SmartSlope

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Description:

SmartSlope is an interactive putting platform that allows golfers to experience real-world green conditions. The system uses an array of servo-controlled actuators beneath modular turf-covered plates to dynamically simulate different slopes, giving users the ability to practice putting on realistic putts. By adjusting the height of each plate, SmartSlope recreates subtle or dramatic contours of a golf green, offering customizable challenges that mimic real-life scenarios. The interface allows manual control as well as randomized presets to keep the practice engaging and effective.

Inspiration and Ideation:

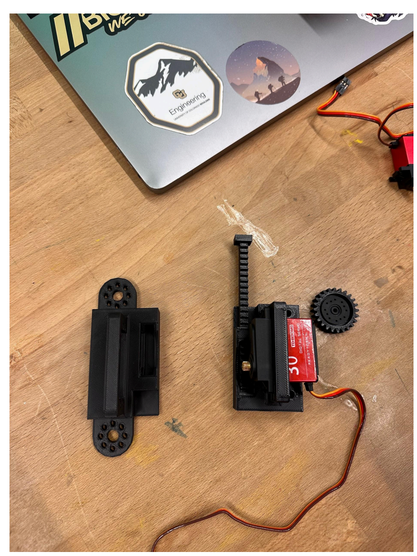
The idea for SmartSlope was born from a shared frustration with how limited and unrealistic indoor putting mats can be. While many golfers rely on flat, repetitive surfaces for indoor practice, these tools fail to prepare them for the real challenges of putting on real greens that have complex contours. Our team wanted to create something smarter, a way to replicate natural contours and bring more meaningful feedback to practice sessions.

Initial brainstorming focused on the mechanisms for moving the surface. We researched hydraulic lifts to inflatable bags, but we quickly honed in on using a 3D printed rack-and-pinion system driven by servo motors for their precision, affordability, and ease of control. Through iterative sketching, prototyping, and feedback from mentors and golfers, SmartSlope evolved into a modular platform that could scale and adapt to various user needs, from home use to training facilities.

Building SmartSlope:

Starting the Project:

We started the semester by diving into early prototyping and foundational research. In the first few weeks, we 3D printed our initial rack-and-pinion systems, explored servo motor options, and began drafting core build plans. These early steps were essential for validating our concept and ensuring we had a strong technical foundation before scaling up.



Servo Selection:

Choosing the right servo motor was one of the most critical decisions in the project. Each actuator needed to deliver high torque, maintain precise positional control, and hold weight under load without drifting. After exploring alternatives like stepper motors and linear actuators, we selected 30kg digital servos for their strength, affordability, and responsiveness to direct digital signals from the Arduino. These servos proved to be ideal for lifting and holding the plates at consistent angles while maintaining reliable performance over extended use.

We used an Arduino Mega, which gave us access to a large number of digital I/O pins, more than enough to control multiple servos directly without needing a multiplexer. This simplified our setup, reduced latency in signal processing, and gave us a more straightforward debugging process.

To safely power the system, we sourced a dedicated DC power supply and built a centralized power distribution hub to ensure stable voltage and current across all servos. Separating power from signal lines was essential to avoid overloading the Arduino and allowed the servos to operate smoothly without power problems.

Plate System Design:

In parallel with motor selection, we invested significant time in the design of our modular plates. These plates form the surface golfers interact with and are responsible for translating servo motion into sloped putting surfaces. After exploring several concepts, we committed to using laser-cut square wooden plates mounted on a grid of 3D-printed rack-and-pinion actuators. This solution offered a stable, repeatable, and scalable design. The racks could be printed in-house and glued directly to the plates, reducing both cost and turnaround time. Their vertical motion, driven by the servo's rotation, provided the level of control and precision we needed to simulate real-world green conditions.

Circuit Planning:

With our physical components selected, we turned our attention to electrical planning. Because we used an Arduino Mega, we had enough digital I/O pins to assign a dedicated signal pin to each servo, removing the need for a multiplexer and streamlining the control system. This setup also reduced complexity and improved the responsiveness of each actuator.

One of the most critical aspects of our circuit design was power distribution. Each 30kg digital servo can draw a significant amount of current under load, so we couldn't rely on USB or onboard power from the Arduino. Instead, we sourced a high-capacity power supply unit (PSU) that converts standard wall outlet AC power to 5V DC at 60 amps. This PSU provided stable, high-current output to safely and reliably run multiple servos across the entire platform.

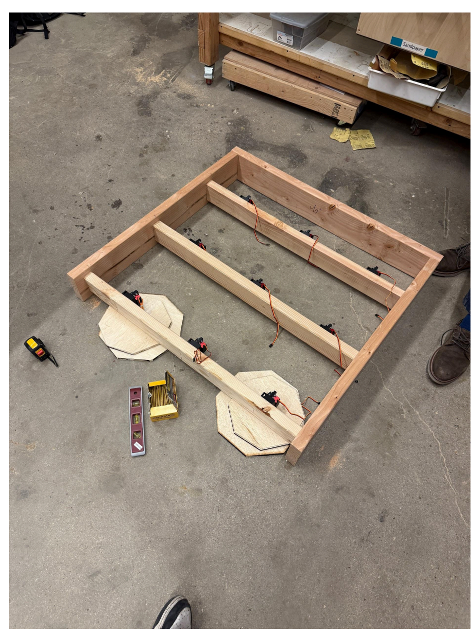
To manage this power effectively across modules, we designed a distributed system using custom power and ground bus bars for each module. Each bus bar served as a local distribution node, providing clean power and ground lines to a group of servos while reducing voltage drops and wiring clutter. These bus bars were connected directly to the PSU using thick-gauge wire to handle the high current and minimize resistance.

By isolating power from the signal, we ensured that servo activity wouldn't interfere with Arduino performance or logic. Signal wires ran from the Mega to each servo, while power and ground lines were routed through the bus bars, creating a modular and scalable electrical system. This organization made installation, debugging, and future expansion much easier, and it allowed us to quickly test individual modules during the build.

The overall result was a clean, robust wiring setup capable of powering dozens of high-torque servos with consistent performance and electrical safety in mind.

First Tests:

Our first functional test featured a single 6-servo module, 3ft by 3ft, simulating variable slopes across its surface. This module validated our mechanical system, proving that our servos, racks, and plates could work together to deliver smooth, repeatable, and precise motion. User testing during this phase showed that the interface was intuitive, and most users needed no instruction to interact with the system. However, some struggled to visualize what the servo input values meant in terms of actual slope. That insight led us to brainstorm UI improvements, including live feedback and preset modes for randomized terrain.



With these early wins and key design decisions behind us, we began scaling the system and refining each component for reliability, usability, and performance.

Day to Day Process:

The success of SmartSlope came not just from good design, but from a well-coordinated, hands-on build process. As a team, we established a consistent weekly rhythm and divided responsibilities based on our strengths. This allowed us to move quickly, solve problems in real time, and steadily build out the system module by module. By dividing responsibilities, one person or more focused on wood and assembly, another on fabrication and printing, and another on wiring and testing, we were able to scale rapidly without bottlenecks. Weekly goals were defined in advance, and we tracked our progress against them to stay on pace for completion.

The modular nature of SmartSlope made this process efficient. Each module was a self-contained unit, frame, plates, servos, bus bars, that could be tested independently and added to the overall platform once verified. This allowed us to iterate fast and build confidence with each completed piece.

Woodworking and Frame Construction:

Each module of SmartSlope is anchored to a wooden frame, which had to be both level and rigid enough to support the weight and motion of the turf plates. It took our whole team to focus on cutting, assembling, and leveling the wooden base, using shop tools to ensure consistent sizing and alignment. Every frame section was built to support three laser-cut plates with clearance for rack-and-pinion travel, and wire management.

Laser cutting and 3D printing:

Team members worked to laser cut the turf plates and 3D print the rack-and-pinion systems. This process ran continuously throughout the semester. The pinion gears, linear racks, and servo mounts were all designed in CAD and iterated based on fit and performance. Once printed, the racks were glued directly to the underside of the wooden plates for a strong, precise connection to the servo shaft.

Wiring and Power Distribution:

We handled all electronics setup and power management. This involved mounting bus bars to each module's frame, carefully soldering and connecting wires from the PSU to each power and ground rail, and routing digital signal lines from the

Arduino Mega to each servo motor. This task was time-intensive and required careful labeling and testing to ensure everything was electrically safe and logically mapped.

Each time a module was built, we would immediately test the wiring and servo motion, often using a simple debug program in Arduino to confirm response and movement range. This let us catch and fix wiring mistakes early and helped validate that the physical and electrical systems were properly aligned.

Mounting and Assembly:

Once plates and servos were wired and tested, we mounted the plates onto the frame using our crossbeam layout. The cross beams were designed to support the servo housings and allow room for vertical travel. After installation, we ran calibration sequences to “zero out” the plates and ensure all servos began from a known flat baseline.

Conclusion:

Working on SmartSlope was an incredibly rewarding experience for our entire team. Throughout the project, we learned valuable lessons in project planning, time management, and technical execution. Clear communication, task delegation, and staying organized allowed us to move efficiently from early prototyping to a fully functional final product. While we faced challenges along the way, our ability to adapt and collaborate made the process both successful and enjoyable. Beyond the technical skills we developed, the project reminded us how much fun it can be to bring an idea to life through teamwork, creativity, and persistence.