

Comprehensive Creative Technologies Project: Simulating the Effects of Climate Change on a Game Environment

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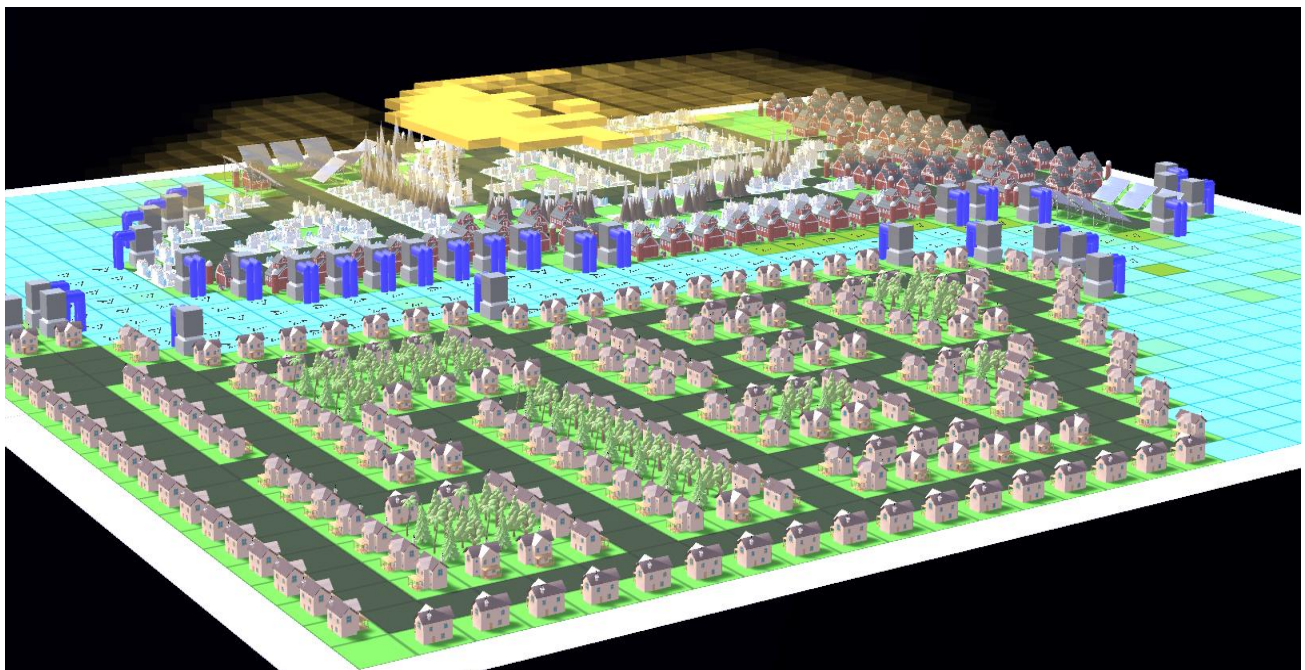
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Abstract

The purpose of this project is to inform and educate about climate change via the medium of a game. This project is a city builder where the user's choices have impacts on the environment and productivity of several aspects of the city.

Keywords: Climate Change, carbon, CFCs, simulation, city, builder, unity, smog

How to access the project:

<https://github.com/Samsei/CCTP---18022609>

Download or clone the repo. Within the "build" folder, run the .exe

1. Introduction

The project aims to educate about the effects of climate change in an engaging way through a medium that is accessible to as many people as possible.

Project Objectives:

- Simulate effects of climate change in a city environment
- Educate users on how pollution will affect a city

Deliverable:

- A city-builder game that simulates climate change and its effects on the city built.

Climate Change is an issue that affects everyone and nearly every aspect of daily life (Perry, 2007), and this project aims to simulate its effects on an environment within a game. For this project, a city-builder like design was chosen to give the user a more direct impact on the output of toxic and greenhouse gasses and how it affects their city.

The project originally started as a pure simulation, with the user being able to input values into a system and watch the effects over time. The decision was made to change it into a city builder to have the pollution effect something the user has built to make it more engaging and educational.

The project explores how pollution will affect a population within a city and its components, such as farms, solar panels, and water sources. An example of how the pollution will affect the population is if the water becomes contaminated and is then fed into the city's water system. This will cause residents to become ill and unable to work, affecting work efficiency and food production in the farms. This is indicative of Flint, Michigan (Zahran, 2018) and the Legionnaires disease outbreak that occurred due to the local government beginning to supply the residents with polluted water from the river (Denchak, 2018).

2. Literature review

Rice and Wheat production

An increase in global temperatures and CO₂ levels have raised numerous concerns about food production and the consequences of climate change on farms. In a study conducted in

Bangladesh, Amin (2015) found that certain types of rice, such as Aman Rice, became greatly influenced by climate conditions when rainfall amounts are changed and exposure to sunlight, along with temperatures, is both increased and decreased. These reduce both the yield and cropping area of the Aman rice, significantly affecting the total production of that type of rice.

However, in contrast, Aman rice is positively affected by humidity in terms of both cropping area and yield. Other types of rice, such as Boro rice and wheat is also affected by an increase in maximum temperature, however, both minimum temperature and sunlight exposure seemed to increase the yield of Boro rice significantly.

Water pollution

Water pollution is harmful to both humans and the environment, as it is a prime breeding ground for diseases such as Legionella (Zahran, 2018) and Cholera (Frerichs, 2021) where several pandemics have taken place due to the deadly disease, and only being linked to dirty water in 1854 by Professor John Snow. These diseases are caused by the consumption of infected water, usually caused by pollution or dirty water sources. These diseases can be deadly to human, but water pollution also affects the aquatic animals and the ecosystem, with some fish becoming unable to find food or dying from illness, or plants unable to photosynthesise due to pollution blocking sunlight (See Fig. 1 below).



Fig 1: Pollution in a Lake (Sourced from History.com)

Coral Reefs are a large part of why water pollution is a growing problem, with coral bleaching (Gibson, 2008) becoming even more of an issue. Coral bleaching starts to occur when the temperature of the ocean starts to rise by as little

as 1°C, cells in the coral structure start to break down exposing the white skeleton. After some time, without cells to provide food or infection caused by the lack of natural defences, the corals die out (JOI, 2017).



Fig 2: Coral bleaching over a year (Sourced from oceanactionagenda.org)

Fig 2 shows the events of coral bleaching, and how it can affect huge bodies of water due to rising temperatures. To be an impactful addition to the project, food sources can be derived from the coral reefs and oceans, where the amount of food produced would decrease as the coral bleaches over time due to pollution and temperature increase.

Wildlife & Habitation

Humans rely on animals and wildlife for a large percentage of our agricultural resources (Ritchie, 2017) at around 80%. During 2019 and into the start of 2020, an Australian wildfire during the wildfire season grew out of control, leaving a devastating trail of burnt forests and fields, and killing or displacing nearly 3 billion animals (Slezak, 2020). Many links have been made about the start of the bushfires and why they spread so quickly to climate change and its effects on Australian weather. On average, the “fire season” in Australia has been 1°C hotter than usual and set a new record of 41.9°C (BBC, 2019)

The wildfires also released an estimated 300 million tonnes of CO₂ into the atmosphere (Lee, 2019), which can contribute to global warming and other issues, such as around 450 people died because of smoke emissions from the bushfires (Hitch, 2020).

Air pollution

CFCs (chlorofluorocarbons) a pollutant, where a hole in the ozone is caused by the chlorine when separated from the CFC, the chlorine then breaks the O₃ (ozone) down into ClO and O₂, depleting the ozone. This is harmful to humans as the ozone helps protect against harmful UV light from the sun (UCAR, Present). Fig 3 below shows the drastic change in density of the ozone layer above the Antarctic.

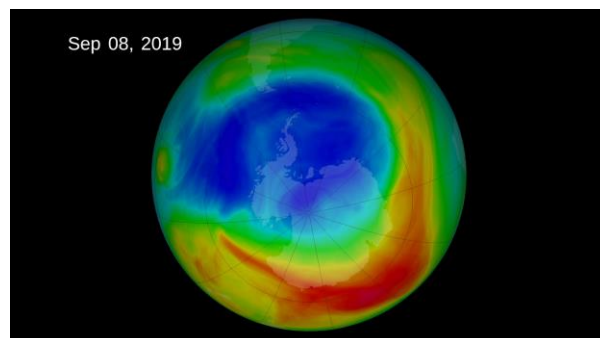


Fig 3: An image showing the density (red – high, blue low) of ozone over the Antarctic in 2019. (Sourced from Nasa.gov)

Smog cause potential breathing and health problems, and in some cases lead to death in the case of Ella Adoo-Kissi-Debrah (BBC, 2020). Air pollution consists of gasses such as Nitrogen Oxide and Sulphur Dioxide, where breathing in these gasses can have harmful effects on a person, to which some can lead to extreme and fatal cases.

3. Research question

Overall question

What effects will simulating Climate Change have on gameplay?

Water

When trying to answer the overall question, it can be split into smaller questions for each part of the project. The first will be:

- What will the effects of the polluted water be on the user?

As water is an important part of a city, furthermore water is one of the most affected aspects by climate change in the world.

Agriculture

Another important section is agriculture, and how the project can show its effects through the medium:

- What effects will this have on the city and the player?

Food growth is essential when building a city, and keeping its populace happy, and these questions can link to the previous questions involving water pollution, as some places in the world rely heavily on fishing for food sources and in some cases, is a large part of the economy.

Air

Climate change is primarily caused by air pollution from gasses like CO₂, where it is causing our planet to warm each year, having unpredictable effects on all aspects of life:

- How will air pollution affect the game environment?
- What effects can air pollution have on the city?

Air pollutants can often cause breathing problems and can even cause death in extreme cases, all the while heating the oceans causing sea levels to rise.

4. Research methods 400w

Primarily using secondary research, creating the artefact involved collecting and referring to sources that have already collected data relating to climate change, some of which is detailed in section 2. This decision was made to use secondary research for this was due to restrictions set in place by the COVID-19 response, where primary research proved difficult to conduct when trying to attain data to base the artefact on.

Throughout the production of the artefact, primary research was conducted through several instances of user testing, where at each stage participants were asked to sample the artefact for 30 minutes and respond to questions given via a Google form. This method was chosen to keep a record of progress between each stage, and how informative and educational the project is when presenting the user with information. The sample size was limited to 7 users, though some of the research outcomes could be considered bias due to the relationships between the participants and the project developer.

During the early stages of the project, these questions tailored towards the groundwork of the artefact, and how the systems introduced worked. These systems include building placement, orientation, limitations and information presented to the user. Responses requested from users included how well the building system worked, as well as data provided to the user.

As the project evolved, questions focused more on the educational aspect of the artefact, and how well the artefact conveyed information. Questions such as how aware the participants are of how climate change can affect an environment and their views on climate change as a topic was introduced to compensate for the additional features of the artefact.

A total of 3 testing sessions were conducted, with the last being conducted towards the end of development. The responses from these testing

sessions were used to improve upon aspects of the artefact that users felt were lacking.

Feedback collected involved both qualitative and quantitative data. These were separated into graphs and practical feedback where the quantitative data was used to focus on overall aspects of the project, such as how clearly information is presented to the user. In these instances, the average score was taken from all participants and is presented in section 5. Qualitative data was measured through user satisfaction with the artefact, and feedback was acted upon during development where suggestions and criticisms had an impact on features implemented.

5. Research findings

Air pollution is currently one of the leading factors causing climate change. To portray this through the artefact, the decision was made to review secondary sources about air pollution and how it affects both people and the environment. Gasses such as Carbon Monoxide or Sulphur Dioxide are dangerous for people when inhaled (BHF, Present) and can cause long term harm or fatal situations. Other gasses such as CFCs and Carbon Dioxide damage the environment in severe ways, such as the depletion of the ozone (UCAR, Present) or the warming of the planet through the insulation of the Sun's heat (NASA, Present).

To show these impacts within the artefact, the decision was made to represent air pollution as a cloud above the city, using the transparency of the clouds to indicate density and effect. Deciding the severity of how air pollution affects the user and the environment came down to the choice to make the project into a playable game, where certain values will be exaggerated when compared to real-world data. This decision was made to engage the user more with the artefact and is a product of the testing sessions conducted, where some users stated, "Air pollution doesn't affect anything to where I feel inclined to avoid it".

Coral Reef bleaching and water pollution can have devastating effects on all life, not just humans, where ecosystems start to collapse due to several different types of pollution. Cases like Flint, Michigan (Zahran, 2018) where severe water pollution caused multiple outbreaks of Legionnaires' can demonstrate the impact of water pollution on humans, however, not only humans are affected – animals and ecosystems become intoxicated and begin to break down, reducing food sources for all dependants. Water pollution can also lead to cases of acidic rain and harmful algal blooms where fish are unable to live and possibly die out due to toxins (WWF, Present).

When presenting these findings through the artefact, a visual representation was chosen to show what tiles are polluted and how polluted they become. Water slowly starts to become a dirty green-brown colour the more it becomes polluted, to relate to the real world and how the waters appearance changes with pollution. The effect pollution and global warming have on water could also be portrayed through having coral reef tiles, where over time as the temperature increases these tiles start to become bleached.

Agricultural effects are not as apparent as other areas of research, due to common practices such as crop rotation that increase yields significantly. However, decreased yields due to climate change, even though small, can be portrayed through the artefact exaggeratedly. Amin (2015) states in the conclusion that climate change has an adverse effect on major cropping regions in Bangladesh, even though some types of crops can be positively affected due to their optimal growing conditions, such as Aman rice and how it favours humid conditions.

Looking at how this research can relate and impact the project, a lot of factors are influenced by current issues and studies, though for the educational message the artefact desires to convey, exaggerations in effects are heavily considered when planning the project around this research, as some results are currently too small or inconclusive to consider viable to use within the environment as of now, although in the future this can be reconsidered.

6. Practice

Pollution

Creating pollution

To visualise pollution, using particles to create a fog effect was an option that was considered, however it proved to be too taxing towards the performance of the project and was difficult to have spread in the desired manner.

Thus, using the Unity 3D object "cube" to represent pollution above the tiles on the map. This, however, set up a roadblock where the original idea was to change the transparency of the block via applying a material to each cube and editing it. This caused every block with the material to change transparency at the same rates.

```
_renderer.GetPropertyBlock(mpb);
mpb.SetColor("_Color", new Color(0.9f, 0.7f, 0.2f,
currentPollution / maxPollution));
_renderer.SetPropertyBlock(mpb);
```

To be able to set each block its own unique material properties, such as transparency, the

direct use of the renderer is required, where the renderer is called and returns the material property block of the object. This creates an instance of the material that can be edited to be given its unique transparency value. It is then passed back to the renderer and each block can have unique transparency.

Pollution tiles are made as children of the map tile they represent, this choice was made to simplify accessing other components from within the pollution, this is especially useful when polluting the water via air and rain. Pollution also moves with the wind, where the wind direction is generated between every 7 and 10 turns and is random. The pollution will slowly move in the direction of the wind, and if the wind is still, it will slowly spread out to the surrounding tiles.

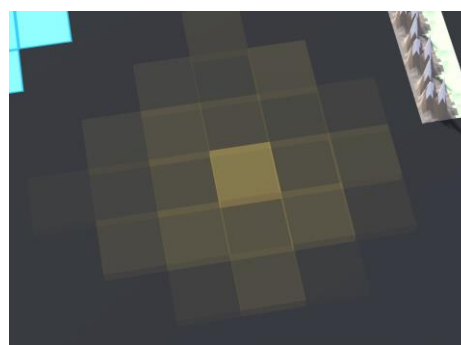


Fig 4: Showing the pollution spread to other tiles (ground tiles disabled to help visibility)

After discussion with the supervisor, mountains were added as a way to prevent pollution from spreading over them. This was in consideration for playability and planning. The mountains can be seen in Fig 4 in the top right and their effect can be seen in Fig 5 on the left where there is a gap in the pollution layer.

Interacting with pollution

Having the pollution interact with the world, the total pollution for a tile had to be given a value. During the creation of the material in 7.2.0, the maximum value of 256 was decided upon due to the material using values of 0-255 for R, G, B, A in the editor. Although, when translated to scripts, the engine preferred a float between 0 and 1. This is again seen in section 7.2.0 where the colours are set as 0.9f, 0.7f, and 0.2f to create a brown-yellow colour.

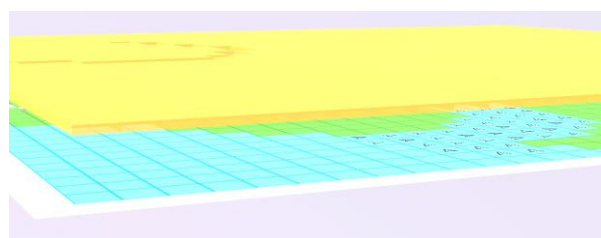


Fig 5: The pollution clouds above the map.

A maximum value allows for the division `currentPollution` by `maxPollution` to give a float value between 0 and 1. This is then used to interact with the map and buildings. An example is when a solar panel has a large amount of pollution above it, where it can decrease efficiency by up to half depending on the density of the pollution above.

$$\text{Efficiency} = \text{maxProduction} / (1 + ((\text{currentPollution} / \text{maxPollution}) / 2))$$

Pollution will also affect the growth of food from farms, where a similar formula to that which is shown above is applied. This is to represent the findings of Amin (2015), although exaggerated for the purpose of the project and its target goal.

Water pollution

In order to capture how pollution moves through a body of water, each water was given an enum containing 5 values; north, south, east, west, and still. These values determine the direction of flow for the water and how pollution will move throughout the body of water. For example: if a tile is set to "still", the pollution contained within that tile will slowly spread to each neighbouring tile, unlike a tile set to "south" where pollution will only move to the tile to the south.

Visualising that a water tile contains pollution is set up in a similar fashion to how the air tiles display pollution – using the renderer and material property blocks.

```
g = 1.0f - (currentPollution / (maxPollution / 4.0f));
if (g < 0.5f)
{
    g = 0.5f;
}

b = 1.0f - (currentPollution / (maxPollution / 8.0f));
if (b < 0.0f)
{
    b = 0.0f;
}

_renderer.GetPropertyBlock(mpb);
mpb.SetColor("_Color", new Color(r, g, b, 1.0f));
_renderer.SetPropertyBlock(mpb);
```

The code above is slightly different when compared to the code used for air pollution, also both share the same principle of editing the material property block at runtime. Air pollution uses a material and sets its transparency, whereas the water material has a colour change applied to it to visualise pollution on that tile. Checks are also made to make sure that the B and G values do not go below certain values, for B this is to keep the colour at a more distinguishable level, whereas for G this prevents the value for the colour from going into the negative which produced some undesired effects.

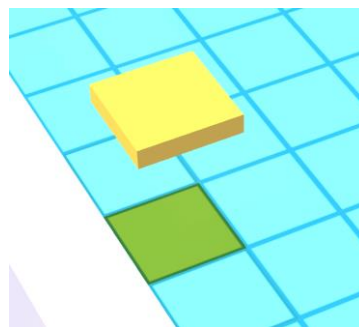


Fig 6: A water tile with pollution compared to surrounding tiles to highlight the colour change.

For air tiles to pollute water, if an air tile contains sufficient pollution a check is made to see if it is currently above a water tile. This is achieved by checking if there is a component in the parent of the air tile that matches "Water", and pollution is then transferred to the water tile from the air tile.

Two other methods that were explored early on during the creation of the project were polluting water from nearby factories and a sewage outlet for waste from buildings. These proved difficult to add and were unreliable when trying to find the tiles that they were required to pollute. These originally used ray-casts to find the object, thought would occasionally return null and cause an error or would select the wrong tile. After switching to the dictionary system, this could be reexplored in further development of the project.

Key aspects of the artefact

The City

Most values for the city are calculated at the end of each turn. The decision to have the project a "turn-based" simulation eases the demand on hardware and also allows for more emphasis on the parts of the project that focus on pollution and climate change.

The city itself is created as a singleton object within the game manager, where the dictionaries for tiles and buildings used within other scripts are stored and accessed. This allows for all of the values to be accumulated at the end of each turn, and for resources to be distributed amongst each building. Each key-value is displayed to the user through a HUD (Heads Up Display).

One flaw with this design is that resources are distributed between buildings in the order in which they are added to the dictionary. An example of this is if the city does not have enough water, buildings placed most recently will always run out of water first, regardless of the distance between them and the water pump. The ideal design would be for buildings furthest away

from the water pumps to run out of water first, and the closest last.

The City's interactions

Each building has its own needs, such as water and electricity. Houses also require clean water and food, and if these needs are not met a warning indicator appears above the building.



Fig 7: Warning symbols above buildings

If the needs are not met within a certain time (currently 20 turns), the building becomes abandoned and does not generate any resources for the city. Likewise, if a house is provided with dirty water, the population of that house slowly becomes ill and unable to work, reducing income for the city. Dirty water is collected through water pumps that are facing polluted water, where the amount of polluted water they accumulate depends on how polluted the water tile is.

Tile information

To make the project more interactive for the user, a function to retrieve and display certain information about a tile was added to the project. Using the middle mouse button (pressing the scroll wheel), the user can bring up a panel that displays the information gathered about a tile. Through string.format, the info panel retrieves information about the object through the use of a ray-cast from the tile the cursor is over depending on what building or tile there is.

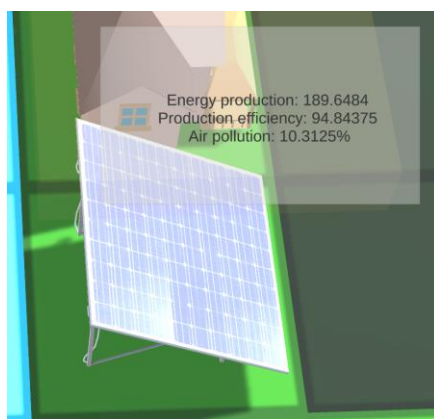


Fig 8: Displaying information about the solar panel tile.

Fig 8 shows the information panel displaying the energy production of the solar panel along with the current pollution over that tile. As discussed in 7.2.1, pollution affects the overall energy production of the solar panel.

$$\text{Efficiency} = 200 / (1 + (0.103 / 2)) = 189.6$$

This is displayed as a percentage efficiency instead of showing the loss in production. This is the same as showing pollution for a tile as a percentage rather than a flat value as it provides a more accurate representation of the data for a tile and is easier for the user to understand.

This was originally not a planned feature, but after user feedback during testing, it became apparent that users would like to see information about a tile, especially buildings and their properties.

How user feedback affected the artefact

User feedback was very valuable during the development of the artefact, where several features and limitations were added as a result. One such feature is the info panel discussed above.

Making the artefact engaging relied heavily on balance and how each component interacts with the wider system. Originally, users discovered that one farm would only provide enough food for two households. Taking up a lot of space on the map to provide enough food put a strain on what users were able to accomplish, so the decision was made to double the output of the farms to give the users more freedom in how they decide to place buildings.

Having building orientation locked to facing roads was another design choice that came from user feedback, where a few users pointed out that buildings not being attached to roads and could be placed anywhere didn't make sense in terms of a city-builder.

7. Discussion of outcomes

The initial concept for the project was to have it as a simulation where the user can change specific values, such as temperature offset and CO2 pollution in the air, where each value would affect specific parts of the simulation. After the initial build, it was decided that the best path for the project would be to turn it into a game environment with the player being able to directly influence aspects through their decisions.

The end product took the path of a city builder project with climate change and pollution aspects in and have the effects of their decisions and building choices show over time. This makes the

project more engaging and investing for the user, although some degree of authenticity is lost as certain parts, such as the effects on farms, have to be emphasised more than real-world examples (Amin, 2015) engage the user more within the game environment.

Outcomes

The project's primary goal was to answer the question stated in section 3. To achieve this, the goal was split into smaller milestones such as water, agriculture, and air pollution. The project itself explores all 3 categories to the extent where each aspect can be affected by the user's choices and playstyles and have those effects tie back in with the core gameplay loop.

Air pollution, being the first problem tackled, fit into the theme of the project well, where each grid tile has its own unique values and has the ability to spread pollution towards other tiles. This was a feature discussed with a supervisor in the early stages of the project, though initial methods struggled to produce desired results, as the project progressed the move from using ray-casts to using dictionaries helped greatly in organisation, reliability, and resource management.

Overall, air pollution seems to have achieved its target in both visual and practical effects, where the user can clearly see the pollution of a tile through both visual indication and the tile information panel. Air pollution also interacts with components of the world and the city, such as water tiles and solar panels in the desired way, although exaggerated for the purpose of the project.

Similar problems began to arise with water pollution and setting up the orientation with stream tiles. Using ray-casts, it was difficult to reliably return the desired tile, as both the ground and water tiles consist of plane objects which have no value on the height, which made ray-casts occasionally miss their target and return tiles that were not intended. This was circumvented by once again using a dictionary, however, there are other (possibly more efficient) ways to achieve this goal.

Water pollution was eventually achieved and produces desired effects on the population of the city, such as drinking dirty water makes residents ill. In the original plan for the project, water pollution had a significantly greater impact on how the player interacts with the body of water. One example of this was the attempt to add coral reefs and fishing dependencies for the city, where water pollution would affect the total output and would eventually kill off the coral reefs reducing sea population and food income (Gibson, 2008).

The effects of pollution on the agricultural aspects were achieved, though became difficult to balance and represent in a turn-based city-builder. Whilst the overall growth and gain from farms were affected based on the number of people working at said farms and the pollution above farms, it had to be exaggerated quite extensively to fit into the balance of the game and have its effects impact the user more severely. This decision was made based on research conducted by Amin (2015) where they saw an annual decrease of yields of around 2-3%.

When looking at the agricultural aspect, it is clear it achieved the desired outcome in a manner that affects the user based on their decisions. However, it could be tweaked further to more accurately represent how pollution and climate change affect farming and agriculture, though it will be a difficult task to balance it within the game environment.

Future improvements

To expand and improve further upon the project, many different aspects can be changed, added, and adjusted to provide a better learning experience for users.

One way this could be added to the project is as a separate layer above the pollution layer, where a hole will begin to open if the buildings use CFCs. This poses a new choice to the user, whether to let the ozone deplete and risk the health of the citizens or try to reduce the use of said CFCs.

Sewage was a suggestion made by a user during user testing, where a lot of water pollution comes from humans dumping wastewater into larger bodies of water like the ocean, or in the case of Flint, Michigan into the rivers. This could be a feature implemented to educate about water treatment and how much wastewater is generated during a set period.

Coral Reefs were one planned feature that did not make it into the artefact, where the user would have been able to cause coral bleaching and have it affect them throughout the course of using the artefact. However, this proved difficult to implement and was ultimately cut out of the project.

8. Conclusion and recommendations

The project along with this paper shows that it is possible to simulate the effects of climate change within a game environment, where each aspect can be altered and has its own effect on the environment and is all caused by the user's decisions. As it stands, data is not accurately represented through the project as in a game environment, it is difficult to capture real-world

data and turn it into an engaging experience through the game. Some values had to be exaggerated, but the overall point and message of these issues are presented to the user with the project. For the purpose of the project, the exaggerated numbers and figures help engage the user within the environment and provide obstacles that the user must consider.

There are many improvements to be made to the project, where different types of pollutions and their effects can be displayed and represented, giving a broader image of the impacts of climate change. These changes can help the delivery of the message that this project is trying to present and how climate change can impact daily life.

Currently, there are a few examples of games that deal with the issue of climate change and present them as issues through gameplay, such as Civilization VI from Firaxis Interactive (2016) or Fate of the World from Red Redemption (2011), where these games deal with scenarios that can be altered by the player's decisions towards climate change.

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Appendix A: Assets used within the project

Solar panel asset: [Fabuan van Dorst](#) using CC Attribution
 Factory asset: [Bunfar](#) using CC Attribution
 Farm asset: [Quaternius](#) using CC Zero
 Power station asset: [Mykhailo Ohorodnichuk](#) – Indicated royalty free
 House asset: [CoralsStudio](#) – Indicated royalty free
 Tree assets: [Ada King](#) – Indicated royalty free
 Mountain asset: [olcaytoibili](#) – Personal use license (non-commercial)