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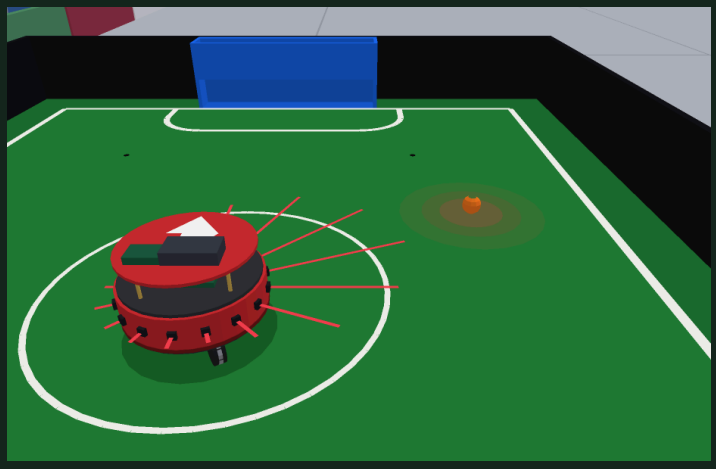
Robot Soccer Lab: Read the Ring, Adding Sensor Readings as Vectors

Grades 9-12 · 45 minutes

Math



Slides, rubric and answer key | Print and go | No student accounts | Chromebook friendly

What's included

- A one-page overview: objectives, essential question, vocabulary, standards and assessment
- A 45-minute lesson sequence: warm-up, direct instruction, guided practice, independent practice, closure
- Slides for the board: a PowerPoint file that also opens in Google Slides
- A student worksheet with a QR code and a table for adding eight vectors
- A 3-question exit ticket, two to a page, with an answer key
- A rubric: 3 criteria, 4 levels, scored out of 12
- Differentiation for English learners, students with IEPs or 504 plans, and students who need more support or more challenge
- Cross-curricular extensions, and notes for teaching it in middle school and in physics
- Standards: Common Core math

Robot Soccer Lab: Read the Ring, Adding Sensor Readings as Vectors

Grades 9-12 · 45 minutes · Math

A soccer robot finds the ball with a ring of 16 infrared receivers, one every 22.5 degrees. Each receiver gives a reading, bigger the more directly it faces the ball. In Level 7 of Robot Soccer Lab students treat each reading as a vector: its length the reading, its direction the receiver's. The brightest receiver alone says the ball is at 45 degrees; added up component-wise, all the readings point at about 51 degrees, which is where the ball is. The magnitude of the sum is not the sum of the magnitudes, and students see by how much. Then they use the strongest reading, which grows as the ball gets closer, to stop 5 to 20 cm from three balls, and find which thresholds work.

At a glance

ESSENTIAL QUESTION

How do many small readings add up to one direction?

OBJECTIVES

Students will be able to:

- represent a sensor reading as a vector with a magnitude and a direction
- add vectors component-wise and find the magnitude and direction of the sum
- explain why the sum points more finely than the largest vector alone
- show that the magnitude of a sum is not the sum of the magnitudes
- use a reading that grows as distance shrinks to choose a stopping threshold

VOCABULARY

Vector, Component, Magnitude, Resultant, Receiver, Threshold

STANDARDS

HSN-VM.A.1, HSN-VM.B.4a, HSN-VM.B.4b

TIME AND MATERIALS

45 minutes, grades 9-12.

- One computer or Chromebook per student
- A projector
- The worksheet and exit ticket, one copy each per student
- The rubric, one copy per student if you grade the work
- A scientific calculator, or one on the computer, set to degrees

PREP

Make copies of the worksheet and exit ticket. Before class, open mytekdev.com/try/robotsoccerlab?lesson=read-the-ring-adding-sensor-readings-as-vectors&ref=tpt-robotsoccerlab-3 once on a student computer, which checks that your

ASSESSMENT

- Formative: the questions under What to look for, asked while students work, and the exit ticket (answer key included).
- Summative: the worksheet, scored with the rubric.

TECHNOLOGY AND PRIVACY

Runs in any browser, Chromebooks included, with nothing to install. Students need no account and no email: the link works signed out, and nothing they do is stored on our server unless they choose to save.

school's filter allows the app, and follow the short guide yourself: about ten minutes.

Lesson sequence

MINUTES	STAGE	WHAT YOU DO	WHAT STUDENTS DO
0 to 5	**Warm-up** Hook	Show the title, essential question and Today I can slides (about 1 minute). Then the warm-up: 3 blocks north, 4 east.	Answer the warm-up on the worksheet.
5 to 15	**Direct instruction (I do)** Model it	Project Level 7 and turn on Robot, Show the receivers' rays. Explain the ring: 16 receivers, receiver 1 straight ahead, numbered clockwise every 22.5 degrees. Each reading is an arrow in its receiver's direction. Set up components: right = reading x sin(angle), forward = reading x cos(angle), with the angle clockwise from the front, the way a compass reads. Work receivers 3 and 4 together: 37.6 at 45 degrees and 36.4 at 67.5 degrees. **It's working when:** Receiver 3: right 26.6, forward 26.6. Receiver 4: right 33.6, forward 13.9. Sum: right 60.2, forward 40.5, magnitude 72.6, direction about 56.1 degrees.	Work the two-vector sum on the worksheet.
15 to 22	**Guided practice (We do)** Check it in the app	Students open the link or scan the QR code. The program prints, before the robot moves, the brightest receiver's direction, the summed direction and the strength: "brightest: 45.0 sum: 51.3 strength: 37.9" on the first run. It stops at strength 95 and bumps the ball. The guide has them change 95 to 75: the robot stops by all three balls. **Watch for:** Students who expect the sum to equal 45. Two receivers read almost the same (37.6 and 36.4), so the true direction is between them.	Follow the guide. Write the print line and the three stopping distances.
22 to 37	**Independent practice (You do)** Eight vectors and a threshold	Pairs add the eight nonzero readings on the worksheet, splitting the rows, and compare the direction with the print line. Then they try thresholds 85, 80, 70 and 65 and record where the robot stops. Each level starts in real time. Speed up and Slower, under the field, change the speed; the round play button starts the level again from the beginning, with the program as it is now. Walk the room with the What to look for questions. **If they ask:** "The eight readings add up to 193.5. Why is the sum's magnitude only about 151.5?" The size of the sum **Watch for:** Calculators in radians. sin 45 in radians is about 0.85; in degrees, 0.71.	Fill in the vector table and the threshold table, and answer the questions.
37 to 45	**Closure** Why add them all? And exit ticket	Show the closure slide and take answers. Hand out the exit ticket.	Discuss, then answer the exit ticket.

Before you teach: a ten-minute walkthrough

Open mytekdev.com/try/robotsoccerlab?lesson=read-the-ring-adding-sensor-readings-as-vectors&ref=tpt-robotsoccerlab-3. A short guide opens over Level 7, Read the ring, with the program in the Python tab. The field is in the middle: green carpet, white lines, the yellow goal (the robot's own) and the blue goal it attacks. The red robot is round, with an arrow on top for its front, and the orange ball glows so the robot can find it. The box on the field says the level's goal and, after each run, what happened and why. The readings beside it show the ball clock, the heading, the speed and how far away the ball is.

1. **The ring.** Sixteen receivers, receiver 1 facing straight ahead and the rest every 22.5 degrees clockwise. robot.sensors() is the list of readings, robot.ball_strength() the biggest, and robot.ball_angle() the direction of all of them added as vectors. Each reading falls with distance and with how far the receiver faces away from the ball; one facing more than 90 degrees away reads 0 (plus a little noise).
2. **The rays.** Robot, Show the receivers' rays (or the box under the readings) draws each reading as a red line from the robot in its receiver's direction.
3. **The program.** It prints the brightest receiver's direction (its place in the list times 22.5), the summed direction and the strength, before moving. Then it drives at the summed direction at speed 40 and stops when the strength reaches 95. The box on the field gives the distance at each stop.
4. **Speed.** Each level starts in real time. Speed up and Slower, under the field, change the speed; the round play button starts the level again from the beginning, with the program as it is now. Each press of play takes the next seed for the receivers' small noise, so times can differ by a few hundredths of a second between runs.
5. **Numbers to expect.** The print line: brightest 45.0, sum about 51 (51.0 to 51.9 between runs), strength about 38. The ball is truly at 51.3 degrees, 64 cm away center to center. Threshold 95: bumps the ball at 1.3 s. 90: usually bumps it. 85: it stops about 5 cm away, at the near edge, and time runs out with 1 of 3. 80: passes, 8 to 10 cm. 75: passes, 12 to 13 cm. 70: passes, 16 to 17 cm. 65: it stops 20 to 21 cm away, at the far edge, and time runs out with 0 or 1. 60 and 50: time runs out, 0 of 3.

> The worksheet's eight readings are the model's values at the start with the noise taken out, so every student gets the same answer: 23.7, 33.2, 37.6, 36.4, 29.6, 18.3 and 4.2 for receivers 1 to 7, and 10.5 for receiver 16 (at 337.5 degrees). The other eight read 0. Their sum points at 51.4 degrees with magnitude 151.5. A student's own printed readings differ in the first decimal.

Background for the teacher

Robots built for junior robot soccer find the ball with a ring of infrared receivers. The simple way is to take the brightest receiver, which says where the ball is only to the nearest receiver. Real teams add the readings as vectors: each receiver contributes an arrow in its own direction as long as its reading, and the resultant points between receivers, at the ball. The app's ball_angle() is that sum. The field and rules are modeled on the RoboCupJunior Soccer rules; the app is not affiliated with or endorsed by the RoboCup Federation.

The strongest reading grows as the ball gets closer, roughly: in the app it is 100 / (1 + d squared / 0.25) for a receiver facing the ball squarely, with d the distance between centers in meters. It is a rough distance sensor, which is why the lesson finds a working threshold by testing.

Robot soccer has led to real companies: Raffaello D'Andrea, who coached Cornell's robot soccer team, went on to co-found Kiva Systems, whose warehouse robots Amazon bought in 2012. Robotics, mechanical, electrical and software engineers all work on robots like these.

What to look for

Ask these while students work. A student who has understood the lesson can answer them without help:

- What are the magnitude and direction of receiver 4's vector?
- Why does receiver 16 add a little to the forward part and take a little from the right part?
- Why does the sum point at about 51 degrees, between receivers 3 and 4?
- Why is the sum's magnitude less than the readings added up?
- Which thresholds stopped the robot 5 to 20 cm away, and why do the others fail?

> The third question is the one that matters. A student who says "receivers 3 and 4 read almost the same, so their arrows pull the sum between them" understands the resultant. A student who says "the program says 51" has the result but not the idea.

Cross-curricular extensions

- Physics: add forces the same way. Two ropes pull a box at 45 and 67.5 degrees: which way does it move?
- Computer science: write the sum in Python with a for loop over the 16 readings, and print it beside robot.ball_angle().
- Earth science: find how a seismograph network or a phone's GPS combines readings from several directions.
- Careers: look up the sensors on a self-driving car and how it combines them to know what is around it.

Vocabulary

Vector	A quantity with a size (magnitude) and a direction, drawn as an arrow.
Component	One of the two parts of a vector at right angles: here, forward and right.
Magnitude	The length of a vector: the square root of the sum of the squared components.
Resultant	The single vector you get by adding vectors.
Receiver	One of the 16 infrared sensors in the robot's ring, numbered clockwise from the front.
Threshold	The value a program compares a reading with to decide: here, the strength at which the robot stops.

Differentiation

ENGLISH LEARNERS

- Keep the vocabulary slide up, and point at the robot, the ball or the box on the field as you say each word: the picture carries the meaning.
- Give a sentence frame on a card: The sum points at ____ degrees, but the brightest receiver points at ____ degrees.
- Draw the eight arrows tip to tail on graph paper, at a scale of 1 cm for 10, before computing.

STUDENTS WITH IEPS OR 504 PLANS

- Pair students, one computing and one recording.
- Give the sine and cosine of each receiver's angle on the worksheet, so the work is the multiplying and adding.
- Where the IEP allows a modified assignment, score the first two rubric rows only.

STUDENTS WHO NEED MORE SUPPORT

- Work the first two rows of the vector table together.
- Add only the three brightest receivers: 37.6 at 45, 36.4 at 67.5, 33.2 at 22.5. The sum points at about 45.6 degrees.
- The print line checks the direction; the box on the field gives the stopping distances.

STUDENTS READY FOR MORE

- Write the sum in Python: import math, then add readings[n] x sin and cos of n x 22.5 for all 16, and print the direction with math.atan2. Compare it with robot.ball_angle().
- Steer at the brightest receiver instead of the sum (brightest x 22.5 as the move angle). Does the robot still stop by all three at 75? Why might a real team still prefer the sum?
- The strength is 100 / (1 + d squared / 0.25), with d the distance between the centers in meters, times how squarely the receiver faces the ball. Find d for a strength of 75 and compare it with your stopping distances.

Adapting for other grades

Younger students: In middle school, draw the arrows tip to tail on graph paper and measure the sum with a ruler and protractor instead of trigonometry. Score the first two rubric rows, total 8, and 6 meets the objectives.

Older students: In physics, the same sum is how forces add: treat each reading as a force and find the resultant. Then explain why a sensor that reads cos of the angle to the source makes the summed direction close to the true one.

Student worksheet

Name: _____ Date: _____

Open the app: scan the QR code, or go to mytekdev.com/try/robotsoccerlab?lesson=read-the-ring-adding-sensor-readings-as-vectors

Essential question: How do many small readings add up to one direction?

Warm-up: 3 blocks north, then 4 east: how far, and which direction? _____

1. **Vocabulary.** Vector, component, magnitude, resultant, receiver, threshold: write each in your own words.

2. **The print line.** brightest: _____ sum: _____ strength: _____
3. **Two vectors.** Receiver 3, 37.6 at 45 degrees, plus receiver 4, 36.4 at 67.5 degrees. Right: _____ Forward: _____ Magnitude: _____ Direction: _____

4. **Eight vectors.** Receivers 1 to 7 (0, 22.5, 45, 67.5, 90, 112.5, 135 degrees): 23.7, 33.2, 37.6, 36.4, 29.6, 18.3, 4.2. Receiver 16 (337.5 degrees): 10.5. Sum: right _____ forward _____ magnitude _____ direction _____. The readings added: _____

5. **Thresholds.** Stopped how far from the balls? 85: _____ 80: _____ 75: _____ 70: _____ 65: _____

1. Why is the sum closer to the ball's direction than the brightest receiver?

2. Why is the magnitude of the sum less than the readings added?

Exit ticket

Name: _____

1. Two vectors of length 10, one pointing at 0 degrees and one at 90 degrees, add to a vector of length: (A) 20 (B) about 14.1 (C) 10

2. A reading of 30 from a receiver at 90 degrees (straight right) has components: (A) right 30, forward 0 (B) right 0, forward 30 (C) right 15, forward 15

3. A friend says the robot should drive at the brightest receiver, because that is where the ball is. Use what you learned today to answer.

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Exit ticket

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Answer key: exit ticket

QUESTION	ANSWER	WHY
1	B	Square root of 10 squared plus 10 squared: 14.1. The magnitude of a sum is not the sum of the magnitudes.
2	A	sin 90 is 1 and cos 90 is 0.
3	Open answer	The brightest receiver gives the direction only to the nearest 22.5 degrees; adding all the readings as vectors points between receivers, closer to the ball (51 against 45 here).

Worksheet: what students should find

BLANK	WHAT THE APP SHOWS
Warm-up	5 blocks, about 53 degrees east of north.
The print line	brightest: 45.0, sum: about 51 (51.0 to 51.9), strength: about 38.
Two vectors	Right 60.2, forward 40.5, magnitude 72.6, direction 56.1 degrees.
Eight vectors	Right 118.4, forward 94.6, magnitude 151.5, direction 51.4 degrees. The readings added: 193.5.
Thresholds	85: about 5 cm, too close to count every time (1 of 3). 80: 8 to 10 cm. 75: 12 to 13 cm. 70: 16 to 17 cm. 65: 20 to 21 cm, just too far (0 or 1 of 3).

> The eight readings are the model's values at the start with the noise taken out, so the sums are the same for everyone. The printed numbers and stopping distances vary a little from run to run because each run takes the next seed for the noise.

Rubric

Score each row from 1 to 4.

Name: _____

CRITERIA	4 EXCEEDS	3 MEETS	2 APPROACHING	1 BEGINNING
Adding vectors	Adds all eight component-wise, finds magnitude and direction, and checks the direction against the app.	Adds the vectors and finds the direction.	Finds the components but not the sum.	No computation.
Explaining the sum	Explains why the sum points between receivers and why its magnitude is less than the readings added, with numbers.	Explains why the sum is finer than the brightest receiver.	States the two directions differ.	No explanation.
Choosing a threshold	Tests five or more thresholds, records each distance, and explains which pass and why.	Tests four thresholds and records each.	Tests one or two.	Does not test.

Total: ____ / 12. A score of 9 or more meets the objectives.

Standards

The lesson is built for HSN-VM.B.4a: students add eight vectors component-wise and see that the magnitude of the sum is not the sum of the magnitudes. The two-vector sum in magnitude and direction form is HSN-VM.B.4b, and reading each sensor as an arrow with a size and a direction is HSN-VM.A.1. The (+) marks standards beyond the college and career ready core.

FRAMEWORK	CODE	GRADES	STANDARD	HOW THE LESSON MEETS IT
Common Core Math	**HSN-VM.A.1**	9-12	(+) Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, |v|, ||v||, v).	Students represent each receiver's reading as a directed line segment (the rays in the app) with a magnitude and a direction.
Common Core Math	**HSN-VM.B.4a**	9-12	Add vectors end-to-end, component-wise, and by the parallelogram rule. Understand that the magnitude of a sum of two vectors is typically not the sum of the magnitudes.	Students add eight readings component-wise, and compare the magnitude of the sum (151.5) with the readings added (193.5).
Common Core Math	**HSN-VM.B.4b**	9-12	Given two vectors in magnitude and direction form, determine the magnitude and direction of their sum.	Students add two readings given as magnitude and direction (37.6 at 45 degrees, 36.4 at 67.5) and find the magnitude and direction of the sum.

Checked November 2026 against: Common Core State Standards for Mathematics: High School Number and Quantity, Vector and Matrix Quantities.

Optional: save student work in a free class

The whole lesson runs at the link on the worksheet, with no accounts and no sign-up.

To keep students' work, and see it all in one place, make a free class. It takes about ten minutes, once, and covers every lesson in this series: mytekdev.com/tools/class-setup

Students in a class open mytekdev.com/tools/robot-soccer-lab/lessons/read-the-ring-adding-sensor-readings-as-vectors/start instead of the worksheet link. Each one gets their own copy of the starter, and the same link reopens it next time.

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