THE DESIGN PROCESS

HOW TO DESIGN A ROBOTICS PIECE

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Introduction

So, you were given the task of designing a piece for the next FRC Robotics Competition. You don't exactly know where to begin but you still have a task to finish. Hopefully, this guide will help you. In this guide, I will be providing you with a plan to help you with creating your robotics piece and will tell you the key points for you to follow. Use this guide as an aid for your design process.

My Design Process

1. Understand
2. Collect
3. Brainstorm & Analyze
4. Selection
5. Prototype
6. Implement

The Design Process

A design process is a systematic series of steps that helps you to define, plan and produce a product that you're building. In our case, that would be a piece for the robot. It encourages efficiency, transparency and helps you create the best product possible. Instead of asking "what's next?", the design process gives you a clear and concise path to follow (Beckler-Jones, 2020). People in the high tech industry will often use the design process.

The design process is iterative meaning that you can repeat the steps as many times as you need, making improvements along the way. Learn from failure and find new possibilities to create a great solution.

Understanding

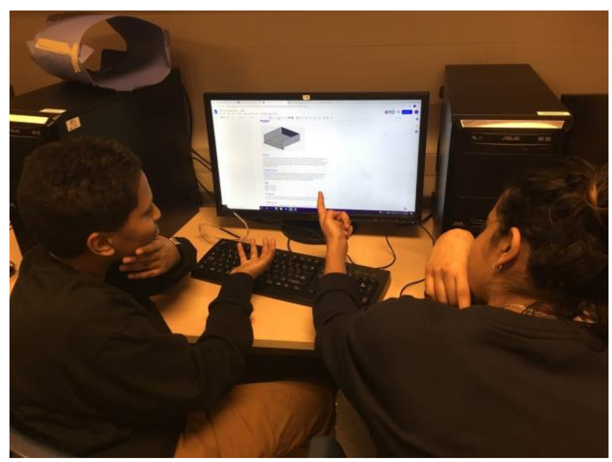
Your first step to designing must always be understanding the problem. If you take a few hours to think about the task you will be able to have a greater comprehension of it, and the problems surrounding it. This may seem like a simple task, but it will help you in the long term (Dam & Teo, 2020; DiscoverDesign, 2019). You will find that almost all of your information about your topic is in your FRC Game Manual. What is important is to try and discover all the elements of your problem. Research the FRC Game Manual so you can discover your complete task and put it together into one problem (FIRST, 2020a). For example, in the 2019 - 2020 season there was a mechanism called the control panel, which involved spinning a “lazy susan” (Lazzeroni, 2013) type contraption and detecting the colors on the wheel. However, this wheel was elevated above the robot, meaning that there was difficulty in reaching it. One solution could have been to just place the mechanism on top of a long bar above the robot but this was not feasible because the robot needed to be able to drive under the wheel as well. As a whole, the problem involved spinning a wheel with a spinning mechanism, raising and lowering the spinning mechanism, and detecting the colors on the wheel.

Identifying Problems/ Challenges

You should be able to identify the possible problems with your task as it would help to enhance your understanding. You should think of problems that are different from your main task. For example, thinking of where your piece will be mounted, how to control the stability of your piece, etc. The main goal of this is so you understand what to avoid when designing your piece. This is so that you don’t design a dysfunctional piece. Efficiency is key in robotics.

Tips for Understanding

- Summarize the Problem
    - Summarizing helps with ensuring that you understand the core of the problem
- Create Analogies to the Problem
    - Using real-world examples can help you understand, solve, and create prototypes
- Draw It Out
    - Ex. Using a Whiteboard and explain to your partner (LDHSS RoboRavens, 2020)



Collect

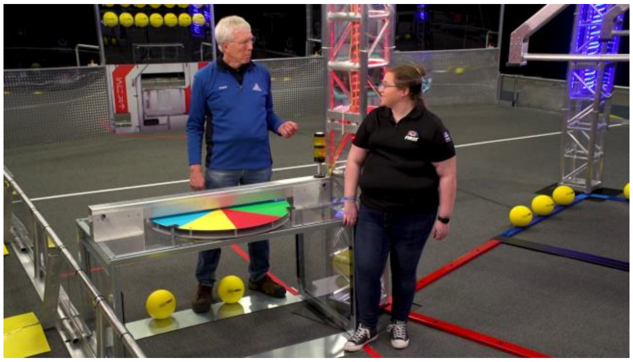
Your second step in creating your piece should be gathering the information necessary for your design. This not only means gathering the data that you need for the build but also gathering inspiration for your design.

Photographs & Sketches

A common method that we use in design is to look at photographs, sketches, or other forms of media to gain design inspiration (DiscoverDesign, 2019). This is where connecting the problem to the real world comes in. A lot of the FRC tasks that we have to do are relevant to real-world tasks. So once you can make a connection to the problem you can create a solution. For example, with the control panel. One of the things that we had to figure out was how to spin it. Attempting to make a real-world connection it would be like spinning a lazy susan from the side. This led us to think about how gears work i.e we could use a small rubberized wheel to spin the big control panel wheel (FIRST, 2020a).

Lazy Susan

(Lazzeroni, 2013)



Control Panel

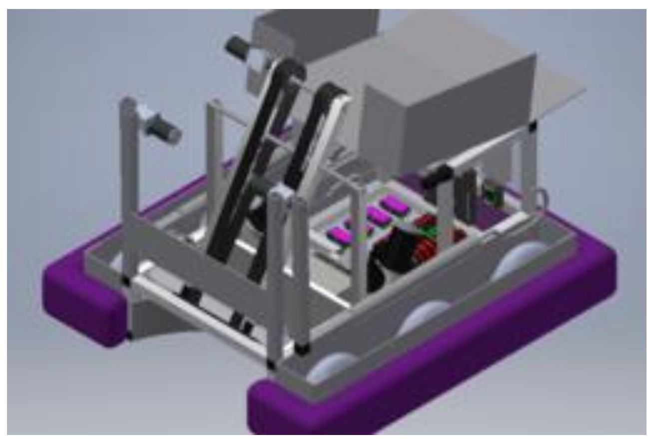
(FIRST, 2020b)

Data

It goes without saying that collecting data is absolutely necessary for your design. You need to be precise with your designs as they are interacting with real physical objects. Accordingly, the margin for error is very low. Obtaining your necessary data however is not very difficult as we have the FRC Game Manual for that. In the manual, you should be able to find at least 75% of the data you need for the design. Design is compromised with quite a bit of math, so if you can't find a certain measurement that you need, calculate it using the data from the FRC Game Manual (FIRST, 2020a). Make sure your math is correct. You will also need to check for any restrictions or rules that are in place for the design.

Tips for Obtaining Data

1. Refer to FRC Game Manual
2. Use the CAD model of the robot or field
3. Ask some members from build (if they are not busy)



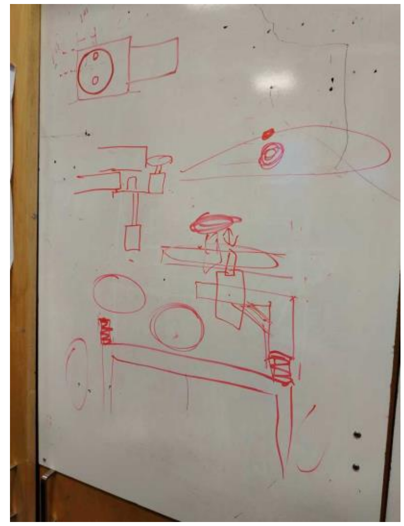
2020 FRC Game Manual

(FIRST 2020a)

CAD Model of Robot

(LDHSS RoboRavens, 2020)

Brainstorm & Analyze



Your third step in creating your design should be brainstorming and analyzing the data and information you've collected. You should be thinking of how your design will be impacted by the new information that you have obtained (Science Buddies, 2020; Dam & Teo, 2019; DiscoverDesign, 2019). For example, it is important to make sure your design isn't breaking any area restrictions. While keeping all of these things in mind, you should begin to make sketches to visualize your piece.

You do not need to use Autodesk Inventor at this stage. I suggest that if you are new to CAD, you should sketch first, then CAD it later. If you are more experienced you can brainstorm with Inventor. **On the right: Early Design for Control Panel** (LDHSS RoboRavens, 2020)

Brainstorming Rules/ Tips

- Set a time limit
  - Brainstorming sessions should be in the range of 15- 45 minutes. Usually, this means 15, 30, 45 minutes.
- Don't listen to judgment or criticism
  - It's important to have a good brainstorming environment and to encourage brainstorming by making clear and unbiased ideas
- Aim for quantity
  - When brainstorming, create lots of ideas and choose the best one. Jot down whatever comes to mind and go to the next idea.
- Encourage new "crazy" ideas
  - Brainstorming is about creating a large number of ideas and choosing the best one. To have a good environment you can never be too ambitious. A good and creative idea could very well win the design award.
- Build on each other's ideas
  - By considering the thoughts of your partners you can create a better idea since usually, one idea leads to another.
- Be visual
  - The act of writing things down often takes too long for some people. One thing that you can do is draw your ideas out. This especially works if you are a visual learner.

Selection

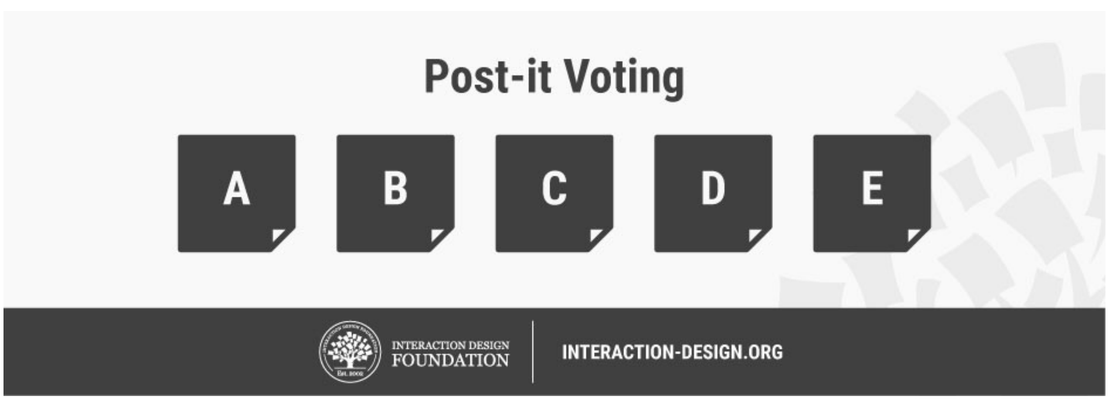
Once the brainstorming process is done, it's time for the selection process. Since the brainstorming process is more about quantity and you will be dealing with lots of ideas, it is important to plan out your selection process. The following are methods that you can use for your selection process.

Idea Selection Criteria

Before you start your selection process, you should think about the criteria that you are evaluating your prototypes with. The idea selection criteria will provide you a guide for choosing ideas that fit well into your goals, your research about the field, it's needs, and how the team will implement the idea.

Post-it Voting

In Post-It voting, every member that is involved has about 3 or 4 votes. The reason why they don't have 1 vote is so that they are not forced to make an immediate decision. When trying to make a decision, gradually go down with the number of votes, and use reason to decide, weighing the pros and cons of each piece. The ideas that you thought of during your brainstorming session will be written on individual post-it notes. Each member will be given 4 stickers to put on the post-its. Members can also put a dot on the post-it note. Choose the post-it notes with the most dots (Dam & Teo, 2019).



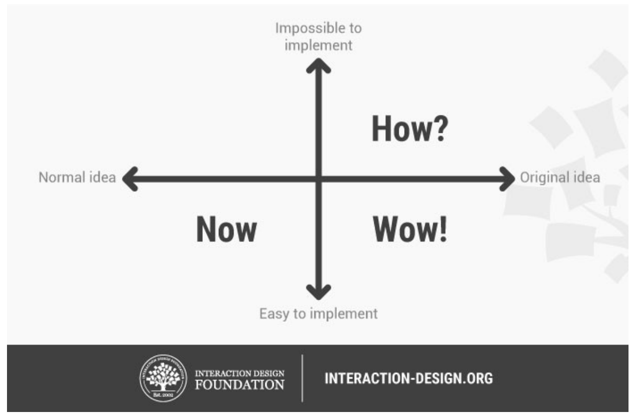
Now Wow How Matrix

The “Now Wow How" matrix is one of my favorite idea selection methods and I believe it should be implemented more in designs (Dam & Teo, 2019). The concept behind it is to evaluate ideas based on the speed of implementation and the creativity of the idea. Creativity is really big in robotics and there are even design awards based on creativity.

Now: An idea that can be implemented now, but lacks novelty

Wow: An idea that can be implemented and has originality

How: An idea that could be possibly implemented in the future



With this method, you should first place all of your ideas onto the chart. I suggest that you try to limit the number of people organizing the ideas to limit the bias with the organization. Someone might rank their own idea higher than another idea. This chart is meant to help you keep your ideas organized. After making this chart, have a discussion with your peers, and talk about what you want to focus on. Do you want to be more creative, or fast? Ideally, it’s both, people want new creative ideas that can be implemented easily by the build team, and programmed quickly by the programming team.

Develop

Now that you have your final design idea selected, it’s time to develop the idea. Brainstorming is moreover geared towards quantity, and because of this, you might not have the time to think of the problems surrounding your solution. The development stage involves the refinement and improvement of the solution (Dam & Teo, 2019). Think critically and try to improve your design.

Prototype

A prototype is a version of a solution that is functional and will work. A majority of the time, prototypes are made with different materials (i.e. wood) than the final version (i.e. aluminium) (Dam & Teo, 2020, 2019). Generally, the prototype is not as polished as the final solution. Prototypes are a key step in the development of a final solution because they allow the designer to test how the solution will work and let them see if there are any changes they have to make. Prototypes are also a good proof of concept.

Low Fidelity Prototyping

Low fidelity prototyping is the usage of basic, scaled down models for testing (Dam & Teo, 2019). The prototype might not be finished or have as many capabilities as the final design, it might also be constructed with different materials, like wood or paper while your final piece will be made of aluminum. Low fidelity prototypes are models that are cheaply and easily made, or just help to visualize the final product (Dam & Teo, 2019).

Low Fidelity paper prototype for a phone app

(Rung, 2012)

Pros of Low Fidelity Prototyping

Low fidelity prototyping is very quick and inexpensive, so you can create this prototype when you're pressed for time. It's also more accessible because of the simplicity of the materials that are involved. Most importantly, low fidelity prototyping allows the designer to get an overall view of the product using minimal time and effort, as opposed to focusing on the finer details over the course of slow, incremental changes. Furthermore, because of the accessibility to these prototypes, it is easy to make instant changes and iterations (Dam & Teo, 2019).

Cons of Low Fidelity Prototyping

Low fidelity prototypes often lack realism, and due to the general difference between low fidelity prototypes and the final product, there will be a lack of accountability from the results of your prototyping. They also might not be completely thought-through making them not account for outside factors on the field (Dam & Teo, 2019).

High Fidelity Prototyping

High fidelity prototypes are products that are closer to the real and finished product. For example, a 3D piece with movable parts. High fidelity prototypes are more interactable. For example, with a 3D piece with moving parts, users would be able to interact with the product and engage with its different aspects. High fidelity prototypes are always considered in comparison to something (e.g. low fidelity prototypes), usually based on the complexity of the piece. For example, a physical model of a product would be considered high fidelity compared to a paper sketch of a product (Dam & Teo, 2019).

High Fidelity Intake Prototype

Pros of High Fidelity Prototyping

High Fidelity prototypes are more user-friendly, one will be able to understand how their piece interacts with the field. These prototypes tend to have a high level of validity (Dam & Teo, 2019). The closer the prototype is to the finished product, the more confidence the team can have in the accountability of the prototype. Testing allows to understand the quality of the final product and its limitations, capabilities, etc.

Cons of High Fidelity Prototyping

High Fidelity prototypes usually take a longer time to produce than low fidelity products and if you are producing a software-based prototype the wait might not be worth it because the results might be flawed. Furthermore, after hours of designing your prototype, you might be inclined to make a couple of changes. However, changes can take a long time and tend to delay the entire project. On the other side, low-fi prototypes can usually be changed within hours, if not minutes, for example when sketching or paper prototyping methods are utilized (Dam & Teo, 2019).

Implement

The implementation stage is where prototyping really comes through, by this point you should have finished all your testing, and have produced what you believe is the best product you can create. When you reach the implementation stage, you are almost finished.

Test and Redesign

The testing phase is commonly concurrently done with the prototyping phase of your design process. Testing and redesigning is the focused testing of your final design and the usage of your results to make changes and improvements (Singh, 2020). By this stage, the main focus of your design should definitely be met. This is the time to focus on the small things. Things that you haven't been able to think about, and minor changes that you can make without disrupting the design deadline and goal. **Test your solution, find new problems, make changes, and test new solutions before settling on a final design.**

Vision Team Testing

(LDHSS RoboRavens, 2020)

Design Implementation

Once you are done with your final CAD design you have to put your design onto the CAD design of the whole robot. To find the CAD for the robot, all you have to do is go on the ldhss Grabcad and find the robot design. Put your design on the robot, and upload it.

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