UCI Samueli
School of Engineering

Team Sky Bison

Project: Steerable Walker 2021

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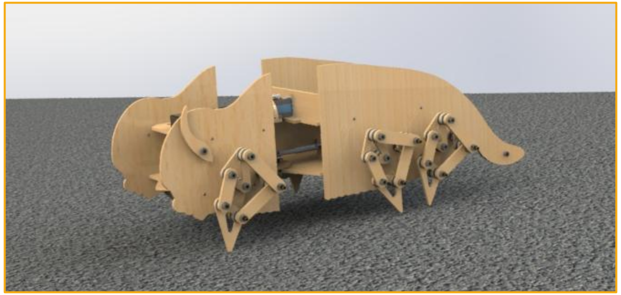
Sponsor: Dr. Michael McCarthy

Advisor: Kevin Chen



STEERABLE WALKER

Problem Definition and Project Overview

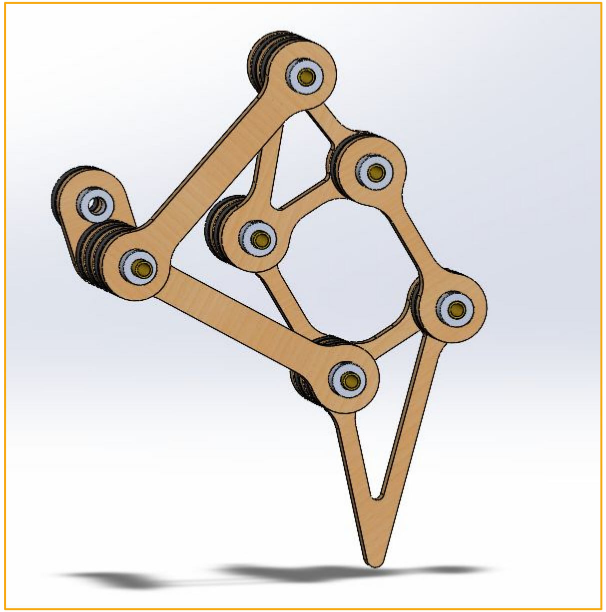
Goal: Design, construct, and evaluate the performance of a six-legged steerable walking machine.

Design Attributes & Requirements:

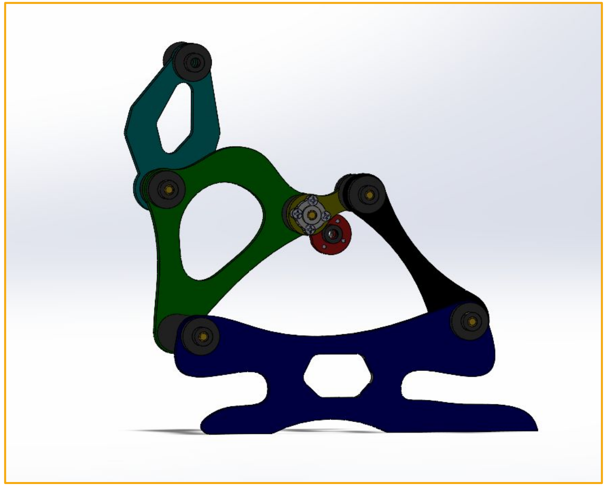
1. Minimally actuated with 2-4 actuators: one motor for locomotion & second motor for steering
2. Six-legged
3. Controlled wirelessly
4. Steerable (Steering angle of 25 degrees)
5. Walk speed of 1.5 feet per second
6. Chassis made of Baltic Birch
7. All components are within the required dimension of 15''x30'' for manufacturing

Leg Mechanisms

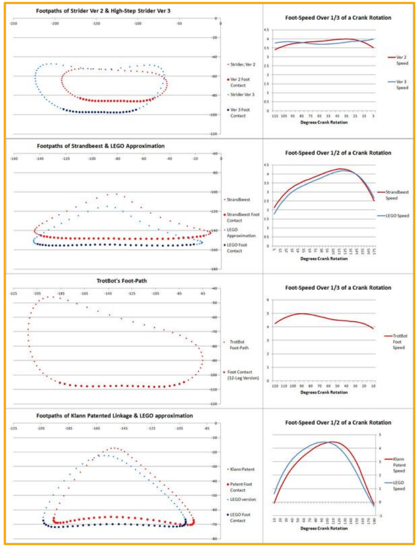
Jansen Leg



Rectilinear



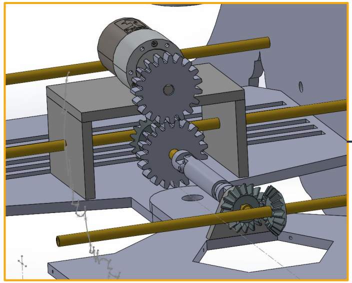
Others (Footpaths and Foot Speed Comparison)

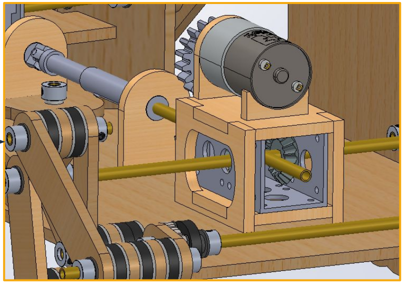


Source: DIY Walkers

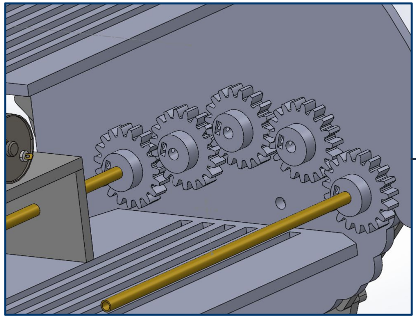
Walking Drivetrain

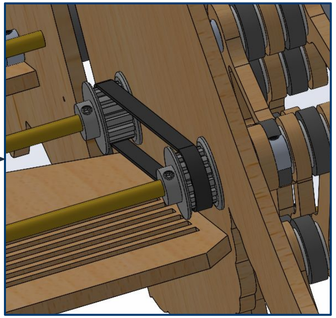
Gearbox & Power Transmission to Middle and Front Legs



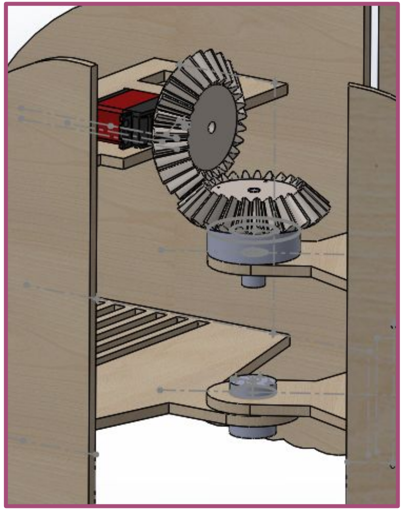


Power Transmission to Rear Legs

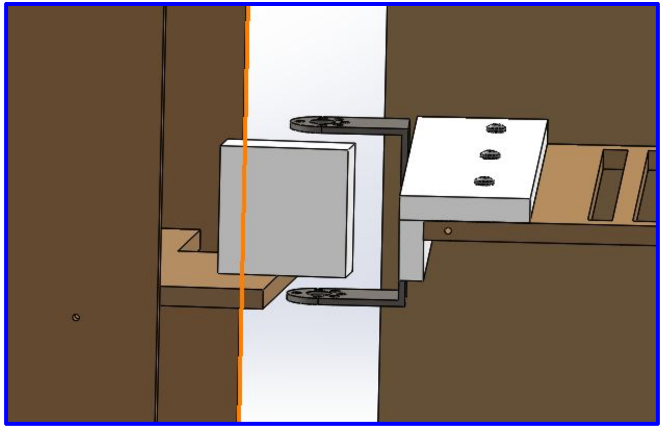




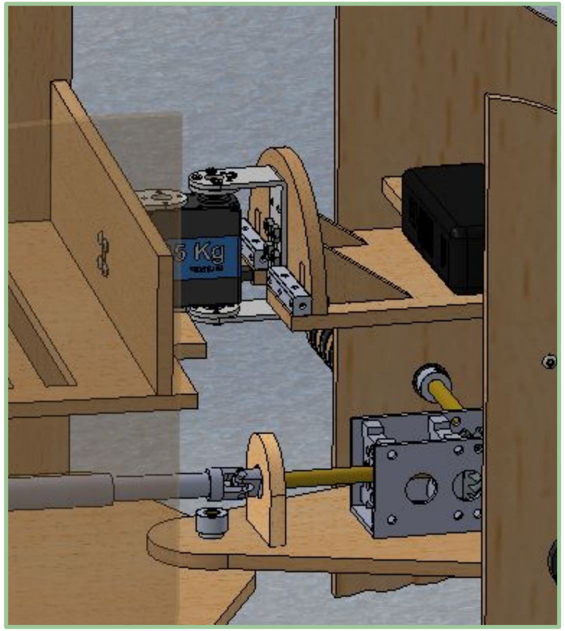
Steering Drivetrain Designs



Design #1: Servo motor with spiral bevel gears



Design #2: Servo motor with 3D printed mount

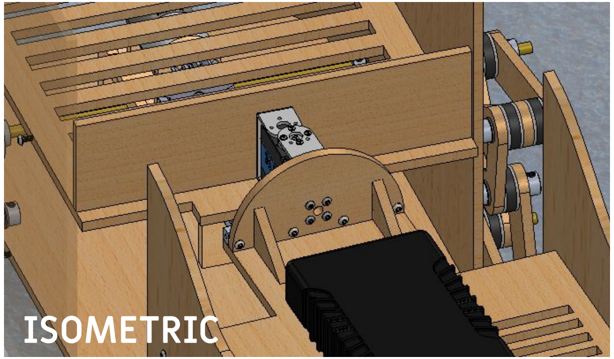


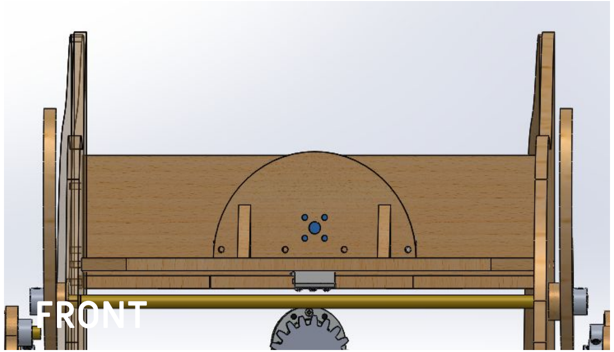
Design #3: Servo motor with nut strips and laser cut support members

Steering Drivetrain Final Design

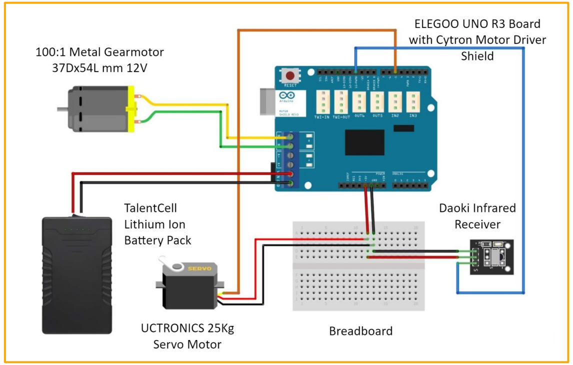
Design Justification:

- The final design is an adopted and improved concept of design #2.
- Avoid using 3D printed parts for mount
- Additional support members to distribute loads when turning
- Easy to adjust for front and rear segment spacing

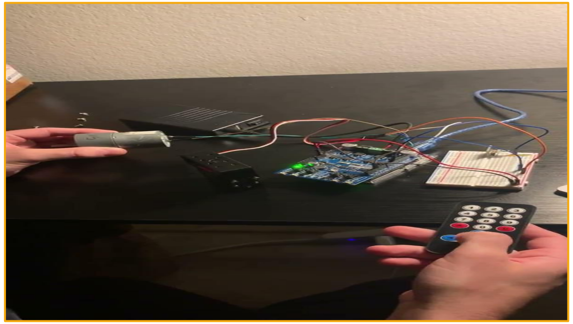




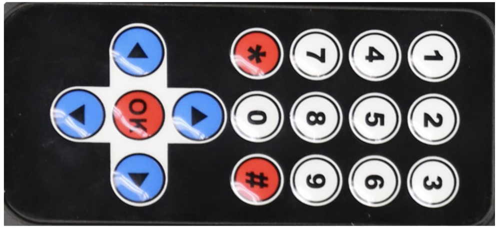
Control Electronics



Schematic of control electronics generated with Fritzing software



Electronics test demonstration

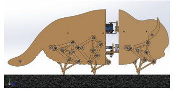


IR Remote / Transmitter

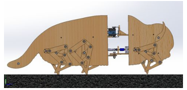
	Command	IR Remote Key
DC Motor Controls	Stop Motor	0 Key
	Full Speed Forward	Up-Arrow Key
	Full Speed Backward	Down-Arrow Key
	Half Speed Forward	2 Key
	Half Speed Backward	5 key
Servo Motor Controls	Straight	OK Key
	Right Turn	Right-Arrow Key
	Left Turn	Left-Arrow Key

Turning Radius Motion Studies

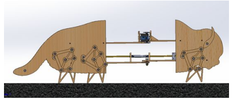
Leg Mechanisms Spacing



6-16 Ratio



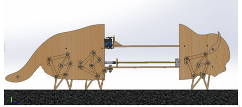
6-19 Ratio



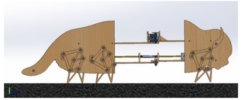
6-26 Ratio

Steering Axis Placement

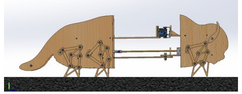
Rear



Centered



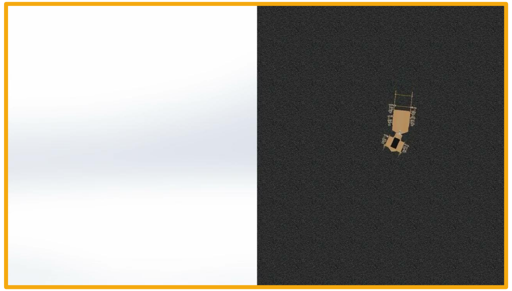
Front



Turning Radius Motion Study Results			
Steering Axis Location	Leg Mechanism Spacing		
	6:16	6:19	6:26
Original	n/a	8.7 feet	11.6 feet
Front	n/a	7.2 feet	9.3 feet
Centered	n/a	6.1 feet	6.2 feet

Top: 6-Wheel car with rear wheels spaced close together; basis for current steering design.

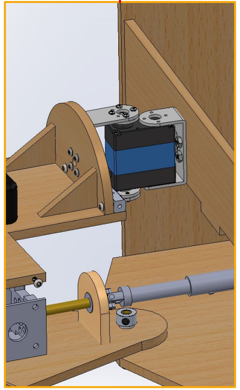
Bottom: Motion Analysis turning radius simulation of final design.



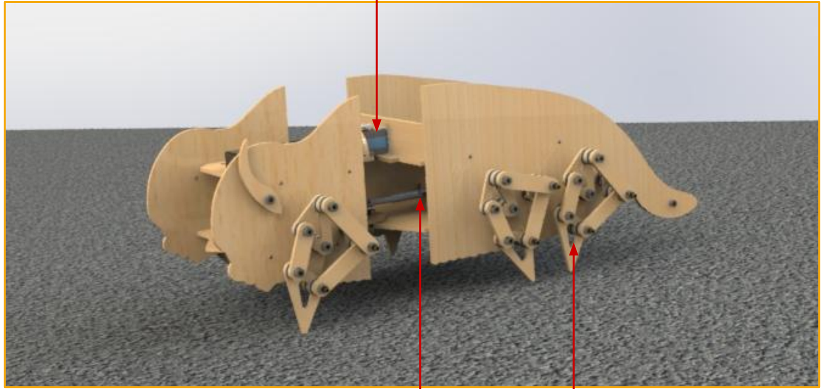
Verification of Requirements

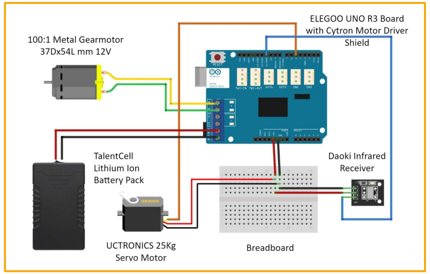
Requirement	C/NC (compliant / non-compliant)	Verification	Notes
1) Minimally Actuated	C	Control electronics schematic / Solidworks model	One motor is used for locomotion and one servo motor is used for steering
2) Walker must be six-legged	C	Solidworks model	
3) Steerable (with turning radius of 6 feet)	NC	Solidworks motion study / Hardware performance review	Servo cannot generate enough torque to move front segment
4) Wireless control of locomotion and steering	C	Control electronics schematic	Controlled by IR transmitter and receiver.
5) Walk speed greater than 1.5 ft/s	NC	Physical model	Motor cannot provide enough torque to walk on ground; drivetrain gears slip
6) Chassis constructed from Baltic Birch wood	C	Photograph of hardware	
7) All components are within the required dimension of 15’’ by 30’’ for manufacturing	C	DXF files for laser cutting	The laser cutter bed size is 18” by 30”

Final Design Description

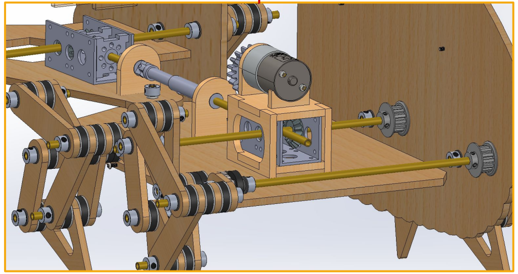


Steering Drivetrain

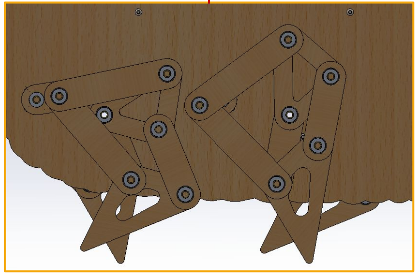




Control Electronics Schematic

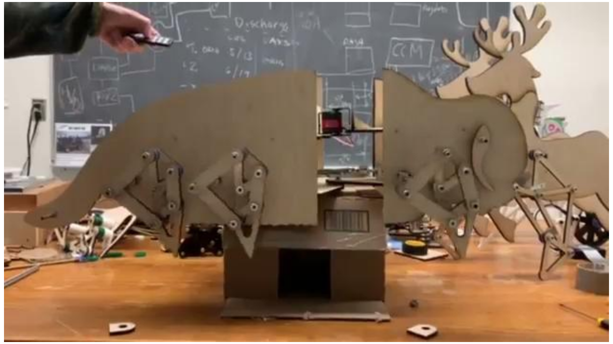


Walking Drivetrain



Leg Mechanisms

Hardware Performance Demo



Risk Assessments (Rating 1-5) 1=least, 5=most

Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk
DC motor failure	Wearing on legs, chassis, or drivetrain parts	Overload: overall walker is too heavy	4	4	5	Reduce material used, cut out more solid wood parts
Universal Drive Shaft locking	component might break, retraction and snapping	over extending (for very sharp turns than design is intended for)	1	3	5	Test how far universal drive shaft extend when at max turning radius
Loosen parts (i.e. shaft collars)	brass tube slips out of positions, assembly misaligned	movements that causes vibration throughout all parts (shear, torque, loading forces)	4	3	4	regular tightening maintenance before operating walker
Servo motor failure	failure to turn	front segment too heavy, servo motor mount becomes loose	4	3	5	steering testing using SolidWorks, electronic testing

Remaining Questions and Concerns / Recommendations for Future

- How can we implement minimally actuated robots into society as additional helping hands?
- With only one motor for locomotion and a second motor for steering, how many legs can we add before the walker fails to function/move/turn?

Recommendations

- Implement a system to have a walking and steering drivetrain that can be easily integrated into a chassis (Work backward? Drivetrain first, then chassis?)
- Before starting motion analysis stage, reduce the amount of redundancy in SolidWorks model (Group into subassemblies)
- Build physical prototypes of essential mechanisms before assembling full design prototype; check to make sure mechanisms behave as expected
- Consider 3-segmented body for future designs (for sharper turning)