The Tethered Mini-Sumo Robot
A Teacher's Guide

Introduction

The tethered mini-sumo robot is a project that I have used successfully with my students for several years now. Although I present the project to grade 9 and 10 students in a general "technology" shop class, the project could be adapted to suit a variety of different shop resources and curricular outcomes. The project also serves as a nice lead-in to the PIC microcontroller controlled mini-sumo robot that my senior students build. (Documentation on this project is under development… drop me an e-mail if you are interested.)

About Mini-Sumo

Mini-sumo is an internationally standardized class of robotic competition. The rules are available on-line from a variety of sources (try http://www.robotroom.com/SumoRules.html) and while most contests are intended for autonomous (computer-controlled) robots, tethered (hand-controlled) mini-sumo bots often compete as a sub-class. The most important rule to keep in mind is that the robot must be 10cm x 10cm or less (when in starting position… it can "expand" after the match begins) and must weigh 500g or less. It may be any height. It is designed for one purpose only… to push another robot out of a ring!

Resources

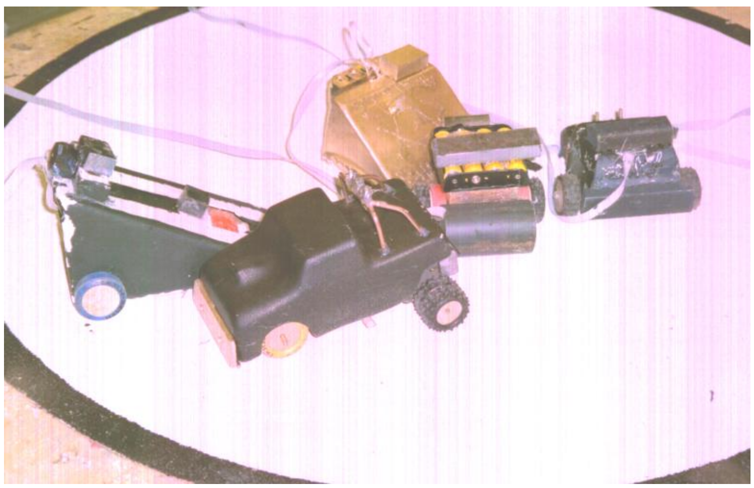
Each mini-sumo robot costs about $12 - $15 to build (I take this out of the $20 project fee I charge for the course as the students get to take their robots home). Although I usually allow about 30 hours of class time to complete the entire project, this is rather generous. I suspect that depending on the abilities of the students and the amount of theory worked in to the project that the project could last anywhere between 20-40 hours of class time.

Each robot will require the following:

> **Tamiya Twin-Motor Gearbox Kit** (part # 799-70097, available in boxes of 60 from Borgfeldt Canada (tel: 905-946-9677, www.borgfeldt.ca) at just under $10 each including tax and shipping – they take VISA and *may take several weeks to ship*.) If you are careful these gearboxes can be re-used from year-to-year, allowing the opportunity for significant cost savings. Smaller quantities of these gearboxes are available from retailers such as www.hvwtech.com at a considerable mark-up.
>
> **Wheels** – my students turn wheels from 1" aluminum rod on the machine lathe, then drill and tap them to allow an 8-32 set screw to hold them tightly to the axle. Each student will need about a 2" length of rod. Other options include any wheel that has some traction and can fit on a 1/8" diameter hexagonal axle shaft. (Old toys are a good source, as are CO2 dragster wheels available from several educational suppliers.) Other teachers have had success with a variety of wooden wheels, including pieces of doweling epoxied directly to the axle. While my

student's wheels come out to about 1 1/8" diameter (with tires), that is pretty small. Larger wheels, in the 1 ½" to 2" diameter ranger would likely be better.

Tires – Princess Auto used to have some excellent surplus tires from small electric race cars. Until I can find another cheap source for tires, I am planning to just use O-rings and/or elastic bands. Another possibility is to find some rubber or foam tubing that will fit over the wheels and slice it in to tire-sized pieces. I believe some people have sliced up old bicycle tire inner tubes to get a nice round rubber tire. Some of the more sophisticated robots I've seen on the internet actually cast their own tires from urethane, which has me considering trying dipping the wheels into the "liquid rubber" that you can purchase at hardware stores for coating the handles of tools. If you develop an innovative solution, please drop me an e-mail and I will add the idea to this write-up. Again, if you are stuck, old toys and lego are likely good sources for tires, and almost every kid has something around the house that will work!



Vacuum Formed Plastic Mini-Sumos at Summerland Secondary

Body – I have my students construct a body from 18 gauge aluminium using the shears, saws, files, and brake in my shop. I'd say that on average each student uses about a square foot of aluminium. Some will polish the body to a shine on the buffing wheel, while others will paint it. I have 4-40 screws and 1/8" pop rivets for making mechanical joints where needed. There is no requirement that the body be made this way… Nick Kast's students in Summerland have made excellent plastic bodies on the vacuum former, while other teachers have suggested that 20ga sheet metal would allow students to weld/solder the joints. Like the wheels, this is a part of the project that is very flexible and can likely be adapted to the resources you have available and the learning outcomes you require.

Power Supply – I give the students a 4xAA battery pack (they have to bring the batteries, although a student teacher suggested I buy batteries in bulk and sell them to create some revenue for the shop). A 9V battery clip is used to connect to the battery pack.

Cable – you will need six (or more) conductor cable for the tether. I have used ribbon cable (get 24 conductor, or whatever is cheap, and rip it up into six-wire cable) and old Cat5 network cable. Each student will need about 4 feet of cable.

Controller – this is made from a 3"x4" piece of 1/8" hardboard, 12 8-32 machine screws (with nuts) and about 12" of the metal strapping used to wrap 2x4s and other bulk lumber when it is shipped. This can be obtained freely from any lumber store if you don't already have some kicking around the shop. If you have money and don't feel like scrounging, tin plate works quite nicely, too. The machine screws and nuts are used to provide solderable, conductive contact points. I have been advised that rivets also work well for this, just don't use aluminium ones! The controller is simple to wire, and essentially consists of two DPDT switches forming a dual H-drive circuit, as shown later in this document.

You will also need:

Mini-Sumo Ring(s) – typically a 2'6" diameter disc of ¾" MDF will do (the official rules say it should be 1" thick, but even ½" works). Painting it flat black with a glossy white 1" ring around the outside is a nice touch and will make it usable for autonomous mini-sumo bots if you decide to build one. You may want to make two rings while you are at it.

Implementing the Mini-Sumo Project

Obviously you will have to adapt this schedule to meet the manufacturing techniques and learning outcomes you desire, however this provides a breakdown of the order in which I present my lessons.

Introduction (1 class)

I show the students some video of previous mini-sumo battles (I have it on CD in MPEG format if you need a copy) and try to make sure I have one mini-sumo ring and at least one robot ready to go for a demonstration. The students all enjoy driving the robot around the ring and pushing things with it. I go over the rules and *stress the 10cm x 10cm x 500g rule*. I go over the marking process and emphasize the importance of quality drawings and following the rules, especially the size rule, to receiving a good grade. I tell students that once they have built their robots, and assuming the robots meet the rules of the competition, that they will be able to compete against other students (and the other classes) for marks, however I reassure them that since only 15% of the mark is based on competition, it is possible to get an "A" without winning a single match. Once the questions are answered, I assign students their first step in the project – rough design sketches.

Sketches and Ortho Drawings & Gear Theory (4 classes)

At the beginning of the year I do a 15 class unit on hand-drawing with my students, where we draw orthographic and isometric views of simple lego structures. Thus my students are usually familiar with my expectations for technical drawing and know how to use a drafting board and squares. If you have not covered these topics previously, you may wish to spend more time at this stage.

In these three classes I expect students to complete rough sketches of three different designs for their robot, then after discussing their ideas with me, to move on to a full scale 2-view orthographic drawing of their robot, complete with title block, border, etc. I allow students who finish this early to do an isometric drawing for a small bonus mark. I advise the students that they will not receive their gearbox until they have completed these drawings to my satisfaction.

Some of the things that you will need to discuss with the students at this stage are:

How do you attach the motor to the chassis?
Where do the batteries go? How do you change them?
Will this meet the size limitations?
Will you be able to access the motors and gearbox in the event something breaks?
Are the wheels and body shown the correct size? Will wheels move the robot?
If the chassis is curved, how will you make that curve out of sheet aluminum?
If you want to add weights later on, where will you put them?

Gear Theory, Torque and Power (inserted into sketching days)

While students are working on their sketches I like to take the first 15-20 minutes of class to review how gears work and what the different gear ratios mean. This allows for a short lesson followed by a work period.

Gear Box Construction (1 day)

I used to leave this until later in the project, but I found it helped the students to have their gearboxes when building their card stock models. As mentioned earlier I will only give out gearboxes to students who have completed their drawings, so you will likely have the less organized students hustling to get their drawings completed rather than building their gearbox today. This is okay, as most students can build the gearbox at home.

Some things to tell students regarding gearboxes:

There are many small parts. Do not loose ANY of them.
(I give them a ziplock baggie to store everything in.)
Engrave or etch your name or initials on the gearbox chassis (and motors?)
Lost gearboxes cost $15 to replace.

Some things to be prepared for:

Students will ask if they can replace the motors with "better" ones from home.
- depending on the motor, this can produce significant benefit
- you may want to either say no, or have "stock" and "modified" 'bots
- in my experience every winning robot has had the stock motors

Students will change the gear set up to produce very fast-turning axles
- this works great when there is no load, but not under load

Students will have both sides of the gear box interconnected
- if one axle turns the other, it's likely due to both set screws being tightened when only one should be

Layout Drawings and Card Stock Models (4 days)

Typically I will start by doing a demonstration of how to convert an orthographic drawing to a layout drawing, suitable for folding into a model. This stage requires lots of card stock (old file folders work great) and tape. You can either have the students do their layout directly on the card stock, or on paper and then transfer it to card stock. Each student should be able to show you how their motor will attach to the chassis and where the batteries (and weights) will go. Most students will have to revise their design at least once. I emphasize the importance of modelling in the design process, and point out that all the mistakes we are catching now would be very expensive and time-consuming if we had gone straight to aluminum stock. I also take pains to point out that the different thicknesses of card stock and aluminum result in a different bending radius at the corners, meaning that complex designs tend to be much more difficult to fold out of aluminum.

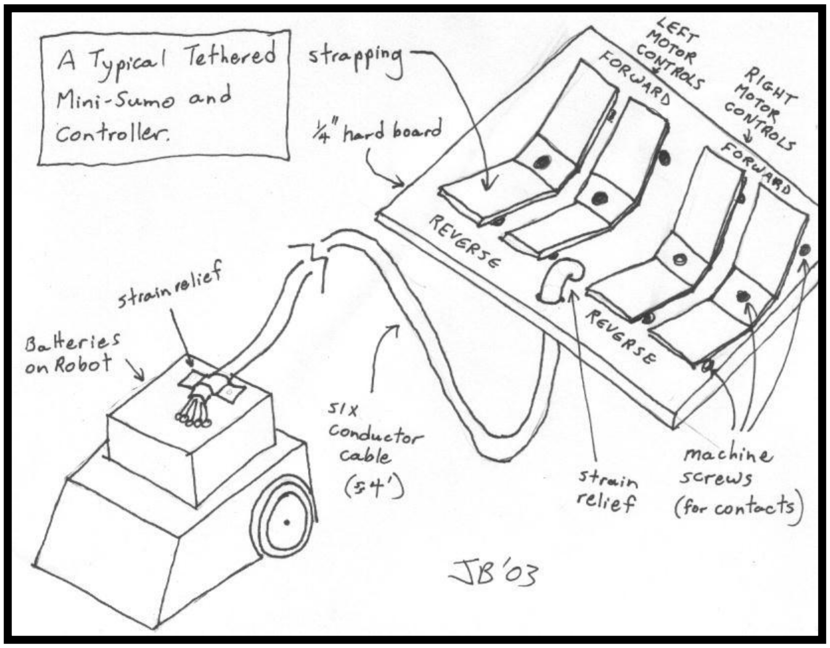
Chassis and Wheel Production (8 classes)

Once students have completed an acceptable model and it has been marked, they can either unfold the model, or use their paper layout drawing to transfer the dimensions on to aluminum sheet. Be very watchful at this stage, as they tend to have very little sense of how to lay out their designs in an efficient manner. I have them lay out their designs using a centre punch to mark each corner and hole and a scribe to mark each cutting and bending line. Once I have approved their layout, I allow them to rough cut their aluminum. Once they have their rough cut stock, the first step is to drill or punch 1/8" holes at each corner. This helps a great deal with the cutting and bending processes. As usual, some students will finish this in about 2-3 classes, while for others this process could take all year.

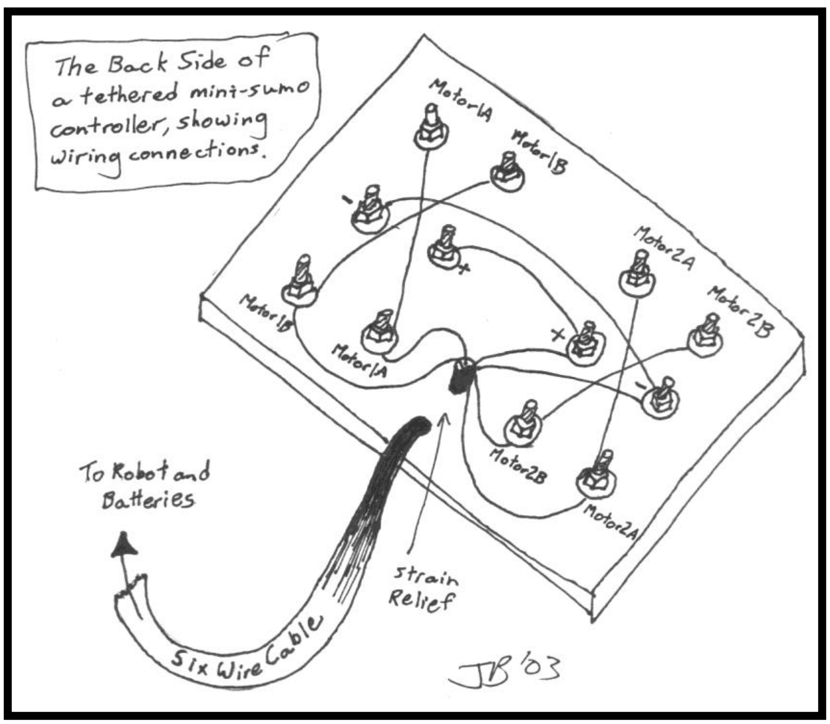
Remember:
- Remind students of the 10cm x 10cm limit.
- If you are turning wheels on the lathe, allow each student at least one class on the lathe, and another half-class to drill and tap the wheels.
- If you are drilling and tapping wheels, the appropriate tap drill for an 8-32 thread is a #29. I tend to use a slightly larger bit as that helps reduce the number of broken taps. (9/64 works okay.) You can also encourage students to drill their hole about ¾ of the way through the wheel. This allows them to cut thread all the way to the axle hole using a taper tap.

Control Board and Wiring (5 classes)

At right is a typical layout for a control board attached to a mini-sumo ‘bot. When correctly wired the two switches on the left hand side will control the left hand motor. When both switches are moved to the “Forward” position at the same time the left wheel should push the robot forward. There are many variations that can be made in the design of the control board, however it is very important that there be some form of strain relief at both ends of the cable.



There is no big trick to wiring up the controller. I usually have the students draw a circuit diagram for me before they begin hoooking it all together, and then let them figure out how to implement the circuit diagram. Usually it looks something like the diagram to the right.



I find that buying 60-conductor ribbon cable is one of the cheaper ways of making cables. Paying the extra for the rainbow coloured stuff makes life even easier. Whatever you use, just make sure that it is flexible, twisted wire, not solid core.

Adding Weight

Towards the end of the project students will start trying to push each other's robot around in the sumo ring. Hopefully one of them will figure out that adding weight to their robot (up to the 500g limit) is a good idea. This is where I manage to unload a lot of old scrap metal. I let them loose with hacksaws to cut up old scrap left over from welding practice or whatever else I would be throwing out anyways. Getting them to keep it neat and tidy is difficult, but I remind them that having ugly weights hanging off their robot will affect their marks.

The Competition (2-3 days)

Prior to competition I use class time to mark each of the robots and have the students demonstrate to me that they are capable of moving a 250g and 500g weight from the sumo ring.

The competition, however, is what the kids tend to look forwards to the most. In a class of 24, I typically arrange them into groups of about 4-5 students for a round-robin competition, then take the top 16 robots from round-robin and place them into a single-elimination playoff structure. It is good practice to weight the robots before each match, as some kids quickly figure out that it helps to slip a little extra weight over their tires before the start of a match. I follow the mini-sumo rules, and call a break whenever the control tethers get too tangled.

I also invite students to play robo-hockey on a 3' by 6' (or so) desk. They form teams of three and each team places their robots at an opposite end of the table. I take a ½" nut, or some other object to use as a puck, and place it at the centre of the table. If a player needs to touch their robot for any reason (ie: to pick it back up after it has been knocked off the table) they are "out" for the duration of that point or period. If a team manages to push the puck over the opponents end of the table then they have scored. I will usually let them play about 3, one-minute, periods.

Other tasks that could be set up would include navigating a "slalom" course to test driving skills, or whatever your imagination comes up with.

A sample marking guide is attached on the next few pages.

Have fun!

Tethered Mini-Sumo

Marking Guide
Robotics and Flight 10
David Thompson Secondary

Student name:____

Your task is to design and build your own mini-sumo robot, using the instructions and equipment provided in class. It will be marked as follows:

Drawings (70 marks possible)

Three different design sketches completed to acceptable standards: ____/5
Quality of design sketches: Barely Adequate: 1 mark
About average: 3 marks
Outstanding: 5 marks ____/5

Orthographic drawing of robot (top and side only) completed to acceptable standards: ____/10
Quality of orthographic drawing: Barely Adequate: 1 mark
About average: 5 marks
Outstanding: 10 marks ____/10

Cardstock model of robot completed to acceptable standards: ____/10
Quality of cardstock model: Barely Adequate: 1 mark
About average: 5 marks
Outstanding: 10 marks ____/10

Layout diagram of robot model completed to acceptable standards: ____/5
Quality of layout diagram: Barely Adequate: 1 mark
About average: 3 marks
Outstanding: 5 marks ____/5

Circuit diagram of robot controller completed to acceptable standards: ____/5
Quality of circuit diagram: Barely Adequate: 1 mark
About average: 3 marks
Outstanding: 5 marks ____/5

Robot Body, including wheels chassis and all components (100 marks possible)

Chassis meets width requirement of 10cm when in starting position: ____/10

Chassis meets length requirement of 10cm when in starting position ____/10
Note: 1 mark will be deducted for every mm over size
Robots over 11 cm in either direction are not allowed to compete in the tournament.

Chassis meets weight requirement of 500g: ____/10
Note: 1 mark will be deducted for every gram over weight
Robots over 510 g will not be allowed to compete in the tournament.

Chassis hides the gearbox: ____/5

Chassis allows easy access to the gearbox: ____/5

Chassis hides the batteries: ____/5

Chassis allows easy access to the batteries: ____/5

Chassis hides weights and other unsightly objects: ____/5

Chassis has a painted or polished finish: ____/5

Quality of chassis finish:	Barely Adequate:	1 mark	
	About average:	3 marks	
	Outstanding:	5 marks	____/5

Wheels are turned, tapped and threaded to an acceptable fit and finish: ____/10

Quality of wheel surface finish:	Rough:	1 mark	
	A few scratches:	3 marks	
	Smooth & Shiny:	5 marks	____/5
Complexity of wheel construction:	Simple Cylinder:	2 marks	
	Simple Spike, etc:	3 marks	
	Really fancy:	5 marks	____/5
Similarity of wheels:	Both are vaguely round:	1 mark	
	Both look the same:	3 marks	
	Can't measure the difference:	5 marks	____/5

Overall aesthetic appeal of robot body when assembled and ready to go: ____/10

Control Board and Wiring (25 marks possible)

The robot reliably moves backwards and forwards and turns left and right: ____/10

The quality of the soldering and wire stripping on the control board and robot are:

Very Rough:	1 mark	
Ok, but could be better	3 marks	
Tight and solid with no slack:	5 marks	____/5

The ergonomics (ease of use) of the controller is best described as:

Almost non-existant:	1 mark	
Some markings or comforts:	3 marks	
Very easy to use and understand:	5 marks	____/5

The control cable has an appropriate strain-relief at each end: ____/5

Non-Competitive Performance Assessments (20 marks possible)

Each of the following is based on the best time from three trials.

Starting at one edge, the robot can remove a 250g weight from the centre of the ring in:

< 5 seconds	10 marks	
< 10 seconds	8 marks	
< 15 seconds	6 marks	
< 20 seconds	5 marks	
< 30 seconds	4 marks	____/10

Starting at one edge, the robot can remove a 500g weight from the centre of the ring in:

< 5 seconds	10 marks	
< 10 seconds	8 marks	
< 15 seconds	6 marks	
< 20 seconds	5 marks	
< 30 seconds	4 marks	____/10

Competitive Performance Assessment (66 marks possible)

Each match won in a round-robin preliminary round:

If there are 4 other robots in your "pool" and in a three battle match you:

Win the first two battles	5 marks
Win two battles	4 marks
Win one, tie one, lose one	3 marks
Win one battle	2 marks
Loose the first two, but try	1 mark
Do not move	0 marks

If there are 5 other robots in your "pool" and in a three battle match you:

Win the first two battles	4 marks
Win two battles	3.5 marks
Win one, tie one, lose one	2.5 marks
Win one battle	2 marks
Loose the first two, but try	1 mark
Do not move	0 marks

The top 16 robots from the round-robin will be placed in a single-elimination playoff grid.

For each three battle match you win you will get: 5 marks

In the event that a "school championship" is held, the top 8 robots will be selected.

For each three battle match you win you will get: 4 marks

In the event that you show up for the "school championship" you will get:

If a robot from your class wins: 4 marks

You may form a mini-sumo hockey team with either one or two other people from your class. You will compete against other teams in your class. You will get to play 2 mini-sumo matches against other teams.

For each mini-sumo match you win:	5 marks
For each mini-sumo match in which you lose, but score:	3 marks

Summary

The entire project from drawings through competition will be marked out of 250 marks. The maximum possible mark is 281/250 (112%) if you score perfect on every aspect of drawing, design and construction, and win every match. If you score perfect on every aspect of design and construction, but never win a match, the highest possible score is 219/250 (88%).

Remember the two most important parts of this project are your construction quality and drawings! If you do well in these two areas, you will likely do well in competition as well!

Good luck!