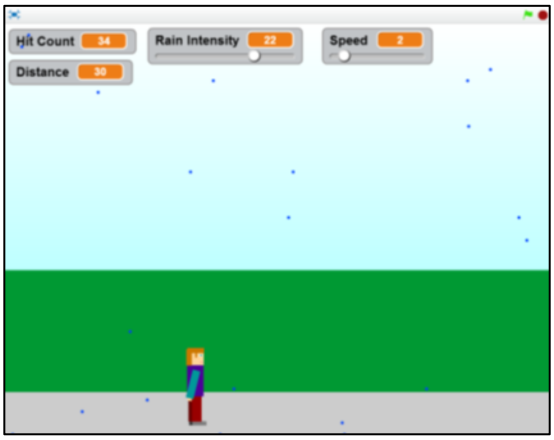
Running in the Rain – Programming a Simulation

When it is raining is it more beneficial to run than it is to walk? If we run then we will reach our destination more quickly, but will we run into more raindrops?



Task 1

Set up a simulation in Scratch to investigate this problem. In your simulation you should be able to control the intensity of the rain and the speed at which the person runs. Your simulation should record the distance the person runs, and how many raindrops he/she comes into contact with.

Hints and Tips:

- Each raindrop should be represented by a separate sprite. The initial *x* and *y*-coordinate of each sprite should be randomly determined. When a sprite reaches the bottom of the screen it should immediately be moved to a random position at the top of the screen to represent a “new” raindrop.

- The speed of every raindrop should be equal and a value should be chosen that is not too large. A good value to use is ten pixels per frame of animation.

- The maximum speed of the man should not be above ten pixels per frame.

- If you set up your code for your first raindrop thoughtfully, you can simply copy and paste the sprite to create all of the other raindrops with only a very small bit of editing required for each new sprite.

- When a raindrop comes into contact with the man/woman it should be hidden, but it should still continue to fall to the ground.

- Increasing the intensity of the rain should increase the number of raindrops on screen at one time. The maximum intensity should be 35.

- Design your person so that he/she is approximately in the shape of a rectangle, as in the example on the right. He/she should be not too small and not too big. See the screenshot above for an appropriate size.

- When the person reaches the right side of the screen, he/she should be immediately be repositioned on the left side of the screen and continue to walk to the right. The *x* and *y*-coordinates of every raindrop should be reset.

Task 2

Use your simulation to conduct an in-depth investigation to determine whether it is better to run or walk in the rain.

Task 3

Set up another simulation in Scratch to investigate whether it is better to run in the rain if we have an umbrella. The width of the umbrella should be approximately equal to three times the width of the man/woman, and it should be centred above the man/woman, as in the example on the right.

Hints and Tips

- Use a colour for your umbrella that is not used anywhere else on your man/woman. When raindrops touch this colour they can simply be hidden.

- You should be able to use a lot of the code from your first simulation.

Task 4

Use your simulation to conduct an in-depth investigation to determine whether it is better to run in the rain if we are carrying an umbrella.

Task 5

Create a report of all of your findings. In your report you should include:

- an explanation of what you are investigating, and how you will investigate it
- a screenshot of the code used for your man/woman, along with an explanation of the functions used and why you used them
- a screenshot of the code used for two of your raindrops, along with an explanation of the functions used and why you used them (you do not need to repeat explanations if a lot of the code is the same in each sprite, which it should be)
- an explanation of why we should choose values both for the speed of the rain and the speed of the man that are not too large.
- an explanation of why we should continue to make a raindrop fall towards the ground even if it has come into contact with the man/woman (for example, why shouldn't we place it back at the top of the screen straight away?)
- an explanation of why we should reposition every raindrop when the man/woman reaches the right side of the screen and is repositioned on the left
- the results of your investigations
- the conclusions of your investigations

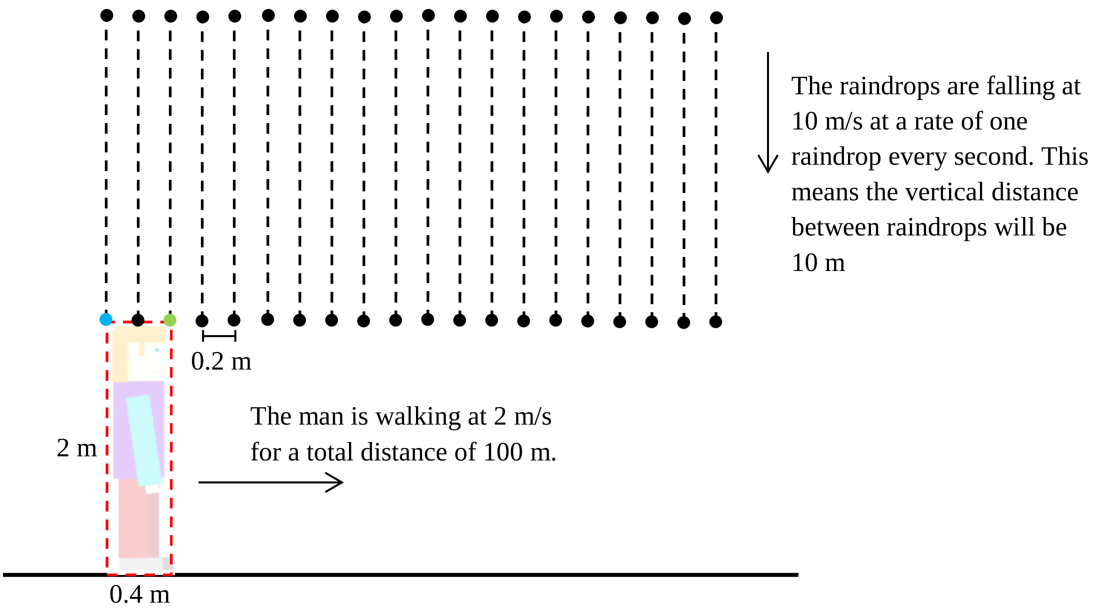
Running in the Rain – A Mathematical Model

When it is raining is it more beneficial to run than it is to walk? If we run then we will reach our destination more quickly, but will we run into more raindrops?

To investigate this we will use a simplified model. The man will be represented by a rectangle of dimensions 0.4 m by 2 m. The raindrops will be limited to falling at specific points placed 0.2 m apart at a speed of 10 m/s and a time interval of one raindrop per second. We will assume the man is walking at a speed of 2 m/s for a total distance of 100 m.

The first set of raindrops will all fall together, one second later the next set of raindrops will all fall together etc.

The following diagram demonstrates this model. We will assume that the first set of raindrops is *just above* 2 m from the ground. This means that the raindrop on the far left (in blue) will just miss the man, and the raindrop closest to the top-right vertex of the man (in green) will land on his head. Note that it is raining for the whole 100 m.



1. Only two sides of the rectangle (which represents the man) will come into contact with raindrops. Which two sides are these?

2. Consider each of these sides one at a time. How many of the first set of raindrops will strike each of these sides?

3. Determine the amount of time it will take for the second set of raindrops to be in the initial position of the first set in the diagram above.

4. Determine how long it will take the man to travel 100 m.

5. Hence, determine how many raindrops will strike the man during this time.

6. Suppose the man now travels at 1 m/s for 100 m. How many raindrops will strike him?

7. Suppose the man travels at a speed of v m/s for 100 m. Determine an expression for the number of raindrops that will strike the man. Hence, determine whether it is better to run or walk in the rain.

8. Suppose the man now carries an umbrella that protects his head from getting wet (i.e. the width of the umbrella is at least 0.4 m). Is it better to run or walk? Does the width of the umbrella make a difference? (Answer this question using diagrams and explanations, not using equations).

Task 6

Add the solutions to these questions to your report. Include an introduction explaining your mathematical model. Your work should be able to stand on its own without having to refer to the questions, and should be written in a natural way, not simply each question followed by an answer.

Comparing the Two Models

We can now compare our mathematical model to our Scratch simulation.

Let all units of distance be *pixels*, and all units of time be *frames*. For example, if the man has a speed of 2 then he moves 2 pixels per frame of animation.

Using your Scratch simulation (without an umbrella) decide a value for the intensity of the rain.

1. If all of the raindrops started from the same height at the same time, as in the mathematical model, determine the average width between them. *Hint: what is the width of the simulation window, and how many raindrops are displayed on screen at once?*

2. Write down the velocity of the raindrops.

3. If the second set of raindrops all started at the same height at the same time, as in the mathematical model, what would be the time difference between the first set and the second set? *Hint: this is equal to the time taken for a raindrop to fall from the top of the screen to the bottom.*

4. Follow steps similar to those of the mathematical model to determine an expression for how many raindrops will strike the man over a distance of 50,000 (pixels) if his speed is equal to v. For the horizontal distance the man travels you should use the actual amount in pixels and not the arbitrary amount you may have used in your simulation.

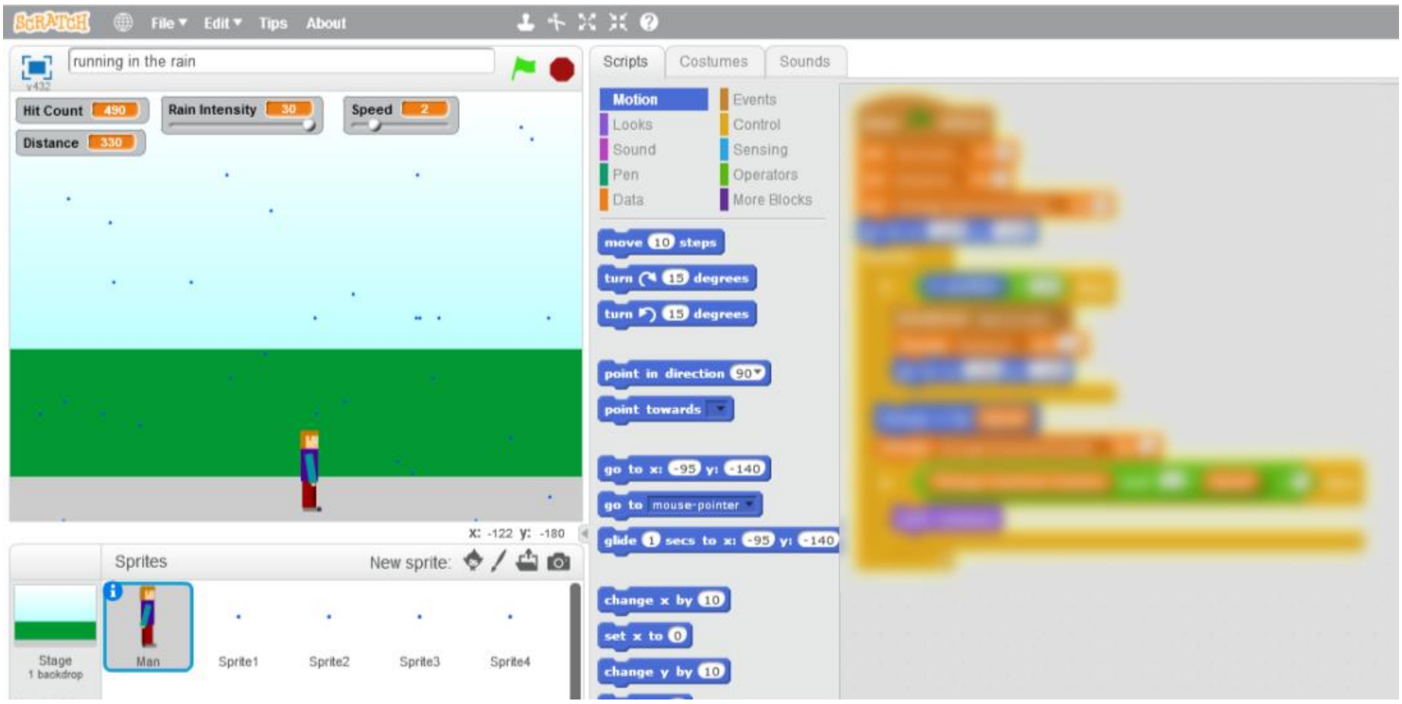
5. Use this expression to graphically compare your mathematical model to your Scratch simulation.

Tip: It is okay to have decimal values in your calculations e.g. 3.5 raindrops strike the man etc.

Task 7

Add the solutions to these questions to your report. Your work should be able to stand on its own without having to refer to the questions, and should be written in a natural way, not simply each question followed by an answer.

There are many ways of programming the simulation, and everyone's code should be slightly different, but the code for each sprite does not need to be too complicated as you can see in the screenshots below.


File
Edit
Tips
About
running in the rain
Hit Count 490
Rain Intensity 30
Speed 2
Distance 330
x: -122 y: -180
Sprites
New sprite:
Stage
1 backdrop
Man
Sprite1
Sprite2
Sprite3
Sprite4
Scripts
Costumes
Sounds
Motion
Looks
Sound
Pen
Data
Events
Control
Sensing
Operators
More Blocks
move 10 steps
turn 15 degrees
turn 15 degrees
point in direction 90
point towards
go to x: -95 y: -140
go to mouse-pointer
glide 1 secs to x: -95 y: -140
change x by 10
set x to 0
change y by 10

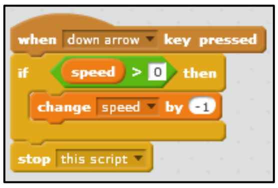

File
Edit
Tips
About
running in the rain
Hit Count 494
Rain Intensity 30
Speed 2
Distance 330
x: 240 y: -180
Sprites
New sprite:
Stage
1 backdrop
New backdrop:
Man
Sprite1
Sprite2
Sprite3
Sprite4
Scripts
Costumes
Sounds
Motion
Looks
Sound
Pen
Data
Events
Control
Sensing
Operators
More Blocks
move 10 steps
turn 15 degrees
turn 15 degrees
point in direction 90
point towards
go to x: 63 y: 60
go to mouse-pointer
glide 1 secs to x: 63 y: 60
change x by 10
set x to 0
change y by 10
set y to 0

An Example of How to Explain Your Code

As part of your report you need to explain all of the code for your man, and the code for two of your raindrops. (Most of the raindrop code should be similar so you don't need to repeat explanations). Here is an example of how to explain the code of the game from the Scratch tutorial.

When the game first starts position the spaceship at (0,-100) and reset the values of *speed*, *direction*, *Player* (Score) and *Computer* (Score) to zero.

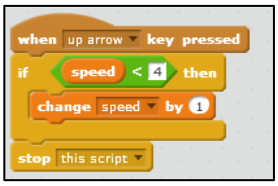
This repeatedly points the spaceship in the direction of the variable *direction* and moves it by *speed* steps. Initially when the game first starts the spaceship will not move, but when the player increases the value of *speed* it will begin to move.



When the *down* key is pressed the value of *speed* will change by -1 only if the current value is above zero. This makes the spaceship slow down until its speed equals zero, when it will stop.

When the *right* key is pressed the value of *direction* will change by 5. This makes the spaceship turn right.

When the *left* key is pressed the value of *direction* will change by -5. This makes the spaceship turn left.



When the *up* key is pressed the value of *speed* will change by 1 only if the current value is below 4. This makes the spaceship speed up to a maximum speed of 4.

When the *space* key is pressed the spaceship broadcasts the message *Spaceship Fire* only if its rocket has reached the edge of the screen. This avoids the problem of a rocket disappearing mid-flight in order to be fired again.

Criterion B: Investigating Patterns		
Achievement Level	Level Descriptor	Task Specific Clarification
0	The student does not reach a standard described by any of the descriptors below.	
1 – 2	The student is able to: I. **apply, with teacher support**, mathematical problem-solving techniques to discover **simple patterns** II. **state predictions** consistent with patterns.	The student is able to: ○ create a simulation in Scratch and use this simulation to investigate whether it is better to run or walk in the rain.
3 – 4	The student is able to: I. **apply** mathematical problem-solving techniques to discover **simple patterns** II. **suggest general rules** consistent with **findings**.	The student is able to: ○ create a simulation in Scratch and use this simulation to investigate whether it is better to run or walk in the rain. ○ attempt to derive a mathematical model to determine the number of raindrops that will strike the man when running at a certain speed for a certain distance. ○ attempt to derive an expression based on the mathematical model for the number of raindrops expected to strike the man in the simulation and use this expression to compare your mathematical model to your simulation.
5 – 6	The student is able to: I. **select** and **apply** mathematical problem-solving techniques to discover **complex patterns** II. **describe patterns** as general rules consistent with **findings** III. **verify** the validity of these general rules.	The student is able to: ○ create an accurate simulation in Scratch that satisfies the requirements of the project, and use this simulation to investigate whether it is better to run or walk in the rain. ○ derive a mathematical model to determine the number of raindrops that will strike the man when running at a certain speed for a certain distance. ○ derive an expression based on the mathematical model for the number of raindrops expected to strike the man in the simulation and use this expression to compare your mathematical model to your simulation.
7 – 8	The student is able to: I. **select** and **apply** mathematical problem-solving techniques to discover **complex patterns** II. **describe patterns** as general rules consistent with **correct findings** III. **prove, or verify and justify**, these general rules.	The student is able to: ○ accurately derive, with full explanations, a mathematical model to determine the number of raindrops that will strike the man when running at a certain speed for a certain distance. ○ accurately derive, with full explanations, an expression for the number of raindrops expected to strike the man in the Scratch simulation and use this expression to compare your mathematical model to your simulation.

Criterion C: Communication in Mathematics		
Achievement Level	Level Descriptor	Task Specific Clarification
0	The student does not reach a standard described by any of the descriptors below.	
1 – 2	The student is able to: I. **use** limited mathematical language II. **use** limited forms of mathematical representation to present information III. **communicate** through lines of reasoning that are difficult to interpret.	The student is able to: ○ attempt to explain what is being investigated and how it is being investigated
3 – 4	The student is able to: I. **use** some appropriate mathematical language II. **use** different forms of mathematical representation to present information adequately III. **communicate** through lines of reasoning that are able to be understood, although these are not always clear IV. adequately **organize** information using a logical structure.	The student is able to: ○ explain what is being investigated and how it is being investigated ○ attempt to explain the Scratch code for the man and two raindrops.
5 – 6	The student is able to: I. usually **use** appropriate mathematical language II. usually **use** different forms of mathematical representation to present information correctly III. move between different forms of mathematical representation with some success IV. **communicate** through lines of reasoning that are clear although not always coherent or complete V. present work that is usually **organized** using a logical structure.	The student is able to: ○ explain what is being investigated and how it is being investigated ○ use clear diagrams/screenshots to justify explanations and calculations ○ explain the Scratch code for the man and two raindrops. ○ create a report that is mostly able to be understood without referring to the task sheet
7 – 8	The student is able to: I. consistently use appropriate mathematical language II. use different forms of mathematical representation to consistently present information correctly III. move effectively between different forms of mathematical representation IV. communicate through lines of reasoning that are complete and coherent V. present work that is consistently organized using a logical structure.	The student is able to: ○ clearly explain in your own words what is being investigated and how it is being investigated ○ display formulae clearly and accurately using the equation editor ○ use clear and accurate diagrams/screenshots to justify explanations and calculations ○ move effectively between explanations, calculations, tables and diagrams with appropriate linking sentences (the following table shows, figure 3 demonstrates, etc.) ○ clearly and thoroughly explain the Scratch code for the man and two raindrops. ○ make good use of space on the page (no unnecessary white space, items positioned thoughtfully etc.) ○ create a report that is able to be understood without referring to the task sheet

Criterion D: Applying Mathematics in Real Life Contexts		
Achievement Level	Level Descriptor	Task Specific Clarification
0	The student does not reach a standard described by any of the descriptors below.	
1 – 2	The student is able to: I. **identify** some of the elements of the authentic real-life situation II. **apply** mathematical strategies to find a solution to the authentic real-life situation, with limited success.	The student is able to: ○ discuss whether it is better to run or walk in the rain
3 – 4	The student is able to: I. **identify** the relevant elements of the authentic real-life situation II. **select**, with some success, adequate mathematical strategies to model the authentic real-life situation III. **apply** mathematical strategies to reach a solution to the authentic real life situation IV. **describe** whether the solution makes sense in the context of the authentic real-life situation.	The student is able to: ○ attempt to use the simulation to determine whether it is better to run or walk in the rain both with and without an umbrella ○ attempt to use the mathematical model to determine whether it is better to run or walk in the rain both with and without an umbrella ○ attempt to compare results of the Scratch simulation to results of the mathematical model
5 – 6	TThe student is able to: I. **identify** the relevant elements of the authentic real-life situation II. **select** adequate mathematical strategies to model the authentic real-life situation III. **apply** the selected mathematical strategies to reach a valid solution to the authentic real-life situation IV. **describe** the degree of accuracy of the solution V. **discuss** whether the solution makes sense in the context of the authentic real-life situation.	The student is able to: ○ use the simulation to determine whether it is better to run or walk in the rain both with and without an umbrella ○ use the mathematical model to determine whether it is better to run or walk in the rain both with and without an umbrella ○ compare results of the Scratch simulation to results of the mathematical model
7 – 8	The student is able to: I. **identify** the relevant elements of the authentic real-life situation II. **select** appropriate mathematical strategies to model the authentic real life situation III. **apply** the selected mathematical strategies to reach a correct solution IV. **explain** the degree of accuracy of the solution V. explain whether the solution makes sense in the context of the **authentic** real-life situation.	The student is able to: ○ create an accurate simulation in Scratch that is not unnecessarily complicated and satisfies the requirements of the project. ○ use the simulation to accurately determine, with thorough evidence, whether it is better to run or walk in the rain both with and without an umbrella ○ use the mathematical model to accurately determine whether it is better to run or walk in the rain both with and without an umbrella ○ compare results of the Scratch simulation to results of the mathematical model using a graph