we used when we started out; designing with pen and paper and cutting pieces with the band saw. Throughout the whole project we always expected to be finished with the car much sooner than we were, this caused us to make some decisions which in hindsight probably were not the best. Specifically the decision to not spend more time getting Catia working may have cost us us a lot of time.

Some of the major attributes we took into consideration when designing the car were:

Robustness We wanted the car to be able to handle being crashed into a wall, which tends to happen every now and then. Ours solution was to screw all parts together. Actually, we started out gluing some parts but quickly moved on to screwing parts together.

Clean Look We tried to keep the exteriors very clean, no wires or unnecessary details.

Functionality Of course everything needed to work as intended. This meant that we were always testing things and making sure nothing was obstructing movement and that the car didn't become too low.

4.2 Electronics

When we started out with this project, we some experience from our previous project course. More importantly, we could re-use the car that we built ourselves as part of said course, which saved us some time and trouble in replacing the motor and ESC.

As mentioned, neat wiring, labeling and color coding were our main motivators to achieve maintainability. Simple enough, to choose color after what type of purpose the wire will serve, and to put tape labels on each cable. Neat wiring, however, was trickier as it requires some planning. This would often come at ends with our lack of direction with building this car. Sure we had some plans for it, but never really established what would be realized. Thus, the cable job is neat at least where it is visible, and not chaotic, but not great, under the hood.

Another element that ties to neat wiring is the number of wires. We noted that the legendary car had one pin used on the Arduino for every LED indicator, three for each side, left and right. This did not go well with us, and so we used one cable from the Arduino to open and close a transistor that would open and close the circuit that powered every LED indicator on given side. We did the same thing for brake lights, and ended up saving around 6 cables that would otherwise add to the cluster of wires on the car. It does not sound like much, but these kind of details tend to add up to real concerns eventually. However, we (Carl) did not do his homework before playing with transistors, and ended up almost frying our Arduino on account of a missing resistor.

This way or thinking ties together with earlier mentions on modularity, and would make out most of the rear LCD panel as well. That module was built to be as independent as possible. Naturally, it would need power, and some signal as the brake lights and indicators are mounted to it, but we aimed to keep it as simple as possible, in case you'd need to remove it. Thus, all the buttons and the LCD were wired directly to another Arduino (UNO) that also was mounted in this component. The LEDs were wired to an output pin per function (indicator left and right, brake lights). To interface with the main Arduino, we had 3 signal pins, power and ground pins, and a USB-cable for the Arduino UNO.

Although we never destroyed anything or set anything (important) on fire, what worked against us was essentially our lacking understanding of electronics. This meant we needed to research more or less every component we used, and even then were often not sure it would behave as expected.

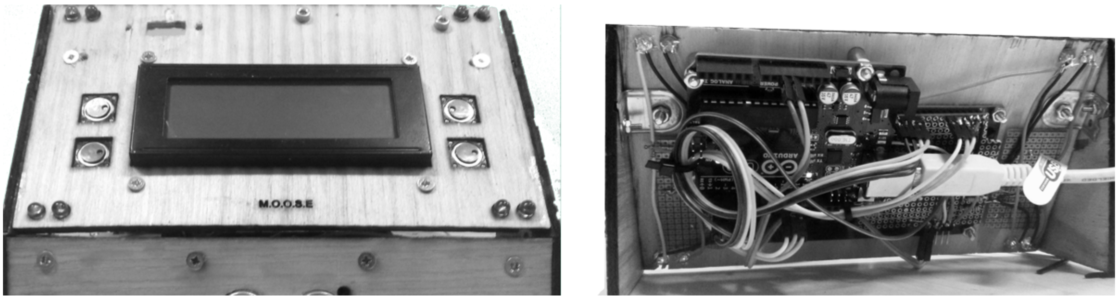

Figure 4.1: Rear panel.

4.3 Tools

Design

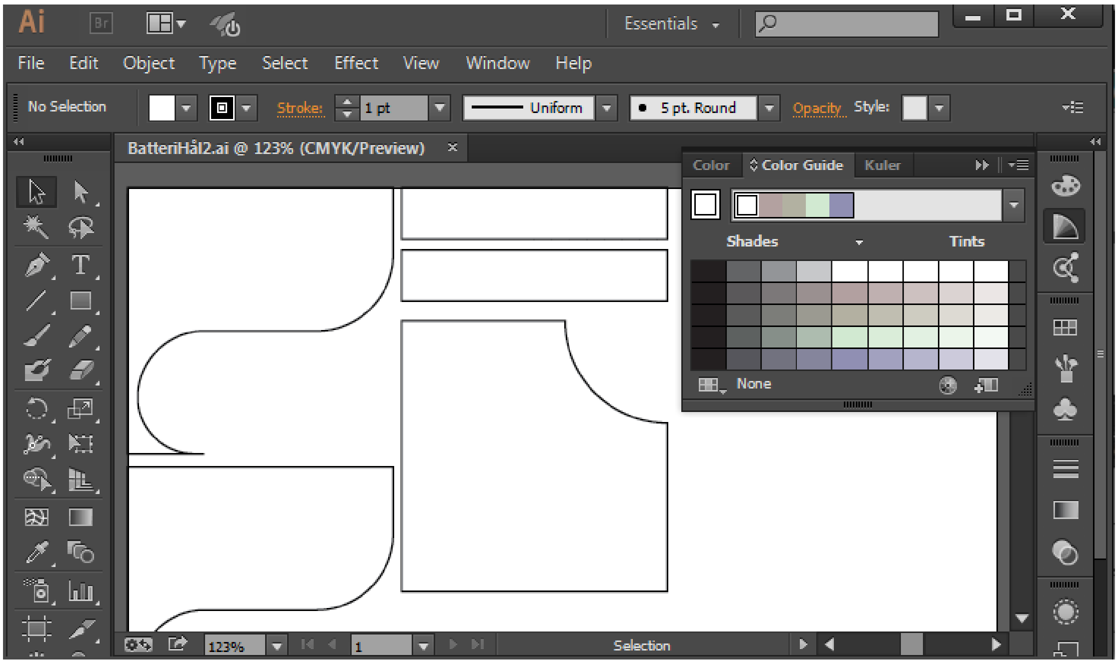

Figure 4.2: Designing the pieces holding the battery in place in its hole

As mentioned previously we used Adobe Illustrator to do most of the design work. This meant that we only worked in 2d when designing. This meant that we had to be careful not to place holes for screws in the wrong places and think twice about orientation of the different pieces. The finished designs was saved in .dxf format, which was the format the laser cutter used.

Laser Cutter

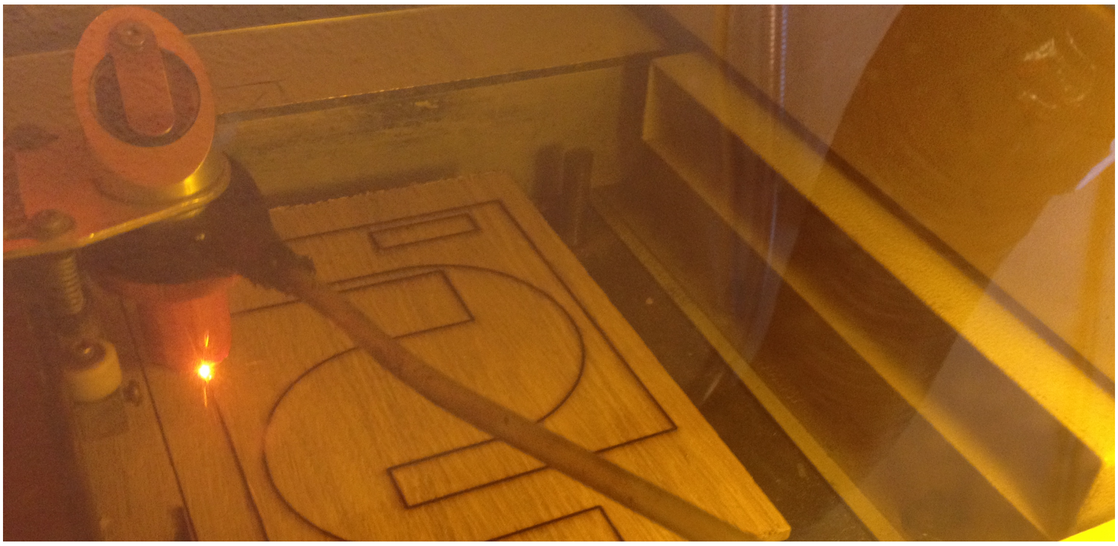

Figure 4.3: Cutting the pieces around the back wheels.

The laser cutter at CRF was a STRONG SG-40A. It worked fairly well with the wood, but it took some time to go all the way through and a lot of times we had to cut parts out with a knife which was quite tedious. The biggest benefit to using the laser cutter was that we could make pieces of wood in practically any shape, down to millimeter precision. The only restriction that applied to this project was that the laser cutter could only cut pieces of maximum size: 210 x 205mm. This was only a problem on a few occasions, namely when we wanted to make pieces which were as long as the car.

5 Suggestions for Carolo Cup 2016

While working on this project we made some mistakes and think that it would be a good idea to share with the guys and gals doing the Carolo Cup competition in 2016 what we learned from making those mistakes. So hopefully they will not need to make those same mistakes again. A lot of what we discuss in this section has been mentioned previously in the report but we think it's necessary to gather all that information in one place since it is quite important.

5.1 System Requirements Specification

The first thing we want to suggest is to make an SRS. We spent quite a lot of time building the car before we got the feedback that it should be more like the Legendary car, or even as close to the Legendary car as possible. This was something that we as a group had never agreed upon. Our idea was to improve on the Legendary Car and if we had tried to build a car like The Legendary it could have saved us a lot of time since we had the design finished. This is not the only reason to make an SRS, the whole modularity concept would have been unnecessary if research had been done about how to design the algorithms and subsequently we would know what the hardware needed to be and as such wouldn't need to change it. Of course this can become a quite time consuming effort so make sure not to overdo it. What we suggest is for the entire team, or perhaps split the team into sub-teams and make one of the teams responsible for making a draft of an SRS, then have the rest give input on it before it is finalized. There needs to at least be better communication in the team.

5.2 3d-modeling

The next suggestion is to model the car before starting to build it. We spent much too much time fixing small errors in the different pieces of wood and trying to come up with sensible designs which would work with what we'd already built. If we had used some 3d-modeling software we could have created the pieces in the simulation and seen immediately if they would work. This would not only save time but is likely to have produced a better overall design.
The Legendary team used a piece of software called Catia which is available to Chalmers students (perhaps GU as well). We did however have some issues with it, specifically that we couldn't open the files due to them having been created with an earlier version of Catia. There is probably some kind of fix for this if you look for it thou. We would

however suggest using SketchUp which seems much more user friendly and easier to learn. However you might need a license in order to save cad files.

5.3 Balance and Calibration

We had problems with the car drifting slightly to one side. This was probably due to the front steering axle of the car being a bit loose. Of course we tried to fix it but the axle was poorly designed and the problem persisted. There were some discussions in the team about changing the alignment of the wheels, the toe, if we'd have toe-in the car would go more straight. Toe-in means that the front wheels are pointed slightly towards the center line of the facing of the car. Another improvement we were looking into is to balance the car properly. This is also to have the car drive more straight. We had 4 electronic scales which we could have used to weigh each wheel and either remove weight, if possible, or add weight.

5.4 Lightweight

While we were at the competition in Germany we saw that most of the cars, the winning car as well, were really lightweight. This enabled them to have much greater control of the car (there were other factors as well) and go faster. They basically tried to remove as much weight as possible and have a removable plastic cover, some teams got covers from their sponsors.

5.5 Modularity

The modularity concept was a mistake. At least in the way we did it. But it is still a good idea to keep in mind that parts brake, plans change and the car might need to change. So designing a car with that in mind might save some time and frustration one day. This could be done quite easily with fixtures that you can screw parts onto and some clever wiring.

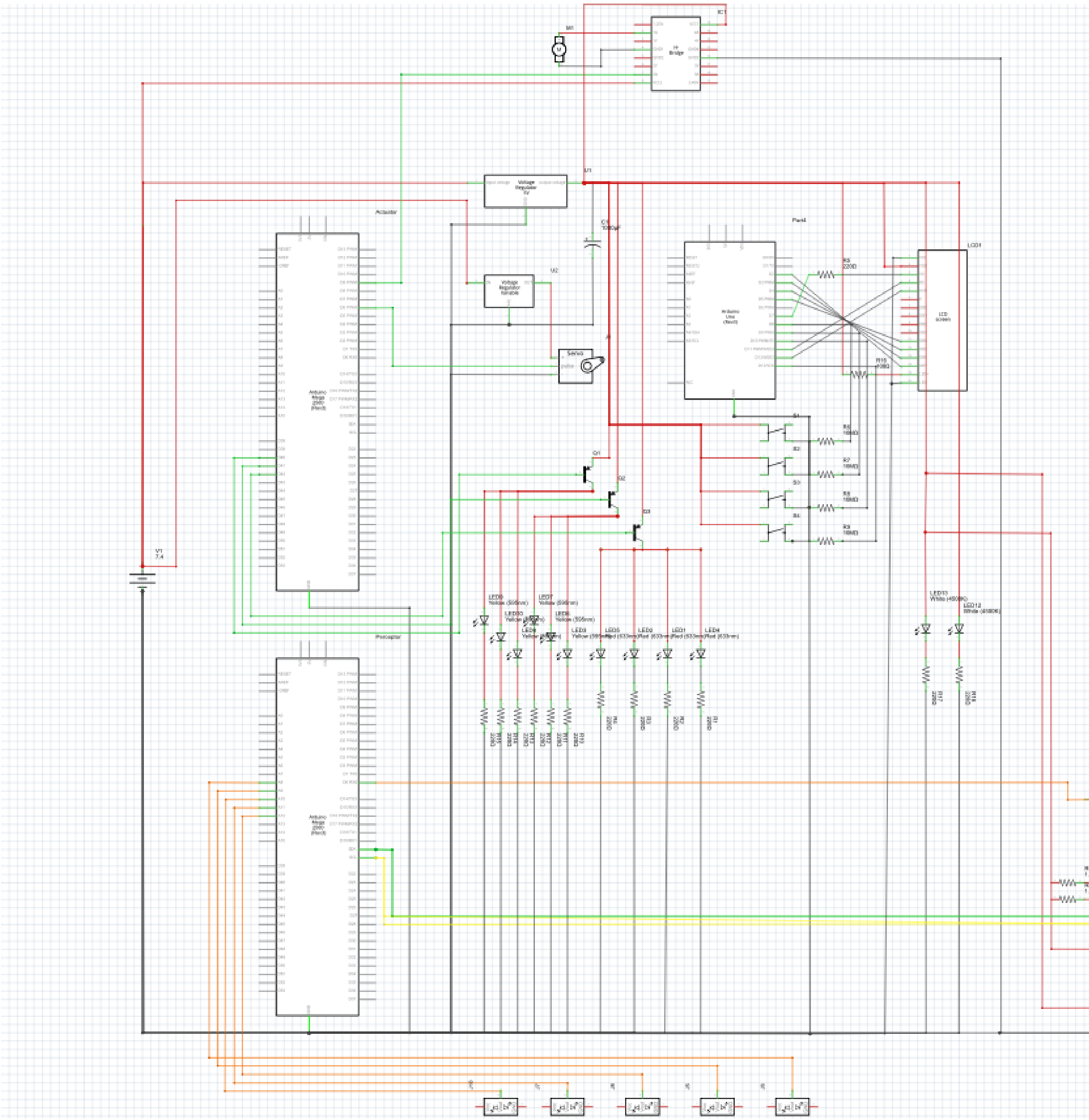

Figure .1: System wide schematic

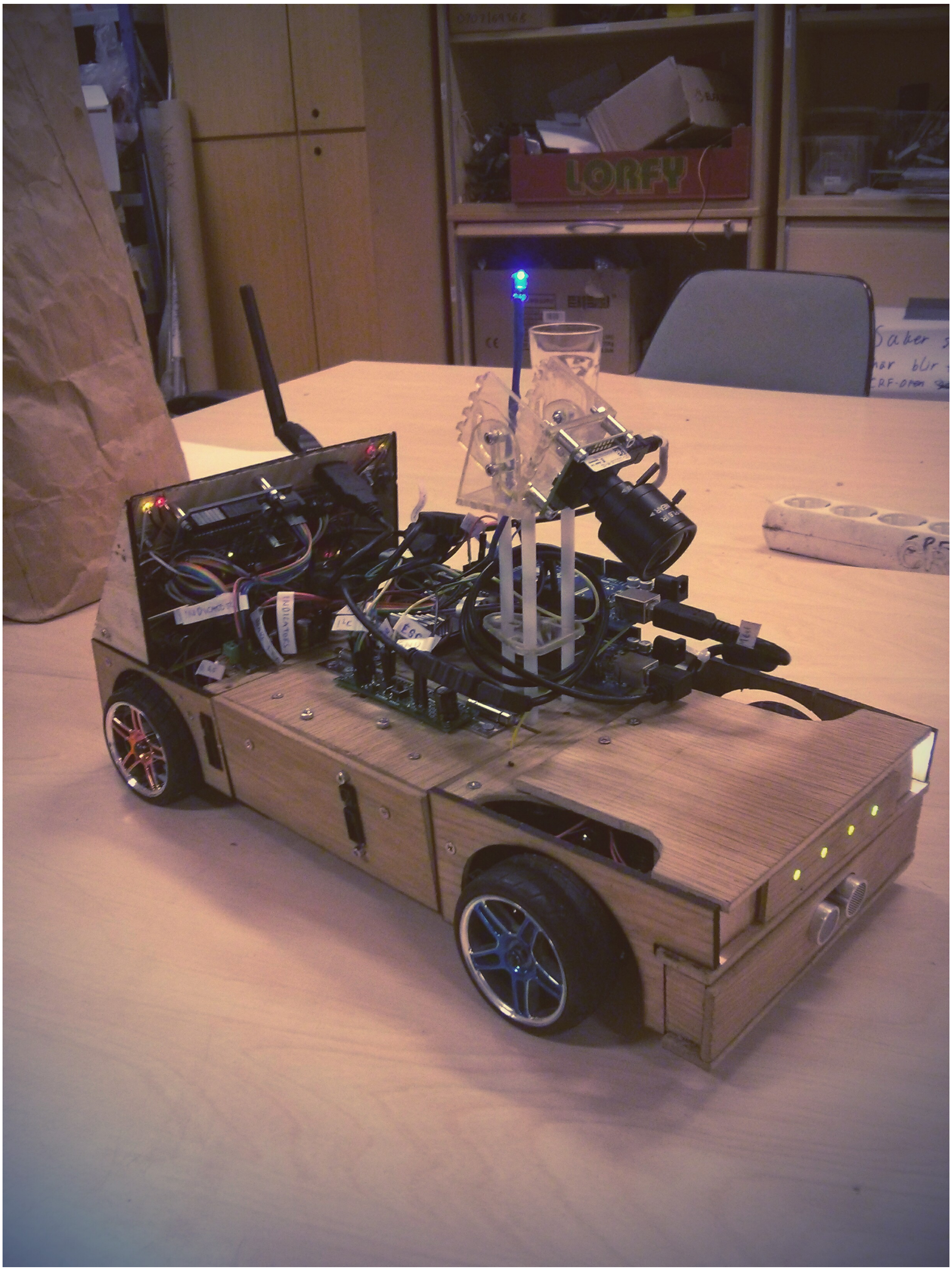

Figure .2: A wooden car.