Innovation Project Presentation

Simon: Hmm, it's so cold in here. Can someone turn on the heater please!

Bernice: *shows temperature increases*

Simon: It feels much better now.

Hannah: In the meantime…

Bernice (TV):
shows money gets burned
trees dying

Simon: Shoot, why is my energy bill so high?!

Danny: you are heating up the entire house, Simon, even though you're the only one here?

Simon: Excuse me??? Isn't that my only option??????? :(I need to stay warm!

Bernice (TV):
BREAKING NEWS! There is an energy shortage crisis this winter due to the war. The government requests all residents to lower the thermostat settings in the house!

Simon: But it's gonna be so cold! What can I do? Solvers of X and Y, we NEED your help.

Tate: Alright! Let's do some research on the internet first!

Internet: Research(Logos): *Statistics Canada & International Energy Agency IEA*
Tate: Look here, according to these agencies, the buildings sector accounts for about a **quarter** of total final energy consumption.

Caden: Yeah, and *65%* of this energy consumption comes from heating and cooling! That's a LOT!!!

Books: *SuperPowered*
Kevin: Ryan, let's find solutions from the book. Look, it says here we can use solar panels and windmills to generate renewable energy. That can help!

Ryan: Yes, I agree. But do you still remember what Elon Musk would do before he starts solving any problem?

Kevin: First Principle thinking (*Elon with Frist principle photo)!

Ryan: Exactly! It we follow this path, shouldn't we try to reduce the energy consumption first?

Kevin: I think both approaches are good. But which one should we focus on?

Ryan: Oh, why don't we do a survey to ask our community for their opinions?

Survey (Pie chart):
Hannah: Judges, our survey shows people would like to reduce energy consumption.
Danny: How do we do that?
Hannah: I think we should ask some experts.

Experts:
Caden: Hi Professor HVAC! Our team is struggling to find something that can help us stay comfortable in our houses, without using a lot of energy. Do you have any suggestions?

Sophie (Professor HVAC): I know! Why don't you use a heat pump? Compared to traditional heating and cooling systems, it is much more efficient, as it does both heating and cooling in one unit! You could get a mini heat pump. So you don't have to heat or cool your house as much. Then you can spot heat or cool the person.

Danny: Okay, but how will we condition the person if they move around?

Sophie (HVAC): Oh, that's not my expertise… Try asking Professor Robot.

Ryan (Professor Robot): Solvers, think about the innovation project you did last year!
Kevin: Oh yeah! We made an AI vision assisted cargo robot. We can use that!
Simon: But hold on, is that robot powerful enough to carry a heat pump?
Ryan: Why don't you hack a hoverboard? It can carry heavy loads, like your heat pump! You can also use your Huskylens AI vision sensor to track the occupant.
Caden: BINGO! Let's work on it now :)

Hannah(drift in with Tesla logo): Fun fact, new Teslas models use heat pumps to condition their cabin!

Hannah: A few months later…

Ryan: Judges, may we present to you our *name*. Judges as you can see, our robot consists of a hoverboard as a base and a mini heat pump unit, powered by the LiFePO4 battery. We use 100w solar panels to charge the battery.

We initially hacked the motherboard of the hoverboard and tried to make it controllable, but we realized that hacking the hoverboard doesn't provide enough resolution to control the hoverboard's speed. Then we used a motor driver board to regulate the three-phase brushless motors.

Tate: We used a low-cost Arduino to make the controls. Additionally, we used an AI vision sensor called Huskylens to track the object so it can follow the occupant.

Kevin: To make it clearer, we made a circuitry to show our control system.
Sophie: Judges, this diagram shows how heat pumps work as a refrigerant system. As you can see from here, it can do both heating and cooling.

Hannah: We've made two innovative improvements over the traditional heat pump. The traditional heat pump has to exchange heat between indoor and outdoor. Our heat pump exchanges the heat within the indoor environment only. The second innovation is on the heating and cooling switching mechanism. The traditional heat pump uses a reversing valve on the refrigeration system to make the switch. Because our heat pump is smaller, we do not have space for a reversing valve. We developed a four-way air-exchange mechanism to instantaneously switch the air between heating and cooling.

Finance…
Kevin

Bernice(TV):
BREAKING NEWS! The situation has become less severe, with Solver X and Y’s innovation! We can all go outside now!

Pans to Solvers X and Y cheering and being happy!

Robot Design Presentation

Kevin: Judges, we developed our robot based on three design principles: Reliability, repeatability, and stability, with the emphasis on error handling strategies.

We use both hardware and software solutions to achieve the goals.

Hardware:

- Core: **Bernice** We went through multiple design iterations and came to this final compact design. We added extra pins and connectors to make the robot's core and chassis structurally solid and to improve its structural integrity.
- Forklift dumper: **Hannah** We developed a unique, and innovative attachment inspired by the forklift and dumper idea. It is driven by a large motor through the parallelogram linkage mechanism. We use this attachment to collect energy cells from the wind turbine by pushing the red bumper (QA sessions: Ryan can talk about how to ensure this attachment rigid enough to push the bumper, hint: support the parallelogram arm). Our innovative solution is to connect the Wind Turbine and the Toy Factory missions in the same run. As you can see, there is a pivot point in the middle of the container part. For the Toy Factory mission, the dumper is lifted to the desired height by the large motor, and by pushing the bottom edge to the top edge of the toy factory opening, the dumper will tilt around the pivot point to release the cells. This makes our attachment both a passive and an active attachment.
- **Caden** We also used this attachment to multitask many other missions such as the Smart Grid, picking up Hydraulic energy cells, delivering cells to the Energy storage missions etc.
- Funnel: **Danny** One of the key things we want to address for our robot, is the error handling ability. We realized, and also found reports from many other teams, that no matter how many advanced coding strategies you use, there will always be some marginal errors. These small errors are sometimes quite critical as the robot may get jammed and eventually fail certain missions. To compensate for that, we made a funnel to align the robot with the mission model to improve the accurate positioning of the robot.

- Software:
  - PID: **Simon** We also use various coding solutions to address the error handling abilities and improve the robot's stability and repeatability. We use gyro sensor-PID strategies extensively throughout our missions to ensure the robot running in straight lines. We also combined PID with speed change, acceleration, and deceleration, to prevent drifting and ensure the stability of the robot, especially at the beginning and the end of each run.
  - Color sensors: **Sophie** There are two color sensors in the front area of our robot, placed in an offset position. We use these color sensors in three different ways to improve the accurate positioning of the robot:
    - Through our testing and experience, we learned that it's not accurate enough for our robot to land at the same position, repetitively, by only

using the rotation degree counts of the wheel. The longer the run, the more errors will build up. So, we use the centre color sensor for the line detection so we can stop at a line, and obtain new references to reduce the proportional errors.

- **Ryan** During our testing, we found that even with the PID and line detection strategies our robot may not position itself to the repeatable landmark, especially for our Run 1, where our robot starts from the East launch area, and goes through the North path to clear 8 missions within one and a half minutes. So, we made an advanced line squaring strategy, and use the two color sensors in offset position to further improve the robot position accuracy.

- **Tate** In addition to improving the accuracy of robot positioning, we also use the Stall detection strategy to recalibrate the starting position of the attachment. For example, this main arm position is very critical to the Hydraulic cell mission because we rely on this attachment to pick up and drop off the cell.

- **Caden** As a team inspired by FLL, we want to give our knowledge and experience back to the community. One thing we found is that many younger kids got frustrated during the robot testing because of the lack of experience and mathematic skills. To help them and ourselves, we developed a program called Path Planner to simulate the mission testing. The Path Planner will tell you the approximate distance that the robot needs to travel and the angle to be turned to with a few clicks of the mouse. We tested this program on our robot as well as three other junior teams' robots, we saw clear evidence of testing time savings as well the improvement in younger kids' engagement.

Mission Planning

- **Bernice** For the robot missions, we have 4 runs in total. The first run is the most critical one since it takes about 1 minute and 30 seconds to finish and needs to clear 8 missions in the North and Central areas (Show a path map). As a matter of fact, we spent most of our time testing this run to ensure a good successful rate. This kind of feedback from our testing helps us improve the robot design in both hardware and software. For example, for the original design, our robot has two medium motors to drive the attachment. After two months of testing, we realized some major stability issues, so we replaced one medium motor with a large motor, and then retested the missions. The Advanced Line Squaring is also the outcome of this type of feedback-testing process.
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Conclusion

Danny Judges, this is the conclusion of our robot design presentation and we are delighted to answer your questions now.

You said you used PID a lot; what is it?

- It is an error feedback algorithm that helps the robot go straight. P is proportional, is the current error. It is integral, is the sum of the historical errors. D is derivative, is the future errors we might make. We combine all of these errors to help our robot move straight reliably.

So what's the coefficient of the PID?

- Our coefficient for Proportional is 0.6. We found this by isolating the P because the P is the most important and relevant error. We did trial and error and observed the performance of our robot. We started with one and slowly changed the number higher or lower to find out the best coefficient. In the end, we found that 0.6 works well as it oscillates nicley. Then we moved onto our integral coefficient. The integral coefficient is 0.0014. Because integral adds all the historical errors together, it will be too large of an error to be represented in the code. Because of that, we had to scale it down significantly so that it could be represented in our code. Our derivative is set at 0 because it is hard to predict and sometimes causes even more error than how it started out. However, we acknowledge that no matter how good our PID is it will still have errors. This is why we made the funnel.

You talked about your advanced line squaring method. What is that?

- Line squaring: Unlike the traditional line squaring method, which uses two color sensors that are along the same line each other, we used two color sensors that are offset for our advanced line squaring. For example, our robot uses the gyro assisted PID when running. There can be errors in that, so we also use a line follower done by the color sensor to make our robot more accurate. We use the center color sensor to follow the edge of the line. We move until the other color sensor detects the edge of the T. This way we can more accurately position our robot than the traditional line squaring. The problem with traditional line squaring is that they can stop at any point along a line and still be perpendicular to it. With ours, it will be perpendicular and still be at the same point every time, making our robot more repeatable.

Summary

What is "*SMACH"*, a.k.a *Smart Mobile Air Conditioner & Heater*?

The goal of our *SMACH* product is to help reduce energy consumption in households as to help with climate change. To do this, our *SMACH* can reduce the energy used for heating and cooling of buildings. *SMACH* allows the occupant staying in a comfortable environment without sacrificing a huge amount of energy. *SMACH* is an AI vision assisted mobile robot that uses heat pumps to condition the nearby environment.

Through this survey, we'd like to get your feedback on how to improve the functionality of this product.

1. Are you aware that heating and cooling is 1/3 of energy consumption in an average Canadian household?(yes/no)
2. Are you concerned of the current climate crisis?(yes/no)
3. Which one is better, energy generation or reduce energy consumption? (open ended or multiple choice)
4. Are you aware of heat pump as a technology(yes/no)
5. Temperature set in house in winter and summer(options)
6. Do you think a mobile energy heater/cooler that can help reduce energy consumption in your household would be useful?