Digital Technologies @ Home
Unplugged activities for students

This activity is for: Years 7-10

Convenient Stores

With thanks to the Girl's Programming Network for providing this content.

This activity teaches…

Technology allows us to innovate and explore ideas without having to physically build them. In this activity we explore the placement of grocery stores and how an algorithm known as *Voronoi Diagrams* can help us determine which grocery stores are the most convenient to travel to.

We'll learn how to create Voronoi Diagrams and test that they are correct. We will also explore how these diagrams can address people's needs for grocery stores and other physical locations, and how the diagrams can fall short.
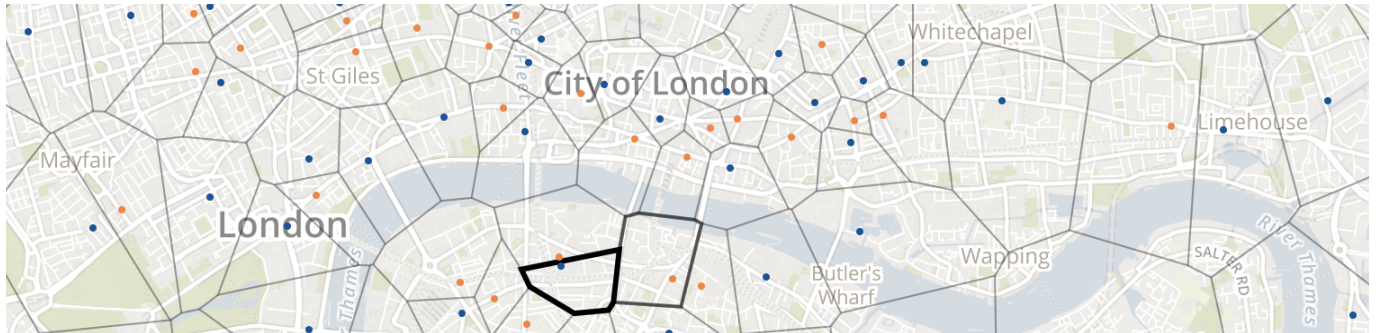
This activity is targeted towards secondary students and is expected to take 1.5 hours, including some discussion time.

You will need…

A pencil, a pen, a ruler

Voronoi Groceries

Which is the closest grocery store?

Voronoi diagram by Keir Clarke for http://googlemapsmania.blogspot.com/2014/06/the-supermarket-voronoi-map.html Map by Mapbox and OpenStreetMap

Voronoi Diagrams

The picture above shows grocery stores as dots on a map. Each grocery store is surrounded by a boundary (known as a *cell*). The cell shows which households are closest to that grocery store. That is, for any house inside a cell, no other grocery store outside the cell is closer.

We can make our own Voronoi diagrams using a simple algorithm.

```
For each grocery store
    For each other grocery store
        Draw the boundary that is halfway
            Between the grocery store and the other grocery store
    For each boundary
        Trim the sections of the boundary
            that fall on the side of another boundary
            that is further from grocery store

    (This is known as a cell)
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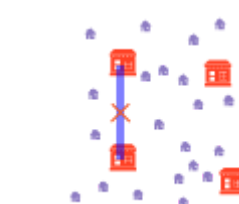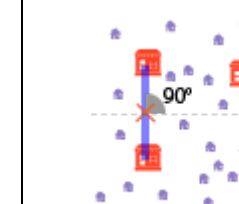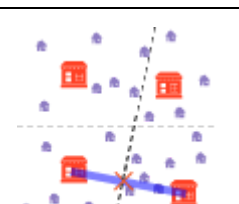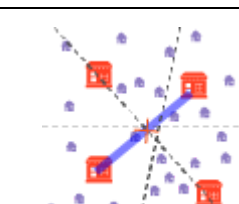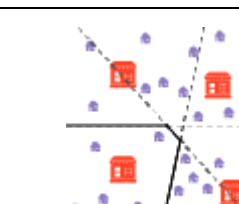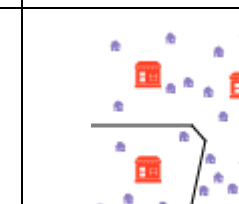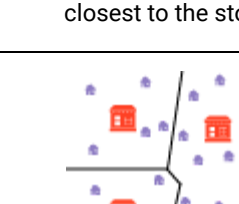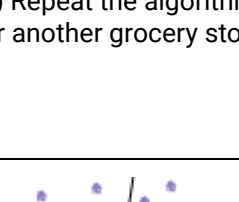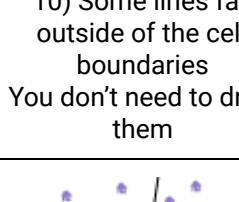
There is an example of the algorithm in action on the next page.

Here's an example of the algorithm in action:

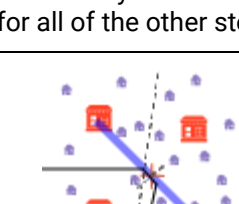|			
1) Start with a map	2) Place a ruler between two grocery stores	3) Find the midpoint between the two stores	4) Draw a guideline perpendicular to the ruler
5) Repeat for one of the previous grocery stores plus a new store	6) Repeat with the same store until you have a line for all of the other stores	7) Trim the lines by drawing the sections of the guidelines closest to the store	8) This **cell** is complete!
9) Repeat the algorithm for another grocery store	10) Some lines fall outside of the cell boundaries. You don't need to draw them	11) Another cell done!	*Tip: Three edges will always meet at a single point* *Tip: Cells will always be convex (no indents in the cell's boundaries)*
12) Repeat for the final cell	13) Complete!	*You can now see which houses are closest to each grocery store!*	

Draw your first Voronoi diagram

Using the steps on the previous page, draw the voronoi cells for this abstract map.
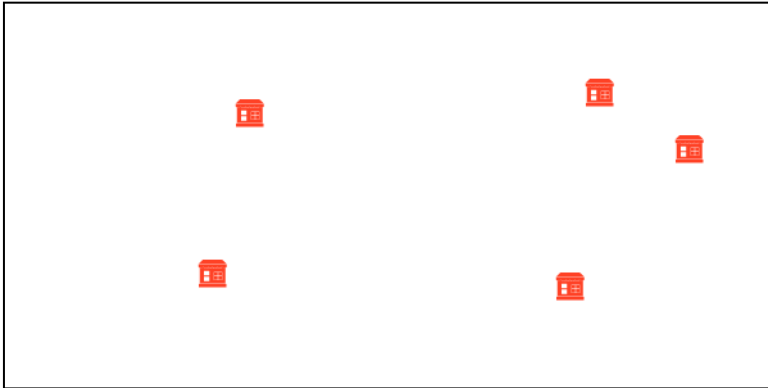
Now use a real map

Now draw the voronoi cells for this real world map.
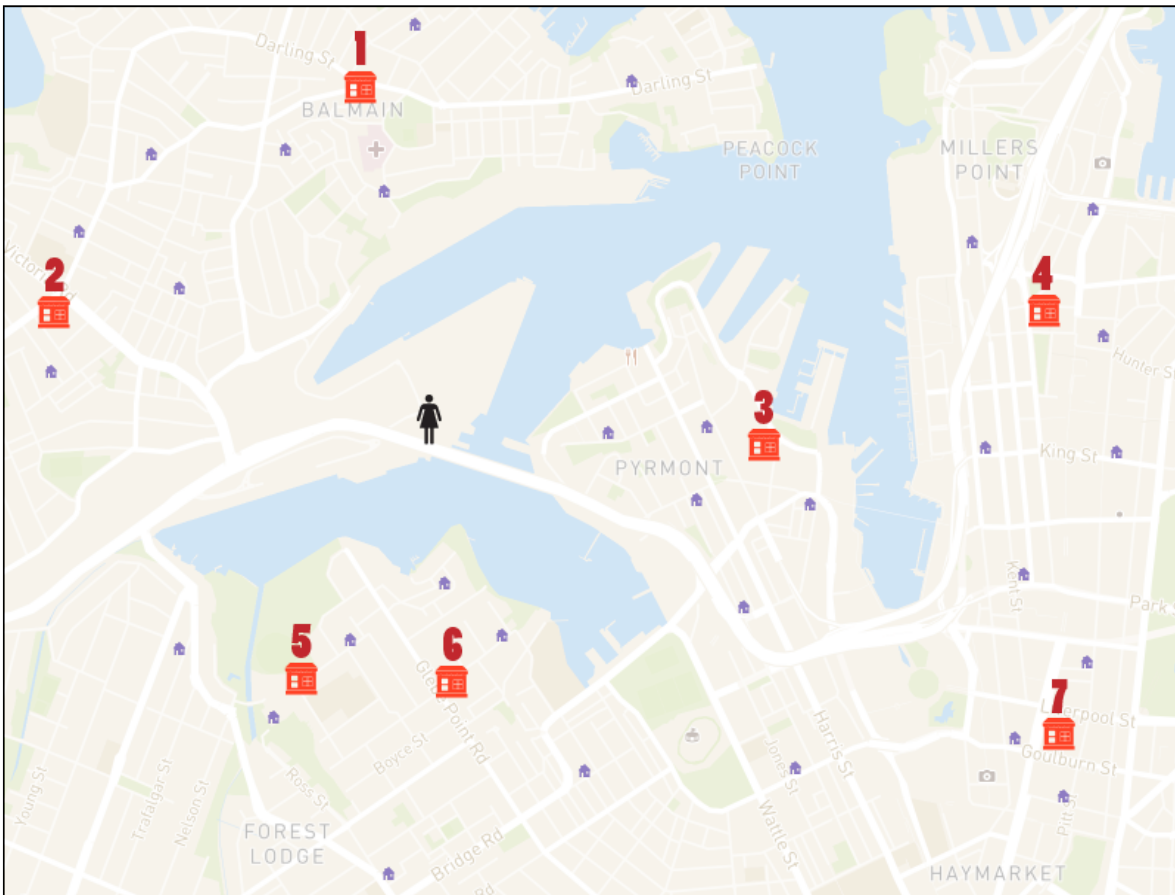
Questions

How many houses are in each cell?

Cell number	1	2	3	4	5	6	7
Number of houses							

Use a ruler to measure the distance directly between the person and each grocery store.

Grocery store	1	2	3	4	5	6	7
Distance from the person							

Which grocery store is closest to the person? Is the person inside of the cell for that grocery store?

_____

Can you find any points on the map which are closer (straight line distance) to a grocery store outside of their cell?

_____

Can you think of any other tests to make sure you executed the Voronoi algorithm correctly?

_____

If you had to drive from the person to the grocery store which grocery store would be the closest?

_____

Impact

How could you use a voronoi diagram to decide where to place a new grocery store to minimize the number of households per store?

The voronoi cells show us the closest grocery stores "as the crow flies", but people drive, walk or take public transport to stores. How are these different modes of travel affected by the difference between the voronoi cells and reality?

What are some other reasons you might not want to go to the closest grocery store?

Students

Custom map

Choose a place and create a new voronoi diagram for it.

It can be your local area or somewhere completely different.

You can place the paper over a screen and trace the map, print a map out or draw a rough map from memory.

Draw the locations for the Voronoi diagram on the map.

You can choose grocery stores, or a new kind of location, such as parks, fast food restaurants or hospitals.

Predict the closest locations for a few different points of interest (e.g., your house) on the map.

Draw the voronoi diagram for your points of interest.

Questions

- Are the boundaries for the closest locations where you expected?
- Have you ever been in a point of interest on the map and gone to a location that wasn't the closest? Why?
- If you were going to add another location on the map (e.g., another grocery store or park) where would you put it? Would a Voronoi diagram help you make your decision?
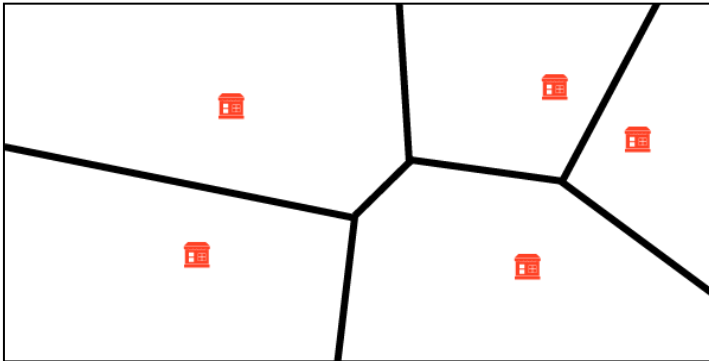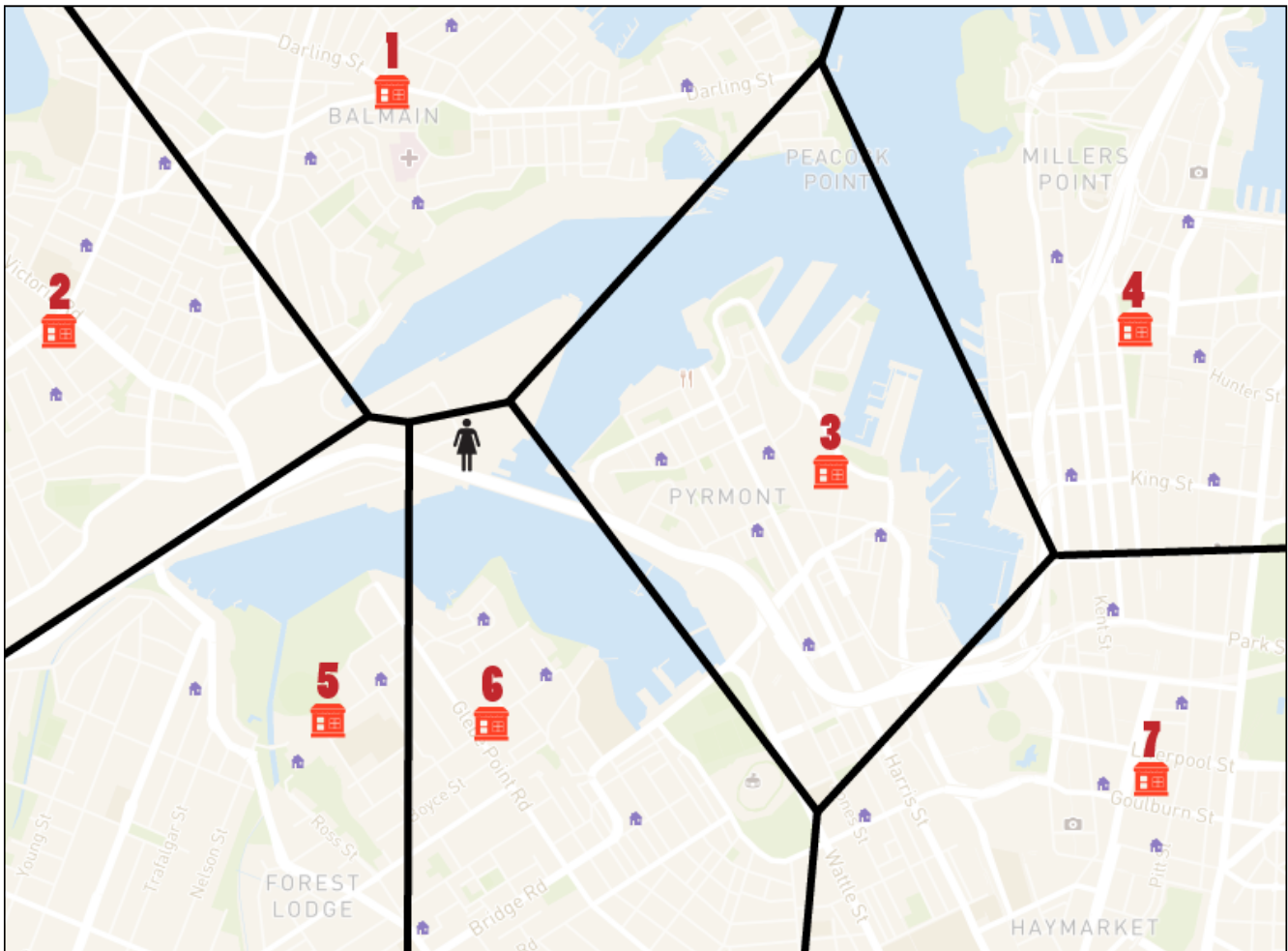- Could you use the voronoi diagram to choose a layout of locations which uses less resources?

Answer key

Print this for your students or keep it to yourself!

Draw your first Voronoi diagram

Now use a real map

Answers to questions

How many houses are in each cell?

Cell number	1	2	3	4	5	6	7
Number of people	4	4	5	5	3	4	5

Use a ruler to measure the distance directly between the person and each grocery store.

Grocery store	1	2	3	4	5	6	7
Distance from the person	4 cm	5 cm	4 cm	8 cm	3.5 cm	3 cm	8.5 cm

Which grocery store is the closest to the person? Is the person inside of the cell for that grocery store?

_____6_____   _____Yes_____

Can you find any points on the map which are closer to a grocery store outside of their cell?

_____No_____

Can you think of any other tests to make sure you executed the Voronoi algorithm correctly?

Check every point of interest on the map! (This isn't 100% proof we've executed the algorithm correctly because there are infinite possible points)

Between three locations the lines should all meet at a single point. This is because there is always a point equidistant between three locations (unless the 3 locations are in a line).

The shape of the cells should be convex (no sharp angles). (Think about bubbles expanding and forming boundaries between each other to get an intuition for why this occurs)

Every point on a line should be equidistant to two points.

If you had to drive from the person to the grocery store which grocery store would be the closest?

_____2 or 3_____

Teachers

Impact answers
The answers below are indicative of the kinds of answers students may give.
There may be other, equally valid ideas the students explore!

How could you use a voronoi diagram to decide where to place a new grocery store?

You could place a new point on the map where stores seem to have too many people. Then you can generate a new Voronoi diagram to see how many people each grocery store has. Then if some stores still have too many people, you could move the new grocery stores closer to the over-assigned grocery stores.

The voronoi cells show us the closest grocery stores "as the crow flies", but people drive, walk or take public transport to stores. How are these different modes of travel affected by the difference between the voronoi cells and reality?

People who drive are affected by high traffic areas. Certain short distances may actually take a long time in traffic..

People who walk cannot walk on highways or across water.

People who take public transport can only go to certain locations, so some physically close stores may take a longer travel time.

What are some other reasons you might not want to go to the closest grocery store?

The closest grocery store may be too expensive or not have the products you desire.

There may be a grocery store close to where you work or go to school.

You may order your groceries online.

Want more?

Here are some further activities, online resources, assessment ideas and curriculum references.

Adapting this activity
Older students in Years 11 and 12 may want to try and implement this algorithm using a programming language. They will need to have the requisite geometry knowledge to calculate the midpoint and intersection of lines.

Keep the conversation going
- The Voronoi diagram algorithm assumes that all grocery stores are equally desirable. How could you adapt the algorithm to account for some grocery stores being worth extra travel time?
- What are the costs (financial, environmental, logistical) associated with travelling a greater/smaller distance to the grocery store?
- What is an innovative product you could create using Voronoi diagrams?
  - Who is the audience?
  - Do they need to see the diagrams or just know the results?

Keep learning
For year 7-8 students who would like to learn basic geometry using algorithms, try this DT Challenge: cmp.ac/geometry

For students interested in learning about Voronoi diagrams in an artistic context you can watch Khan Academy's video about their use in Pixar's movies: https://www.youtube.com/watch?v=Q804hv73L6U

You can use the interactive Voronoi Diagram tool from the Statistics Online Computational Resource: https://socr.umich.edu/HTML5/others/Voronoi_App/

For teachers creating a portfolio of learning or considering this task for assessment
Ask the students to use the custom map question for their portfolios. Use the associated questions or create your own to add as explanation to their portfolios.

Linking it back to the Australian Curriculum: Digital Technologies
The content descriptors below are for years 7-10. This activity covers a single example of tracing algorithms to predict errors, using test cases, and evaluating information systems to take account of future risks (see **bold text**).
x
In order to meet curriculum requirements, students should apply the investigations used in this activity to their own algorithms and hypothetical solutions and other, additional algorithms and real world scenarios.

Algorithms
Design algorithms represented diagrammatically and in English, and ***trace algorithms to predict output for a given input and to identify errors*** (ACTDIP040 - see cmp.ac/algorithms)

Impact
Evaluate how student solutions and *existing information systems meet needs,* are innovative, and take account of future risks and sustainability (ACTDIP031 - see cmp.ac/impact)

Refer to aca.edu.au/curriculum for more curriculum information.