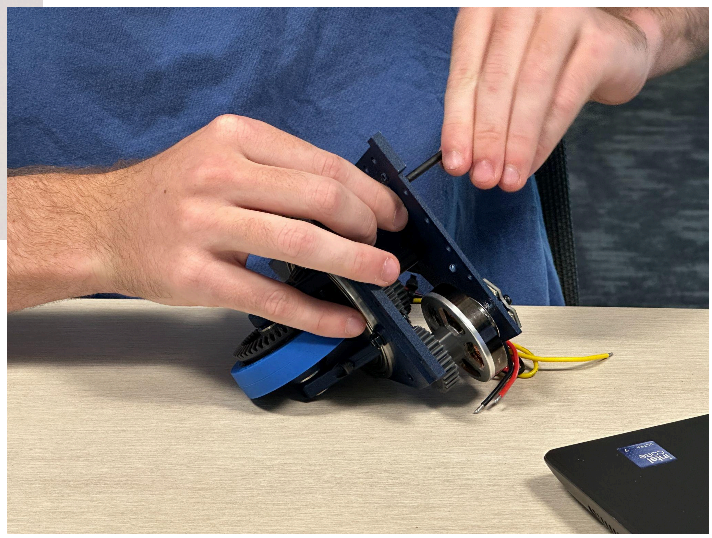
Assembly Manual Prototyping for the OSH-1 Drive Base



(Link to Prototype)

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Hypothesis and Rationale

The Open Holonomics project is a collection of hardware and software reference designs that can be modified or implemented directly into a robotic system to provide low cost, high performance holonomic motion. The goal of this project is to be a competitive choice for research teams or robotics competitions while also serving as an educational platform for beginners and hobbyists. A core tenet in support of this goal is documentation that is both meticulous and accessible.

Documentation of this type is, of course, all encompassing. It touches many different areas of the project, and will take on many different forms depending on the context (software documentation would most likely be very different from hardware documentation). For this design sprint, documentation took the form of an assembly manual prototype for the swerve module.

Our hypothesis throughout this sprint was that a manual that utilized as little text as possible would best support our accessibility goals, as we would not be relying on the user having some previous knowledge or experience with the various technical terms used. Rather, we would focus on visual representations of the concepts we were trying to convey.

We took inspiration from other open source hardware documentation like the manuals for the Prusa i3 Printer and the Voron Design V2.4, as well as from more commonplace assembly manual examples like those for Ikea furniture or Lego toys. Our initial MVP consisted of 10 powerpoint slides showing each assembly step as an exploded view from the OnShape design document.

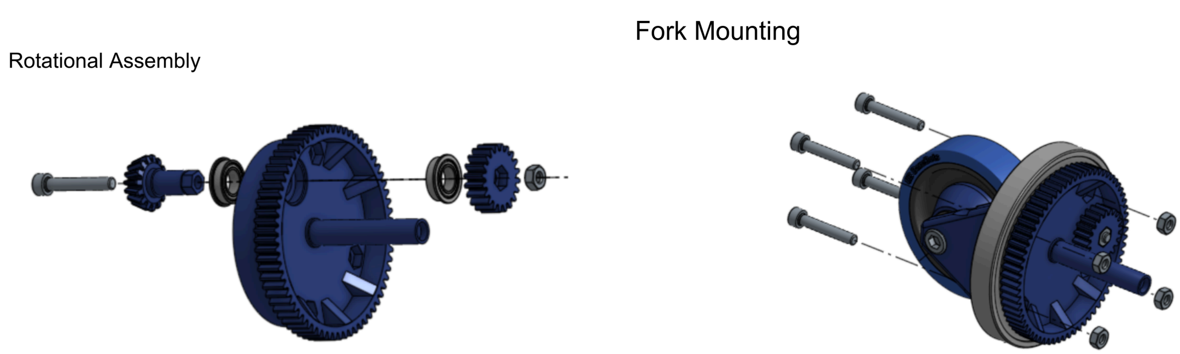

Figure 1: MVP Prototype Examples

Our target audience / user base for this prototype is robotics hobbyists and high school students participating in FIRST robotics competitions. These users would have the least amount of technical experience out of any from the wider project audience, and so supporting their understanding is paramount in our documentation efforts.

Initial Testing

We engaged in usability and user experience testing with five high school freshmen on FRC team 1410 in Denver, CO. The students took a pre-assessment questionnaire to determine their relative comfort and skill level with different robotics concepts. Students rated their level of comfort with 3D printing a part, uploading a program to an Arduino, soldering wires together, and creating a simple part in CAD. Students were also assessed on their knowledge / understanding of swerve drives and their comparative advantages over other choices for mobile robot drive systems. This was primarily to ensure that we were indeed engaging with users of the appropriate skill level for our goals.

The students were then provided with a bag containing the assembly components and the instructions as a PDF on a laptop. They then assembled the components with facilitators observing, answering questions, and noting mistakes or points of confusion. Finally, students were asked to rate the assembly experience on a scale of one to ten.

Questionnaire Data

We found that students were most comfortable with the physical aspects of robotics, such as 3D printing a part and soldering wires together. All of the students rated these tasks as a four or five in terms of level of comfort. Students were slightly less comfortable with using a CAD program to design a part (2 of 5 students rated their comfort at or below a 3) and were most uncomfortable uploading a program to an Arduino (all students rated this at a 1 or 2).

These results were expected and confirmed that these users generally reflected the baseline level of experience that we aimed to support through our documentation efforts.

Results

During the assembly process, we observed several common mistakes and areas of confusion. These were primarily caused by the absence of a sense of scale and from the perspective used in the exploded views making parts difficult to differentiate. For example, in the wheel assembly step shown in figure 2, three out of the five students confused the correct bearing with bearings that were used in a different step. This was due to the fact that the bearings had a very similar outer diameter (15 vs 14mm) and because the perspective of the exploded view made it difficult to determine the inner diameter of the correct bearing.

We observed similar behavior with the various different bolt lengths used throughout the design. Each step in the process only used one kind of bolt, so the students had no visual indication of the size of the bolt due to an absence of scale.

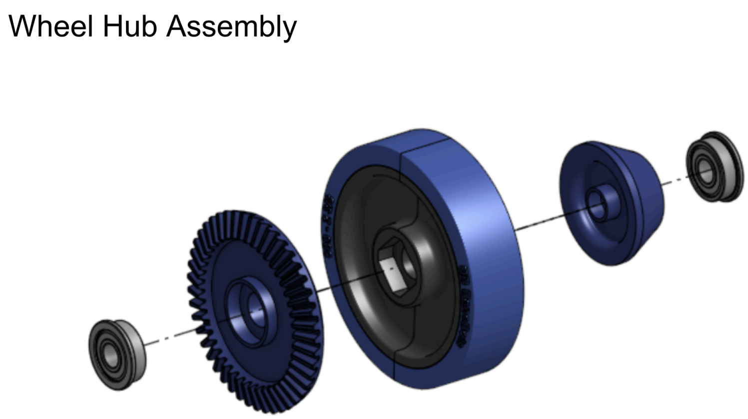

Figure 2: Wheel Hub Assembly Step

Finally, we observed some minor sequencing issues with one student. Some steps in the assembly process are made considerably easier with proper sequencing. The fork mounting step (shown in figure 1), for example, is much easier when inserting and tightening one bolt at a time rather than inserting all four bolts and then attempting to tighten them. The most prominent case of this we observed was in the fork assembly step shown in figure 3.

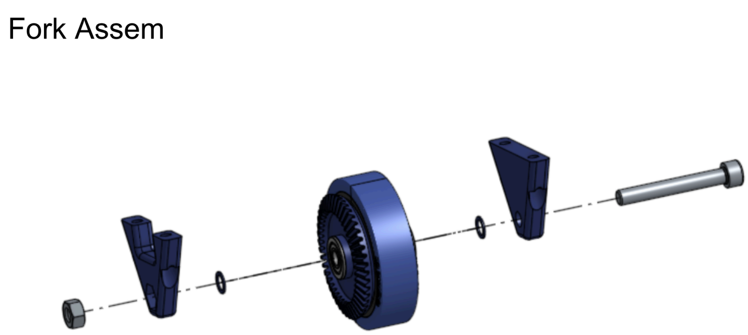

Figure 3: Fork Assembly Step

This step is best completed by stacking elements onto the central bolt one by one. We observed one student attempt to insert the bolt while holding the rest of the components together, which became frustrating.

Redesign Decisions

After the initial testing round, the observations made were used to drive design decisions for the next iteration of the instructions. The most common error that was made during the assembly process that occurred in some way for every individual who tested the prototype was confusion around which bolt or bearing to use during a certain step. To remedy this, the simplest solution was to add a small comparison callout in the step that used a piece that could easily be confused for another.

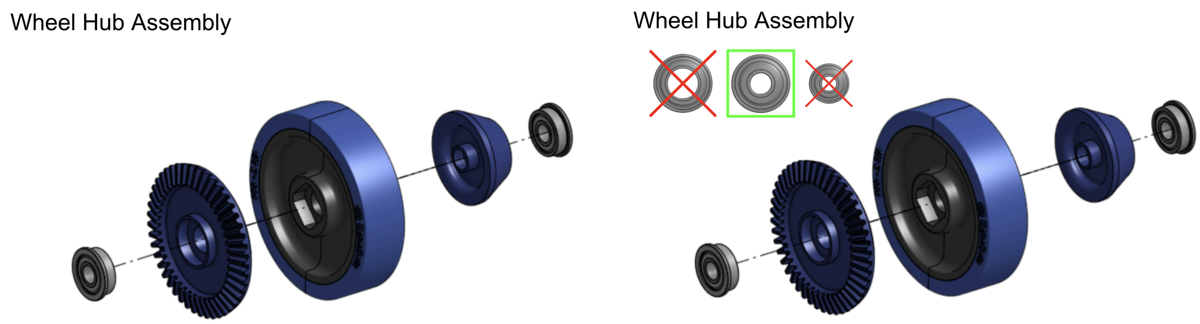

Figure 4: (L) Step Before Redesign, (R) Step After Redesign

Another box was included in the corner of steps that needed to use one of the two allen keys to screw in a bolt. This reminder was added after some students were not aware of the fact that they needed to use the provided tool to secure the bolts. On top of these additional images that provided clarity to each step in the instructions, some of the instructional image views were also updated to improve comprehensibility. These changes included slight tweaks to the exploded view angle and part distances to more clearly depict the parts, as well as an update of the model used for the locknut to be more accurate to the actual part. Another mistake that was made was the missequencing of the parts on the fork assembly for the wheel, and in an attempt to prevent this error, a number sequence and arrows were added to show sequencing and directionality. All of these changes to the instructions were made with the hopes of reducing the frequency of the previously observed errors.

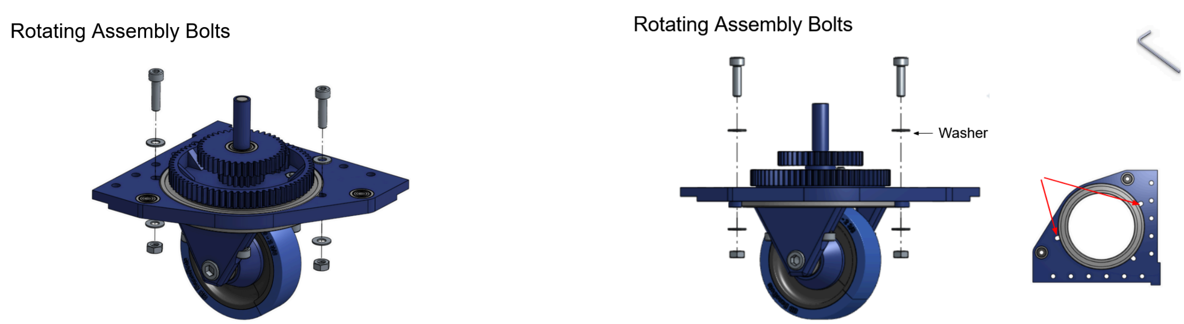

Figure 5: (L) Step Before Redesign, (R) Step After Redesign

Redesign Testing

A second usability and user experience test was run with a group of three freshmen at the Colorado School of Mines robotics club. Similarly to the initial testing round, facilitators provided these students with a brief statement assigning them the goal of assembling the swerve drive module, before giving them the necessary components and the revised instructions in PDF form on a laptop. Students were then observed and timed during the assembly process as the facilitator watched for mistakes and points of confusion and answered questions as they arose. These three tests were also recorded for analysis at a later time.

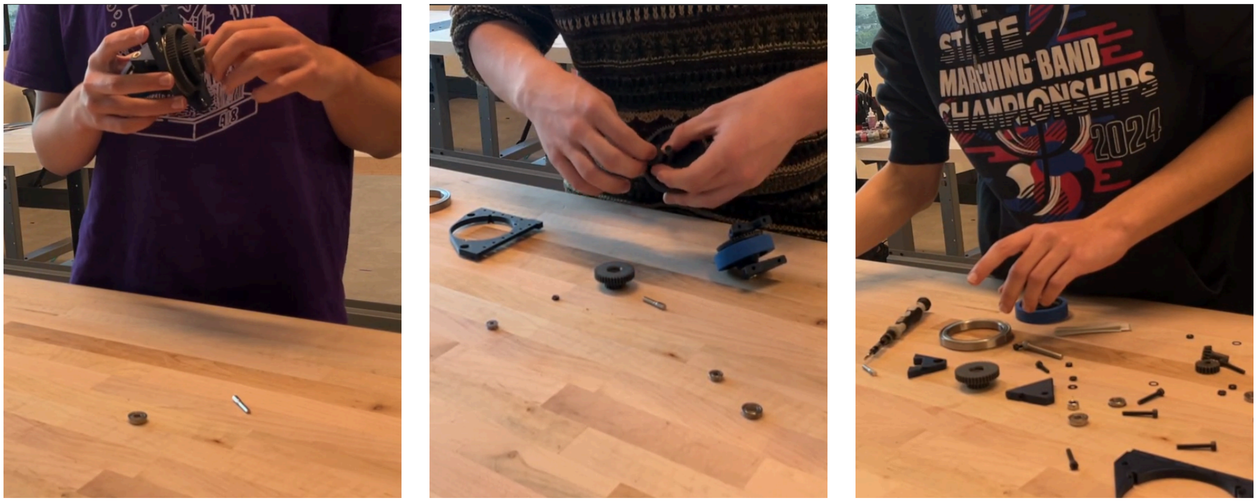

Figure 6: The three users for the revised testing

The tests took an average time of around 15 minutes each, with an average of 4.7 (4, 6, 4) times where the user asked the facilitator for clarification or made an error during assembly. During all three of the tests, there were several usability issues that arose, some of which occurred in more than one test. In multiple instances across the three tests, students would experience confusion over the different lengths and sizes of bolts, spacers and bearings. Directionality and orientation of a few key components was also observed during testing, as students would confuse which side of the wheel or mounting fork was being depicted in their respective stages of the instructions. Another common error was the over-tightening of the wheel bolt, which led to a limitation on the smoothness of the wheel's rotation. One success was seen as a student began by looking at the parts list, and sorting the parts before beginning the assembly process. This data seems to show an improvement in the overall clarity and comprehensibility of the instructions and the images on each page, but also highlighted areas where the visuals could be further improved. Exploration could be done into part labeling or other ways of conveying the information needed to distinguish parts from one another.

Data Usage

Qualitative

Our qualitative data came from the first round of testing. As previously stated, each student filled out a form about their technical experience before beginning assembly. We recorded their process, focusing on mistakes they made, questions they asked, and moments of confusion. These observations allowed us to identify which parts of the manual required redesign and improvement.

Quantitative

We gathered quantitative data during the second round of testing. We recorded how long it took each user to complete the assembly, the number of mistakes they made, and how often they asked for assistance. While similar data was not collected during the first round, this information establishes a valuable baseline for future testing. It will help us measure the impact of revisions guided by the qualitative feedback from the second set of interviews.

Discussion of System Validation

Through our user testing, we were able to identify how effectively the assembly manual met our accessibility goals. Our original hypothesis was that primarily visual instruction, using as few words as possible, would make the manual easier to understand and more approachable for users regardless of their prior technical experience.

A key functional requirement of this prototype was that the manual should enable users with limited robotics experience to correctly assemble the swerve drive base without outside assistance. The usability testing with high school FRC freshmen showed promising results toward meeting this requirement. All users were able to follow the steps with minimal intervention, demonstrating that the overall visual layout successfully communicated assembly intent. However, the testing also revealed that some instructions became unclear without supporting text. The lack of scale made it difficult for users to distinguish between similar parts, such as different bolt lengths or bearing sizes, when relying only on pictures.

These findings validated that while primarily visual instruction supports accessibility, it must be supplemented with clear visual differences between parts, consistent scale indicators, and occasional short text prompts or annotations to explain non-obvious details. The redesign decisions made before the second round of testing, such as adding part comparison windows, numbered sequences, and tool indicators, directly addressed these weaknesses and improved user comprehension in later tests.

Overall, the testing results partially validated our system goals. The visual-first approach proved to be an effective foundation for creating accessible and user-friendly documentation, fulfilling the functional requirement of enabling basic assembly by inexperienced users. However, it also revealed several shortcomings with our implementation of this approach. Future iterations will focus on improving visual clarity and part identification to further enhance usability and ensure the manual fully meets its accessibility objectives.

Reflections

Through this design sprint, our team gained valuable insights into how users interact with documentation and how small visual details can significantly affect usability. Our initial assumption that minimal text would make instructions more accessible proved partly true. The testing process revealed that the accessibility we were looking for involved not only in reducing words but also in creating clear, informative visuals that communicate scale, orientation, and sequencing.

The iteration process was a key learning experience. After observing confusion during the first round of testing, we adapted by redesigning our assembly manual to include comparison windows, numbering sequences, and visual tool indicators. These changes led to less confusion during assembly during our second round of testing, showing the value of rapid, feedback-driven design cycles. However, the second iteration also provided more feedback on visual clarity in our images that was missed in the initial round of testing. For future iterations, we will focus on refining the visual clarity of the manual, focusing on clearer colors, and clearer sense of scale in our comparison windows.

Team collaboration was consistent and equitable throughout the project. The assembly manual design received equal contributions from all members. User interviews were conducted by Westly and Michael, while Max focused on analyzing and interpreting the resulting data. All major design decisions were made collaboratively, and communication within the group remained open and balanced. This equitable distribution of work ensured that the final product reflected the collective effort of the entire team.