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Title	Agent Based model to simulate the effects of inequality on crime
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1. Introduction

1.1 Overview

This is a research project to study to create a simulation using the Agent Based Model. This simulation will replicate the functions of a simple society, populated with citizens (agents), that will exist and behave autonomously. The simulation will attempt to help to see if economic and societal factors contribute to a rise in criminal tendencies. The argument for a connection between inequality in a society and the prevalence of criminal activity in that society was first advanced by Gary Becker in the 1970s. This simulation will provide a useful tool for testing how certain types of behaviour emerge based on the status of an individual and the status of those he lives with. As countries around the world develop at differing rates this model will provide a way of predicting what trends could cause a rising crime rate and how to prevent them.

1.2 Business Context

As a research tool we are mainly designing the simulation for use by students and academics in fields like Social Sciences and Economics.

1.3 **Glossary**

ABM: Agent Based Model. A form of simulation that is useful for studying emergent behaviour among multiple autonomous "agents"

Gini coefficient: is a measure of statistical dispersion intended to represent the income or wealth distribution of a nation's residents, and is most commonly used to measure inequality.

Lorenz Curve: a graph which shows the cumulative percentage of total national income and is plotted against the percentage of the national population

Site: may refer to the different static entities that an Agent will interact with, such as a work place, residence, shop etc.

Agent: An autonomous populant of the world. They represent the "citizens" of the society. They are individual agents that have specific needs and wants at any given time.

2. General Description

2.1 Product / System Functions

The general functionality of the system is to provide an environment for autonomous agents to exist in and find what factors contribute to the emergence of criminal behaviour in the society. As a simulation using the Agent Based Model, the agents will be programmed to make decisions based on a probabilistic decision theory. Their environment and other agents will also be a factor when making their decisions. The simulation runs for a set amount of time and as the agents interact with the environment and one another their status will change. This will be shown through graphing and real time statistical feedback. In 1968, Gary Becker, published a journal “Crime and Punishment: An Economic Approach” in which he argues that as the gap in wealth inequality widens, the more likely a would be criminal will be to commit a crime, like stealing. There have also been several surveys conducted that ask those living in different countries how safe they feel walking home. When compared to the inequality in that country, as measured by the Gini Coefficient, it showed a strong relationship between these two factors, supporting Gary Becker’s argument. The agents will have several statistics that will factor into the decisions they make. The agents will have jobs and an income that they will independently work at to acquire wealth. The amount of wealth available in the society will be a parameter that can be altered each run to see it’s effects. The wealth of an agent will allow it to increase it’s happiness. The agents will possess a happiness level that will vary during the run. How much free time the agent gets and using wealth to increase their life satisfaction will be ways of reducing the propensity to commit a crime. Agents will also have a home to live in at differing areas. They will have to pay rent to live in determined areas. The prevalence of criminal activity in an agents proximity will reduce the happiness of the agent. The agents will also have certain needs they must attend to, like eating, which also requires wealth. If an agent is unable to feed itself this will heavily affect the agents happiness and further increase their likelihood to commit a crime. We will use the Gini coefficient to measure the level of inequality in each run.

2.2 User Characteristics and Objectives

The expected user community will be academics, economists and those involved in social sciences. The system will need to be designed for ease of use for those that may not be particularly tech savvy. Parameters and environmental adjustments will need to be easy to edit and understand. Much of the graphing and statistical feedback will also need to be clearly illustrated and easy to read, with more advanced data being made available if the user so wishes The environment will need to be highly customizable for the needs of the users. They will need to be able to change the locations, starting values, availability of resources and easily be able to understand what happened during the simulation to draw well founded conclusions as to the effects of these changes.

2.3 Operational Scenarios

[Use Case]

A user may be an economist that is studying a particular country, for example Brazil. Brazil has been experiencing a widening wealth gap and has a high crime rate in the many parts of the country. To conduct their study the user may create a simplified area of one of the cities to study and attempt to replicate the area in the simulation. There may be a proposed policy change within the government to increase taxes and redistribute the wealth to poorer sections of the city. The simulation can be run to recreate the before and after scenario in the system and study what potential impact it may have on the agents in the system. If there is a reduction in the criminal behaviour or not. Another policy change may be to relocate people from areas of high criminal activities to lower crime areas. This could help the researcher determine which approach may be better in tackling crime in the city.

2.4 Constraints

As Agent based modelling is mostly new to us, we're going to have to do some extensive research about the topic. We have to understand terminology, the whole ABM concept and then look into possible software or frameworks that could help us such as MASON. Making the simulation as customizable as possible will be an important feature of the system. The UI interface will need to be clear and easy to understand at a glance, while providing a sufficient amount of detail so conclusions can be drawn from the final results. The simulation will need to generate a sufficient number of agents so that a great enough disparity between the conditions of the agents will be clear. We are unsure of the computing power that will be required for larger scale simulations

2.2 **User Characteristics and Objectives**

Describes the features of the user community, including their expected expertise with software systems and the application domain. Explain the objectives and requirements for the system from the user's perspective. It may include a "wish list" of desirable characteristics, along with more feasible solutions that are in line with the business objectives.

2.3 **Operational Scenarios**

This section should describe a set of scenarios that illustrate, from the user's perspective, what will be experienced when utilizing the system under various situations. In the article Inquiry-Based Requirements Analysis (IEEE Software, March 1994), scenarios are defined as follows: In the broad sense, a scenario is simply a proposed specific use of the system. More specifically, a scenario is a description of one or more end-to-end transactions involving the required system and its environment. Scenarios can be documented in different ways, depending upon the level of detail needed. The simplest form is a use case, which consists merely of a short description with a number attached. More detailed forms are called scripts.

2.4 Constraints Lists general constraints placed upon the design team, including speed requirements, industry protocols, hardware platforms, and so forth.

- As Agent based modelling is mostly new to us, we're going to have to do some extensive research about the topic. We have to understand terminology, the whole ABM concept and then look into possible software or frameworks that could help us such as MASON.

3. Functional Requirements

3.1 Environment

Description:
The environment will be somewhat of a sandbox where the Agents will interact with each other. It will also contain sites, which will have several different functions.

High Criticality: Setting up the environment for the simulation will be important. This will be a virtual world in which the agents act and interact. It will be a 2D sandbox and is a place that has no effect on the agents, but where the agents will spend all their time inside of.

Technical issues: None

Dependencies: all other requirements depend on the Environment as it is the medium in which all other entities, such as Agents and Sites, spend their time in.

3.2 Sites

Description: sites will then be implemented and must have specific functionality. Sites are locations within the 2D Environment where Agents go. Agents can interact with the Sites in different ways.

- There are four different types of sites:
  - Work
  - Recreation
  - Shops
  - Residential
- *Work*: an Agent may go to a work Site to gain money depending on how much time they spend there.

- *Recreation*: here, an Agent will pay a sum of money to partake in recreational activities to reduce their stress
- *Shops*: Shops may be used by the agent to buy food or drink to help with their overall needs.
- *Residential*: An Agent will live in a Residential block and will allow an agent to sleep, to reduce their sleeping meter.
- A site will only allow an Agent to spend a certain amount of time within it.

High Criticality: as Sites have an important role in their environment, they have a high criticality since Agents must interact with them for several different reasons.

Technical issues: None

Dependencies: Sites depend on the environment. Without an environment, there are no sites. It will also be dependant on behaviours.

3.3 Agents

Description:

- Attributes - hunger, thirst, sleep, stress, moral etc.
- Crime is committed if moral is low enough and stress is high, stress is the trigger. (if an Agent doesn't have money to buy food or water, stress goes up. If an Agent doesn't have money to pay rent, stress goes up. If an agent witnesses another crime, stress may go up.)
- The agents are representative of the citizens or people of the society. They will be fully autonomous and will make decisions based on the environment and their individual needs. Some agents will have their needs more fulfilled than others. The disparity between the status of the agents is where emergent behaviour will become apparent. As these agents exist in the world, their interactions with one another will may or may not cause conflict (crime) to occur. As an agents needs are not sufficiently fulfilled, they may resort to criminal behaviour to seek to fulfill some of their needs. We would expect to see the greater the disparity in status between the agents, the more crime that will be committed.

High Criticality - <u>Essential</u>

Technical issues: As the world will need to be populated with a sufficiently high number of agents, we may have performance issues with the system

Dependencies: The agents will be dependant on the behaviour and world features. If there is no behaviour feature the agents will not be able to function autonomously or make decisions. They will also rely on the world to satisfy their needs.

3.4 Behaviours

Description

- Crime - can steal from shops, other agents and work.
- Interactions with sites :
    - Agent gains money once inside work site
    - Reduces stress if doing recreational activities
    - Reduces the need to sleep and stress if spending time at their residential area.
    - There'll be multiple residential areas, so if crime happens inside of one, it may affect other Agents whom live inside of the same residential block.
    - Can buy food and water in Shops to meet needs.
    - If an Agent starts to starve or is thirsty, stress goes up. May cause them to commit a crime if desperate enough.
- The behaviour model will be the most important part of the model. Without it the agents will not be able to independently make decisions on their own. The behaviours will be determined be each agents individual stats and what they deem to be the most essential to them at any given time. The behaviours will be a for of AI programming. The agents will determine what their priority at any time will be determined by probabilistic algorithms.their needs and wants will be assessed based on how their stats are at any time and if low enough, the priority will rise. If an agent is in a state of extreme hunger, they will prioritise the need to satisfy this over other needs and wants.

Criticality: <u>Essential</u>

Technical issues: As a multitude of behaviours will be needed for the agents to function autonomously, several behaviours may be in conflict with one another. We will need to develop a way for the agents to prioritise certain behaviours over others

Dependencies: Will be dependant on the Agents and Sites. Without agents for the behaviours to act upon the function is redundant.

3.5 user determined input fields

Description: This will be implemented to give each user the ability to manipulate the environment. Once the Agents are working properly, are autonomous and can interact with entities in their environment in different ways, should user determined input fields be implemented.

This will allow users to have the freedom to add as many Agents or sites into the environment as they wish. Users will also be able to determine:

- income distribution amongst the Agents,
- expenditure distribution,
- the maximum amount of time an agent can spend at a site,
- the time an Agent must wait before being able to commit another crime
- Moral or stress gain if a crime has occured around an Agent
- Moral or stress gain if a crime has been committed on an agent
- etc.

High Criticality: This will be an important part of the system. Users must have the freedom to put in any values that they wish for the simulation.

Technical issues: None

Dependencies: This will heavily rely on Agents, Sites and the environment being implemented first.

3.6 Graphing and statistics

Description: Allowing each user to see graphs and statistical feedback at the end of a simulation will be important. A user will be provided with feedback **after** the simulation has ended.

High Criticality: This is another important requirement because it will allow every user to see what exactly happened during the simulation.

Technical issues: May cause performance issues if too many agents and sites are spawned into the environment.

Dependencies: the graphing and statistical part of the system will rely on Agents, Sites, the environment and behaviours being implemented since the graphs will get all of their data from the different interactions that these entities will have.

3.7 real time graphing and statistics

Description: This requirement is here to allow a user to see the results of a simulation as it is running in real time. We will most likely be using a combination of swing, Mason and JFreeChart as Swing and JFreeChart work great together and can handle high buffering of new values when generating the graphs.

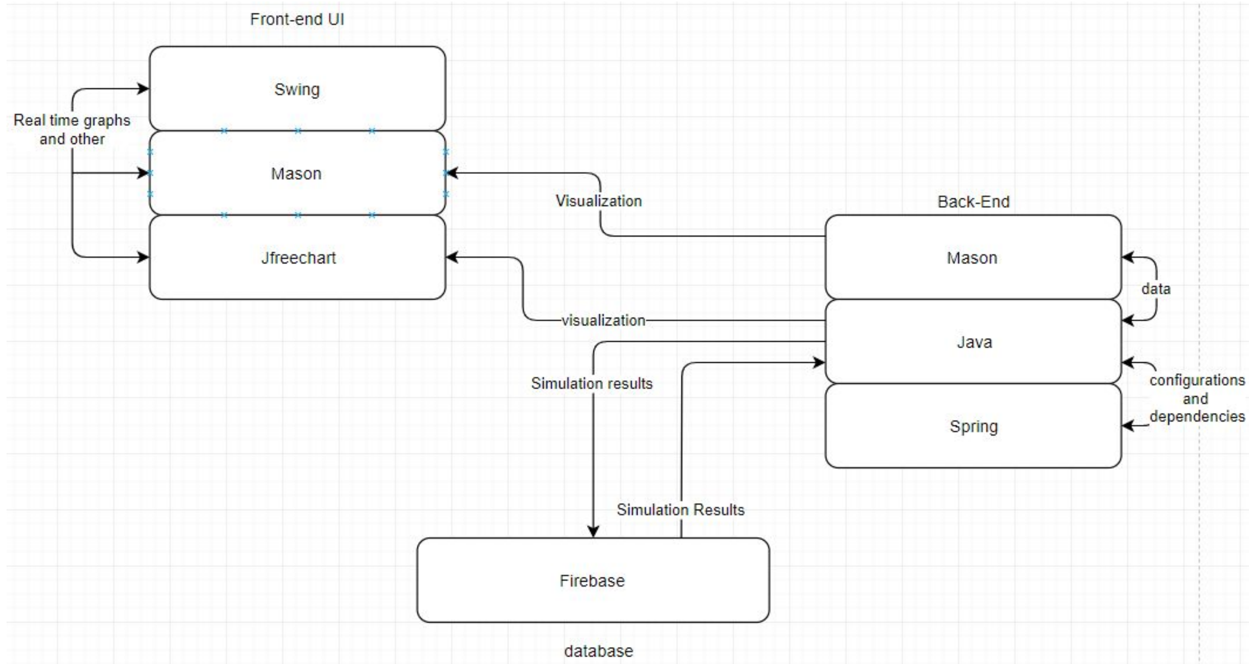
Medium Criticality: This requirement is less critical to the system. It would look great and be a nice addition to the overall system, but it is not as important compared to the above requirements.

Technical issues: Real time display of statistical and graphical feedback may cause performance issues. The simulation may be running for several minutes and each simulation will constantly be generating dozens of values for the dozens of Agents, such as income values, morality, stress, hunger, thirst, etc per second.
This may cause performance issues due to all of the values used in generating the graphs that must stay up to date with the simulation for the user to see.

Using a combination of JFreeChart, Swing and MASON should solve this issue as JFreeChart can handle graph refresh rates in a good way by using threads.

Dependencies: This will rely on the graphing and statistics functionality being implemented.

4. **System Architecture**



Swing: Swing is used in building GUIs for Java. It's an API and may be used with spring and JFreeChart. As MASON can provide a very basic GUI, Swing can be used instead or in combination with MASON to create a far more robust, sophisticated set of GUI components.

Firebase: Firebase will be used to store and retrieve the different results for each simulation.

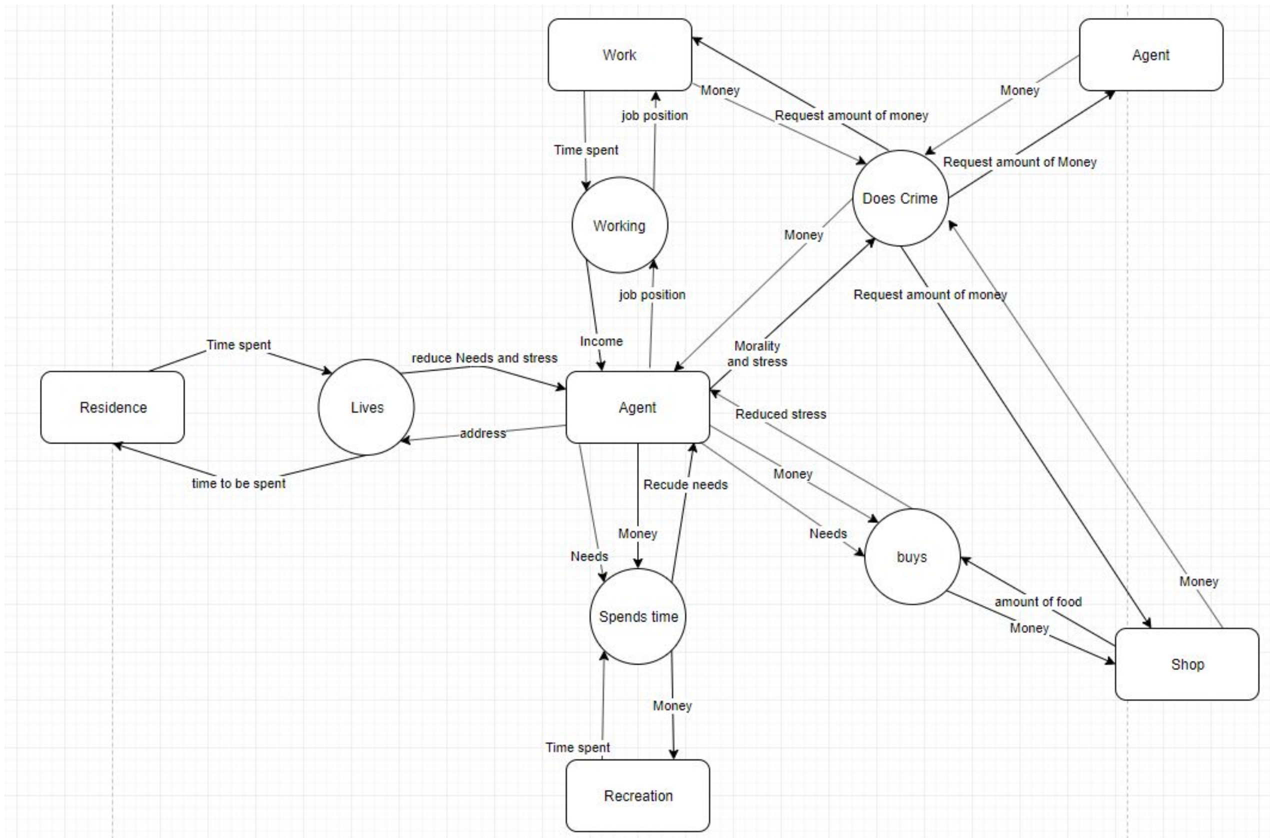
JFreeChart and Swing: Since the simulation will have graphing and real time statistical feedback, we will have to use good tools or libraries that can handle constant update rates of values and graphs. Such libraries from JFreeChart will be very useful to us as it can do that and it can be integrated with standard Swing framework.

MASON: Mason is a Java Toolkit that is used in the create of many different types of simulations. It provides an environment and the basic elements required to set up our simulation. It is highly programmable and implemented using the Java Development Environment. The toolkit has a GUI that we will be able to use to develop much of the basic functionality of the system.

Spring Framework: We will make use of the Java Spring Framework for dependency management and the inclusion of useful APIs. Spring will allow us to easily manage the dependencies that we require for the graphic libraries and APIs. It will also be useful for editing model configurations

5. **High-Level Design**

Data Flow Diagram:

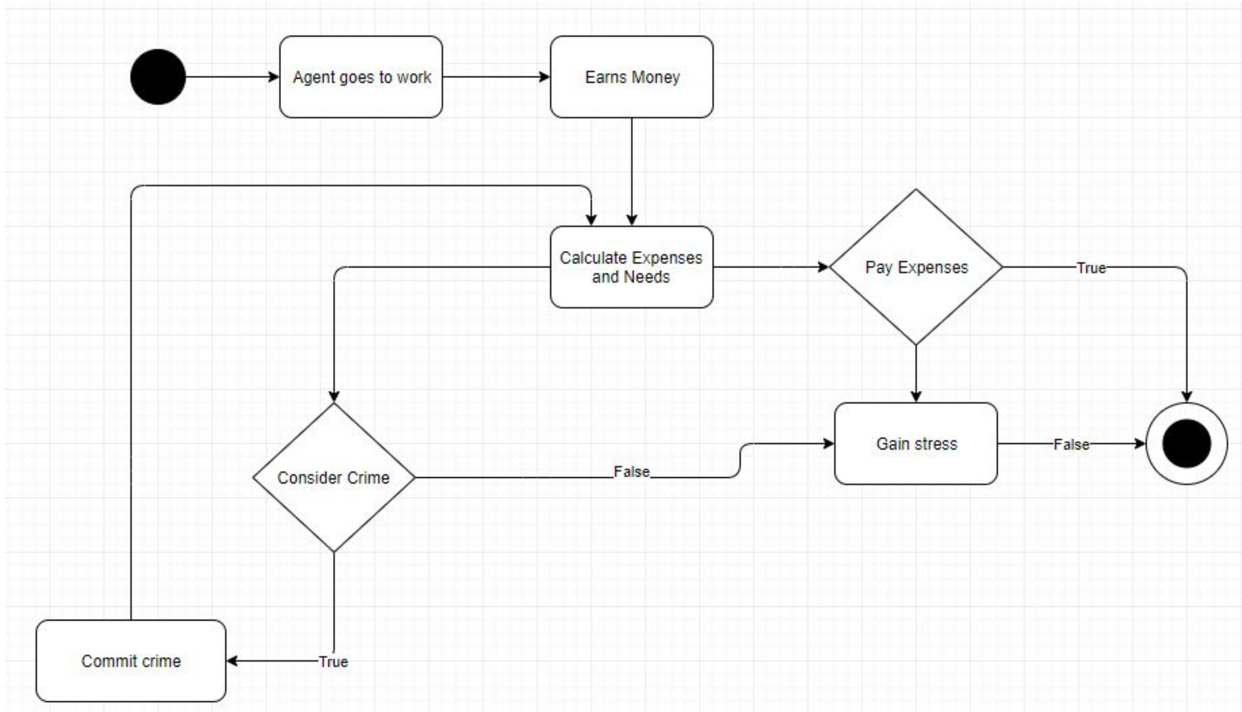


The above is a Data Flow Diagram depicting the several different interactions that an Agent will have within its environment. The Agent can interact with their Residence, Shops, Recreational places and Work for different reasons.

When it comes to crime, An Agent may Steal money from either a place of work, a shop or another Agent.

The flow of data between the entities can be seen in the diagram.

Activity Diagram:

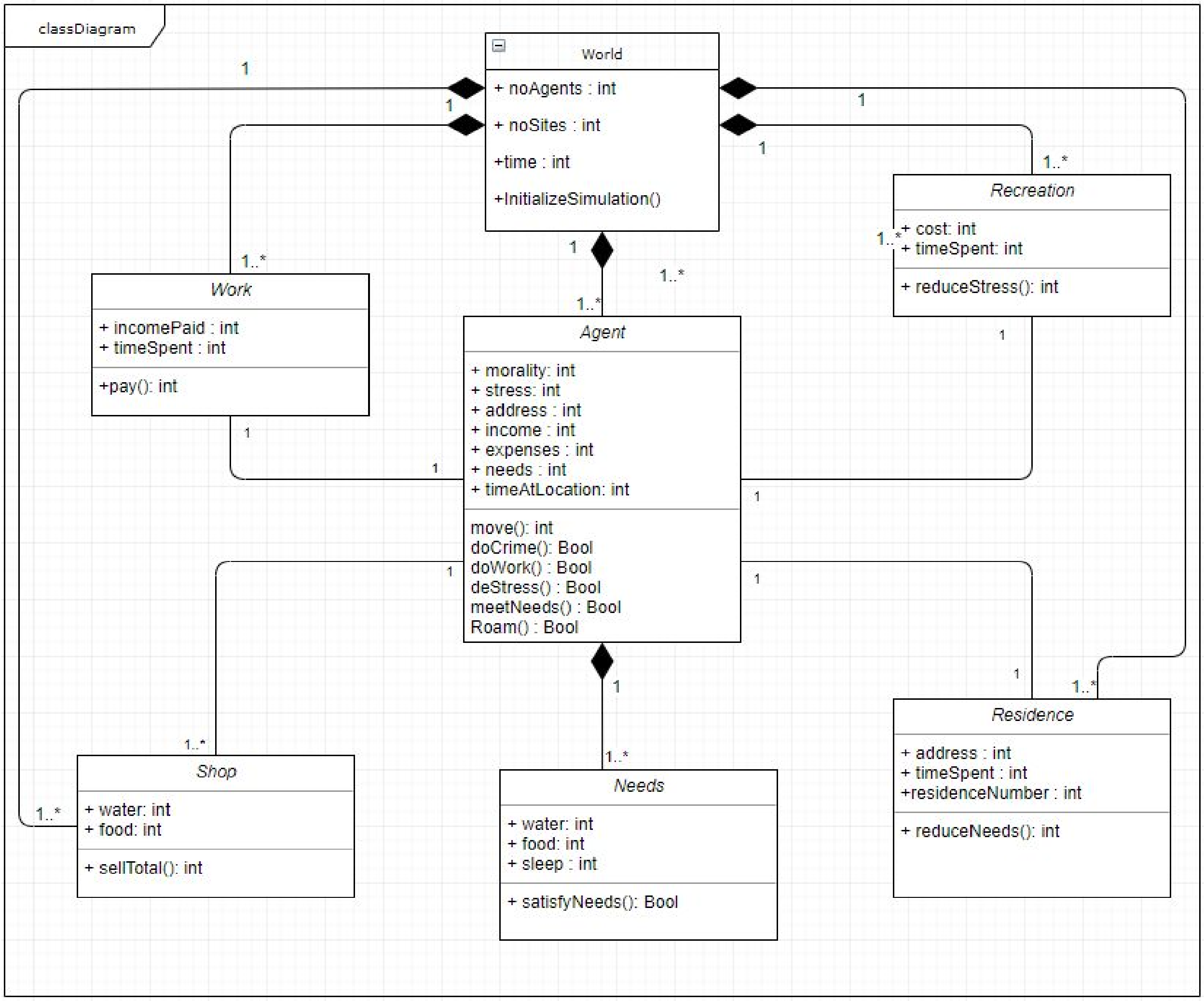


An activity diagram above, depicting how the Agent will act when needing money to pay general expenses.

The primary goal for an Agent is to earn money to pay weekly expenses (which could be anything from electricity bills to rent). Once an Agent has made a sum of money, they will calculate their expenses and Needs and then act correspondingly.

The agent may consider crime under certain circumstances, but failure to pay their weekly expenses results in an increase of stress for the Agent, which could be avoided if the Agent commits a crime.

Class Diagram:

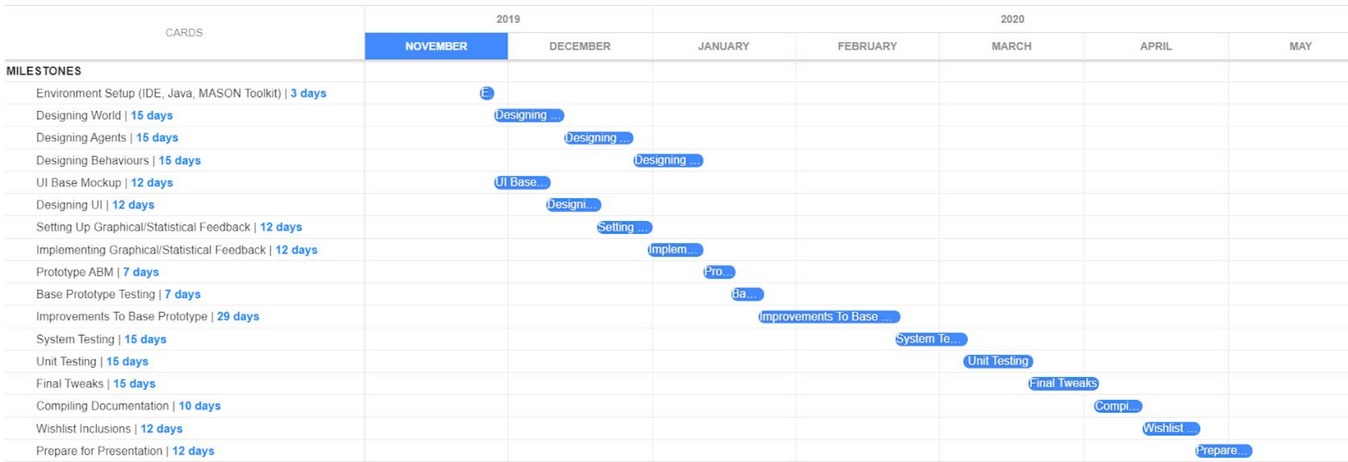


As shown in the class diagram above. The World will be used as an Agent's environment. It will keep track of the number of Agents and the different Sites. All the other classes will be dependant on the World as they will exist within the world.

Each Agent will have Needs which will be dependant on the Agent i.e. if there's no Agent there's no needs. They will have one place where they work, a place where they live, a place where they may do recreational activities and can visit shops to buy things to meet their needs.

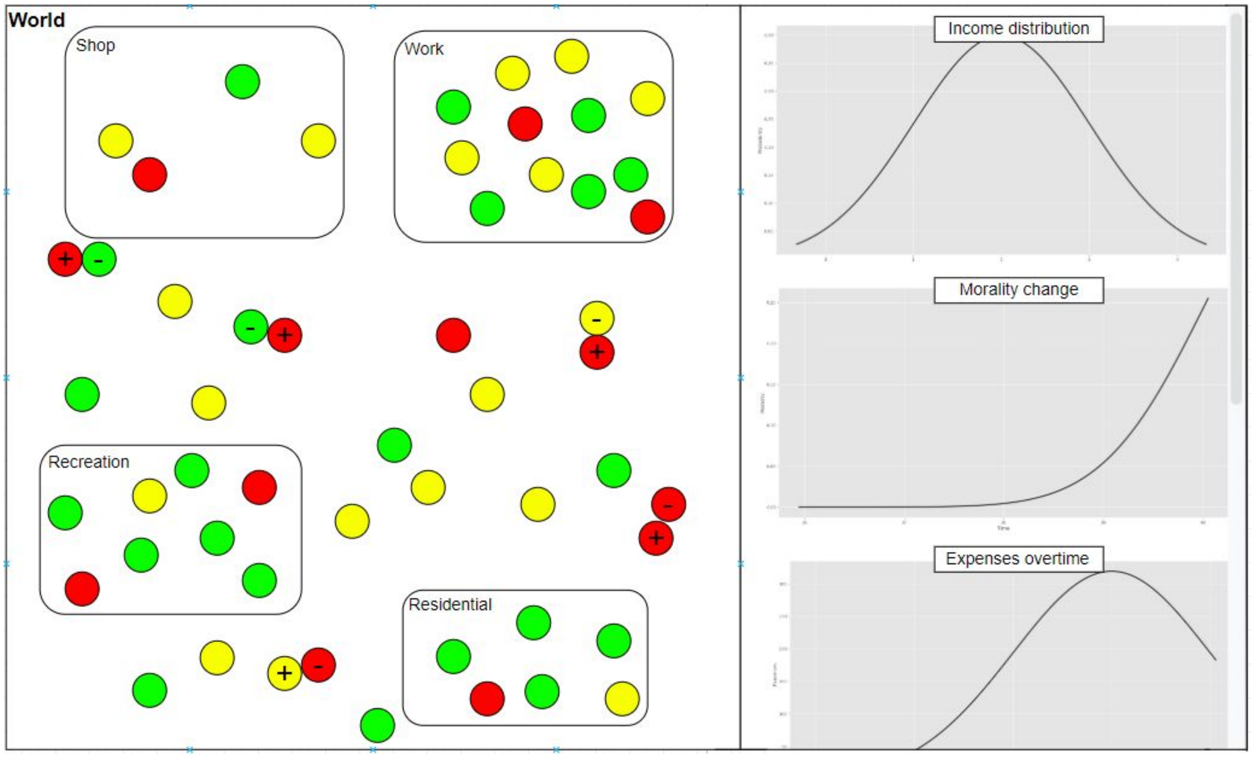
6. **Preliminary Schedule**

6.1 GANTT chart:



7. **Appendices** Specifies other useful information for understanding the requirements.

7.1 UI Mockup



The above diagram shows a rough idea of how the different interaction may occur between the agents. An Agent will seek another Agent if they want to steal from them.

An Agent's colour will vary depending on their Morality.

- A Red Agent signifies Morality close to 0%
- A Yellow Agent shows that the Moral of the Agent is close to 50%
- While Green shows that the Moral of an Agent is close to 100%

You can also see the interactions of the Agents with the different sites and a possible placeholder for real time graphs and statistics being generated on the right.

7.2 other Information for understanding the requirements better.

World:

The world is the environment in which you find each of the Agents and Sites. It can contain many different sites and dozens if not hundreds of agents.

An Agent may roam around their environment when not doing work or recreational activities.

Agents:

Agents are there to simulate people. They’re autonomous and interact with their environment in different ways.

Income: Every agent must earn money at a working Site. Once inside the site, the Agent will start earning money based on the amount of time spent inside the site.

Expenses: Agents must pay a varied amount of money based on the time spent inside of the society. This money will simulate their weekly expenses. This may include rent, food, insurance etc.

If an Agent is unable to pay these expenses, they will accumulate causing problems for the Agent later on in the simulation.

Varying income: Each agent will have a different set of income that will be calculated by a user determined range of numbers.

Morality: Each Agent has a morality meter. This meter will decrease depending on the stress put upon the Agent. If the agent needs money to pay their weekly expenses, their stress level goes up and their morality may decrease. If the Agent reaches a certain Morality threshold, they may end up committing a crime.

Stress: An Agent will gain stress if they cannot pay their weekly expenses. They may also gain stress if they are in dire need of food, water or sleep. The Agent may do some Recreational activities to reduce stress, but the agent will need some money to do so.

Crime: When an Agent has reached the Morality threshold, they may start committing crime. As shown in the diagram above. An Agent may steal money from another Agent if they become desperate enough. An Agent may also steal money from a Site.

Needs: Needs can be broken up into a food meter, a thirst meter and a sleep meter. These meters will gradually decrease and an Agent may replenish their respective meters by either going to a shop and buying food, or Sleeping at their residence.

Sites:

Work: This site is where an Agent will go to earn money.

Recreation: An Agent will decrease stress once in this site.

Residential: An Agent will come here to reduce stress and Sleep, Not as effective as a Recreational Site.

Shop: An Agent will go to a shop to buy things to meet their needs, such as thirst and hunger.

8.0 **References**

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