Introduction to LEGO MINDSTORMS Robotic Sumo

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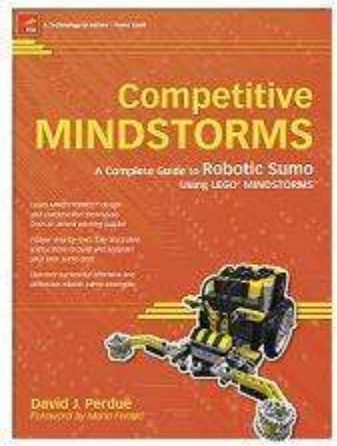
Today, we demystify the process of making a robot that you can use to participate in a robotic sumo event -- a sumo-bot. The purpose of a sumo-bot competition? To be the first to push an opponent from a raised platform. (No swinging blades or flame throwers required.) Get details on design and construction planning. (From the book, *Competitive MINDSTORMS: A Complete Guide to Robotic Sumo Using LEGO MINDSTORMS*, by David Perdue, Apress, 2004, ISBN: 1590593758.)



You may have seen fighting robots on TV shows, and your head may be filled with images of mechanical monsters equipped with spinning blades and flamethrowers. Amidst showers of sparks, screaming fans, and an energetic host who keeps shouting something, it's obvious the show's purpose is to impress you with "deadly robot warriors." Indeed, the robot's goal usually appears to be to tear the opposing robot to shreds. So, these robots are monstrous, lethal, ferocious machines whose sole purpose in life is to destroy, right? Wrong.

In robotic contests, sometimes the two adversaries are trying to win points by accomplishing various goals; other times, they are trying to shove each other into a hole in the ground; and on some occasions, they are placed on a raised platform, and their goal is to be the first to push their opponent off that platform. The latter scenario is what *robotic sumo* is all about.

In the literal sense, robotic sumo is played on a platform—called an *arena*—which is outlined with a thick line, and the goal is to push the other robot out of bounds. In the more abstract sense, robotic sumo is not a game about turning the opponent into junkyard material, but a game of strategy and skills.

This book will demystify the process of making a robot with which to participate in a robotic sumo event—a *sumo-bot*. But we're not going to be looking at just any sumo-bots in this book; we're going to be looking at LEGO MINDSTORMS sumo-bots. When the worlds of MINDSTORMS and robotic sumo collide, the result is more than amazing. By building and programming the sumo-bots described in this book, and understanding how their design and construction was planned, you will become a robotic sumo expert. This chapter will get you started by explaining the basic concepts of robotic sumo and sumo-bot construction.

Can You Build a Sumo-Bot?

On the TV shows featuring fighting robots, we all see those guys who walk around and get to show off their robots. People say, "Wow! He designed a *robot*. He must be a rocket scientist or something." I'm sorry to disappoint any fans or aggravate any of those "rocket scientists," but the simple fact is that those "robots" on TV aren't really robots at all. A robot is a contraption that's completely autonomous, which means it's capable of making its own decisions. The machines on TV are controlled by humans via huge remote controllers, so they are *not* autonomous. The robots described in this book really *are* robots.

The RCX, the microcomputer that comes with every LEGO MINDSTORMS Robotics Invention System (RIS), is the brains of these robots (see Figure 1-1). You can program it to perform a wide variety of actions and make its own decisions. It is even capable or some artificial intelligence. The RCX is also one of the largest and most expensive LEGO pieces ever made. With a retail price of $120, this is not an easily borrowed LEGO brick.

Taking a huge box of LEGO pieces, building a robot from the ground up, and then programming it sounds like a daunting task. If someone asked you if you could build a LEGO sumo-bot, could you? With a bit of experience using the RIS, guidance from the *Constructopedia* included in the RIS, and maybe some help from friends, chances are you could probably make a decent one. On the other hand, any LEGO MINDSTORMS fan can make a little sumo-bot that has two wheels and goes. It's making a *good* sumo-bot that can be difficult.

On the side of the RIS box is a paragraph defining the purpose and philosophy of LEGO MINDSTORMS:

The philosophy behind LEGO MINDSTORMS is to not only allow you to understand technology but to also become a creative master of it. This happens when you design, construct, and program your own intelligent inventions.

This is not only true of LEGO MINDSTORMS—it also applies to robotic sumo. You must become a creative master of it by designing, constructing, and programming sumo-bots. The first step toward your "creative mastership" of robotic sumo is to fully understand how robotic sumo is played.

How Is Robotic Sumo Played?

What happens in robotic sumo isn't much like the robotic mayhem portrayed on TV shows. First, robotic sumo events usually don't take place in surroundings such as those seen in "warrior robot" TV shows. Instead, you'll find them in a variety of other places—some you can probably guess, others might surprise you. For instance, you can find robotic sumo events in someone's living room, the middle of a RadioShack, and at scientifically or technically inclined museums.

There's a lot of variety in where a robotic sumo event can be held. Likewise, there's variety in how a robotic sumo event is operated. However, it's not difficult to describe a basic LEGO MINDSTORMS robotic sumo event. First, two sumo-bots are placed—usually facing in opposite directions—in the arena and are started either remotely or with a flick of a bumper or a switch mounted on the sumo-bots. At this point, a *round* has been initiated. A round will usually last for a period of about 3 minutes, and the *host* or *judge* will keep track of the time. Within this round are *bouts*. Each time one of the sumo-bots is defeated, it's set back up to start another bout. This continues until the time period for the round has run out.

The arena in which the sumo-bots "play" is circular and measures usually between 3 and 5 feet in diameter. The thick line encircling the arena is for the sumo-bots. Once they've detected the line, they know they've reached the outermost part of the arena and need to turn around. The size of this line can vary greatly, but it will often be about 2 inches thick. When both sumo-bots are moving around on the arena, they must take great care not to accidentally go over this line and off the arena, because this ends the bout and gives the victory to the sumo-bot still on the arena.

We hope that most of the sumo-bots' time won't be spent in accidentally falling *off* the arena, but maneuvering *on* the arena. They will scurry all over the surface, reverse or turn around each time they detect the outer line, bump into each other, and possibly use sumo-bot searching techniques until one or both of them gives its opponent a good, direct hit.

Offensive and defensive mechanisms and subassemblies then come into use, and it becomes a matter of pushing, escaping, or smartness—whether in the construction or programming. Once the unfortunate one has been pushed off the arena, the victorious sumo-bot is awarded his hard-earned point(s), and the two bots are set back up for another bout, if their 3-minute round hasn't run out.

How many rounds a sumo-bot will go through and how long an event will take depend on two factors: the number of people participating and the rules. Obviously, an event with a lot of people will take longer than an event with only a handful of people. However, you could have a rule for a small event that states that every sumo-bot goes through 10 rounds, which makes for a long event.

As you can see from this description, robotic sumo is a harmless game. But it isn't a predictable, easy, or simple game. Robotic sumo relies heavily on strategy, and there's a lot more to it than there seems at first glance. You'll see this for yourself as you work through the rest of the book. And just one object—something you can't really touch but can only see—controls all the aspects

of robotic sumo we have just discussed, as well as many others I haven't yet mentioned. That object is a *rule set*.

A rule set is a compilation of all the rules for an event, and every aspect of the event revolves around that rule set. This is why, in order to participate in robotic sumo correctly and efficiently, you must thoroughly know the rule set for the event in which you are participating. In addition, you must also have a sound knowledge of the tools— what you'll use to build and program your sumo-bot. The materials that you are *allowed* to use in your sumo-bot's construction are nearly as important. Let's take a look at some common rules first, and then we'll cover building and programming tools.

Rules of the Game

What Are the Rules of the Game?

The first thing you should know is that there isn't a robotic sumo organization that dictates a set of rules for everyone to follow. However, several basic rules apply to all robotic sumo events because they represent robotic sumo itself. Also, some rules vary from event to event and person to person, and sometimes there are variations to the game itself.

The Basic Rules

In order to have a law-abiding, decent sumo-bot with good survival capabilities in most rule sets, the sumo-bot must

- Comply with rules on weight
- Comply with rules on width
- Not intentionally damage or harm the opposing sumo-bot in any way
- Not drop any pieces intentionally on the playing ground
- Have an efficient, sturdy, and well-attached line detecting mechanism for "seeing" the line around the perimeter of the arena

Let's take a closer look at each of these basic rules and how they affect your sumo-bot's design.

Weight and Width

First, weight can be a factor. Some rules state that your sumo-bot may weigh up to 2 pounds. As you will see later in this book, weight and brute force do not always matter the most. Sometimes, going with a slightly lighter sumo-bot is better.

Similar to the weight rule—similar because it will affect the size of your sumo-bot—is the maximum width rule. The width is measured in *studs*, a basic measuring and LEGO term. A stud is the round "button" on a brick that has "LEGO" inscribed on its top. The studs system easily shows the measurements of a brick or model. For an example, if you have a 2x4 brick, this means the brick is two studs wide and four studs long. The first number in a measurement (2 in this example) is the width, and the second (4 in this example) is the length.

Having a maximum of 30 studs wide is one example of a sumo-bot width rule. This rule is designed to prevent those participants with a large inventory from making a giant sumo-bot capable of sweeping the competition off the board!

Intentional Harm

Robotic sumo is a nonviolent sport—violent behavior or intentional abuse of the other sumo-bot is always forbidden. Hurting the other competitor's sumo-bot or actually breaking or ruining (melting?) it's pieces is just not part of the robotic sumo game.

But what happens if a sumo-bot gets flipped over or stops working? If a sumo-bot is overturned or somehow no longer functional, the other (functional) participant is declared winner of that bout. You can come to two conclusions from this statement. First, you can use this to your advantage and design a sumo-bot that relies on a strategy that will flip the opponent. Second, you must be careful to protect your sumo-bot from getting flipped. Both of these ideas will be discussed and put into practice later in the book.

Loss of Pieces

Something that is inevitable in a game such as robotic sumo is pieces falling off. It *will* happen. To deal with this, rule sets often have a rule that addresses this specific situation. Basically, if a piece or pieces are dropped during play in the ring, those objects will be immediately removed by those running the event. This means that your sumo-bot cannot drop pieces during the game! (So much for that LEGO land mine idea.)

Sometimes a sumo-bot will crash into another one at high speed and send a piece flying—whether from itself or the competitor. When this happens, you might say, "Hey! I couldn't help it!" Don't worry; you won't get thrown out of the competition if your sumo-bot accidentally loses a piece somewhere on the arena. Cases such as this just confirm the great unwritten MINDSTORMS building rule: Make your robot as robust and break-free as possible. After all, if you place a sumo-bot that can fall apart easily into the ring, it will! Once it gets slammed, pieces will start falling off, and that is definitely *not* good.

Line Detection

The line that encircles the arena is an extremely important element. It must be very "seeable" for the LEGO MINDSTORMS light sensor, because if it isn't, there are going to be a lot of sumo-bots blundering off the playing area.

Often, the line will be black, and the surface of the arena will be white or vice versa. The line itself should be at least several inches thick to give the sumo-bots time to slow down and turn around once they see it. The LEGO light sensor (see Figure 1-2) must be attached very sturdily to your sumo-bot and will often be in the very front for early detection. You will see and build examples of light sensor attachments later in this book.

A Common Rule Set

The following list contains a sample of a few rules from a common and basic rule set. This is not a full rule set (which can be rather long); its purpose is to help you get an idea of what can be expected from a full rule set.

- The sumo-bot must be built within the limits of *one* RIS, *one* LEGO MINDSTORMS expansion pack of your choice, and *no more than* 100 bulk bricks.
- The sumo-bot may use up to three (3) output ports on the RCX (or NXT).
- The sumo-bot may use up to four (4) input ports.
- The sumo-bot may be up to 30 studs wide.
- The sumo-bot may *not* use any custom sensors.
- The sumo-bot may use *only* normal alkaline or rechargeable batteries. Any other battery setups are *not* allowed.
- Rounds will be exactly 3 minutes long.
- The sumo-bots will play in a white, circular arena, 4 feet in diameter, outlined with a 2-inch-thick black line.

These rules are typical of all rule sets. You must look at *all* the rules in a competition very carefully before designing your sumo-bot, paying special attention to the details.

Chapter 11 of this book will provide a more detailed discussion of rules. In that chapter, you will see a full rule set, get some ideas for making your own set of rules, and learn how to check your own rule sets for loopholes.

Now that you have seen some rules, let's examine the tools.

Tools for Building and Programming a Sumo-Bot

What Are the Tools for Building and Programming a Sumo-Bot?

When it comes to building your sumo-bot, you can choose from a wide range of pieces and programming languages. Although some are better than others, there is no one perfect programming language or set (the RIS comes pretty close though!). To give you a better idea of what is available, what works well with LEGO MINDSTORMS robotic sumo, and what is used in this book, I've listed a few of the possibilities in this section. Let's begin with the building side, and then look at programming in the LEGO MINDSTORMS world.

Building Tools

When you are building a sumo-bot, think carefully about what pieces you choose. The pieces you use will directly affect your sumo-bot's performance. Your best bet is to use the famous LEGO MINDSTORMS RIS, which is certainly the most popular in its line of products (see Figure 1-3). This set includes the bright-yellow RCX, with the distinctive "beep-beep" sound it plays on activation. Using other sets with their own LEGO microprocessors, such as the MicroScout, Scout, or CyberMaster is a possibility; however, the RCX delivers the most power and flexibility.

This book is based on the RIS, and the sumo-bots I describe here do not use any LEGO microcomputer other than the RCX. But these sumo-bots are not just made out of pieces from the RIS. In some projects, I have used pieces that are not included in the RIS or are not included in sufficient quantity in the RIS. I'll provide the parts list, bill of materials, and information about where to get pieces that may not be included in the RIS where necessary to assist you with the construction of your sumo-bots.

Building Blocks

If you aren't going to be using only the RIS, what else will you need to make a sumo-bot? The truth is *any* LEGO piece will do, as long as it fits within the rules. If that piece helps you accomplish something you want your sumo-bot to do, if it makes your sumo-bot stronger, if it makes your sumo-bot just plain better, then by all means use it!

An example of a set you could buy to expand your inventory is one of the official LEGO MINDSTORMS Expansion Packs. As of this writing, there are currently five of them: RoboSports, Extreme Creatures, Exploration Mars, Ultimate Builders, and the Ultimate Accessories Set (if that can be counted as an Expansion Pack). Some of them are useful, while others are not quite so useful.

The RoboSports and Extreme Creatures Expansion Packs appear to be designed to appeal more to children, and they are also the least popular ones. The Exploration Mars Expansion Pack is, in my opinion, better than the RoboSports and Extreme Creatures Expansion Packs (if you don't need the extra motor RoboSports offers). Exploration Mars holds both useful and interesting pieces, including very long electrical wires, super-large plates, and extra gears and axles.

The more popular Ultimate Builders Expansion Pack and Ultimate Accessories Set work well for any MINDSTORMS builder and have a more "mature" feel. Ultimate Builders offers pneumatics, an extra motor, and many useful pieces. Ultimate Accessories provides a remote control, extra touch sensor, LEGO lamp, rotation sensor, and a handful of colorful and specialized building elements.

There are also many other types of pieces you could use as well, such as those from the TECHNIC line of products. The TECHNIC line works best with MINDSTORMS, as the pieces in the RIS set actually are TECHNIC pieces. There are large numbers of TECHNIC sets to choose from, although the smaller ones generally do not provide you with many useful pieces. Bulk bricks are also an option, as are pieces from theme sets (pirates, space, and so on). TECHNIC pieces remain the most useful, but you shouldn't limit yourself entirely to them.

The bottom line is that you should use whatever pieces are necessary to build your sumo-bot so it serves its purpose and you are pleased with the results. Don't be afraid to walk into a competition with a sumo-bot bearing a pirate sail. I've seen a space mini-fig (a small LEGO character that comes with a theme set) placed on top of a robot at a MINDSTORMS competition!

TIP *A great place to look for MINDSTORMS pieces and sets (especially rare ones) on the Internet is BrickLink, at* www.bricklink.com. *Also be sure to look around on eBay for good deals.*

Navigational and Searching Mechanisms

When giving their robots navigational abilities, people will mount homemade electronic compasses, rotation sensors, and other amazing devices on their robots. Then they will load custom firmware into their RCX to complement these devices.

Unfortunately, just about any possible sensor or amazing contraption made for navigation you might place in your sumo-bot will not operate properly in robotic sumo. It simply will not work! This doesn't have anything to do with the quality of the device or software. The reason is that when a sumo-bot is hit by another sumo-bot (which *is* going to happen in robotic sumo), it confuses the internal software, and the sumo-bot is immediately lost.

Can you use custom (homemade) distance sensors (a sensor that can see if something is in front of it) to help your sumo-bot search for its opponent? Some events do not allow custom sensors, so they are not implemented in the sumo-bots described in this book. As an alternative, the light sensor can be used to detect the proximity of another object, to some extent. There are also other methods you can use to help find the opposing robot, one of which you'll see in a later chapter.

Programming Tools

The programming language included with the RIS—RCX Code—has been greatly improved since its first release. It is very capable of programming a sumo-bot efficiently and reliably. But the RCX Code language can be difficult to read with a large program, and people who are used to using textual programming languages can find it hard to work in this programming environment.

To program the sumo-bots described in this book, I have chosen the programming language NQC (for Not Quite C), which was created by Dave Baum. This is a very powerful textual language that is fairly easy to understand and learn. It is quite well known among the MINDSTORMS community, and many builders use this language to program all types of robots, including other LEGO microcomputers.

Robotic Sumo: A Game Within a Game

When some people look at robotic sumo, they might consider it just a game of robot A crashing into robot B and knocking him out of the ring. As I said earlier, while this might *seem* to be the case at first glance, it really isn't true. In reality, robotic sumo is a game *within* a game. There are other aspects to robotic sumo that are so important to the outcome that they become whole tasks themselves! Many of these go on behind the scenes before the competition even starts.

One of the first "games" inside robotic sumo you should consider is the process of picking a strategy for your sumo-bot (strategies are covered in the next chapter). Related to this is the building game—building a sumo-bot is indeed a whole game in itself. The design and construction of your sumo-bot will depend greatly on the strategy you have chosen.

Another unseen portion of robotic sumo is programming. *Definitely* unseen from the outside, it can easily be taken for granted. This was apparent at a MINDSTORMS event (sponsored by RoboLab) I recently attended. After the competition was over, one of the competitors, just for fun, placed his robot on the large track that had been built for the entries. The little bot was following a certain path and making interesting maneuvers once it saw a black line. It was going up and down an elevated portion, through a bumpy terrain section, and trying to ring bells. It was obvious to me that a great deal of thought went into the programming that led to such an impressive performance. Another guy watching this little robot picked it up and flipped up and down a movable attachment that held the light sensor. He looked at the creator and shouted above the din of the crowd, "I still really like this part!" The point is that you'll find it a lot easier to impress people with your robot than with your programming skills.

But don't ignore this important task! A sumo-bot with an empty RCX (no programming) would just sit in one place; it certainly wouldn't win any competitions. This is exactly why you must take the time to create *good* programming in order to make a *good* sumo-bot. As I have heard it said, a robot is only as good as its programming, and a program is only as good as the robot it is in.

These are all "games" within the game of robotic sumo that deserve your attention. Remember not to zone in on just "playing robotic sumo" and forget these important tasks. If you look at the whole picture, your sumo-bot's overall performance will be much better.

Conclusion

This chapter covered the basic concepts of LEGO MINDSTORMS robotic sumo. Understanding how everything works and why it works the way it does is important. Without a sound knowledge of these concepts, you can easily introduce errors into your sumo-bots that could hinder your progress in a robotic sumo event.

You must carefully plan the process of designing and constructing a sumo-bot to make sure that you've taken care of all the necessary tasks and that any mechanisms, parts, and subassemblies aren't in conflict with each other. Factors that influence how you make your sumo-bot are the rules for that event, your inventory, and the extent of your knowledge and experience.

Another factor that will affect your sumo-bot's design is the strategy you pick and use. The next chapter describes various sumo-bot strategies you can use in your sumo-bot, as well as the strategy of thinking about what your opponents might be planning for *their* sumo-bots. Turn the page to take the next step in this competitive journey!

Taken from *Competitive MINDSTORMS: A Complete Guide to Robotic Sumo Using LEGO MINDSTORMS*, by David Perdue (Apress, 2004, ISBN: 1590593758).