An Agent-Based Modelling Approach to Understanding Circular Economies

Samuel Moor-Smith
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Introduction

I will be working on a project as part of the Computational Social Science (COSS) Group under Prof. Dr. Dirk Helbing and Dr. Dino Carpentras. The project focuses on the concept of circular economy and especially on the question of how we can develop stable and reliable circular systems. This research question will be explored using agent-based models and agent-based simulations.

Circular economy

The circular economy is an economic model designed to minimize waste and make the most of resources. Unlike the traditional linear economy, which follows a "take, make, dispose" pattern, the circular economy aims to keep products, materials, and resources in use for as long as possible. This involves recycling, reusing, refurbishing, and remanufacturing products to create a closed-loop system, reducing the need for new raw materials and minimizing environmental impact.

In a circular economy, waste is seen as a resource, and products are designed with their entire life cycle in mind. By prioritizing durability, repairability, and recyclability, this approach helps reduce pollution, conserve energy, and promote sustainable growth. The goal is to decouple economic activity from the consumption of finite resources, creating a more resilient and sustainable system for future generations.

Circular economy can be built around the following principles:

1. Garbage is to be avoided.
2. Unavoidable garbage is to be recycled.
3. Unrecyclable garbage is to be disposed of in a generally acceptable way. ("allgemeinverträglich").
4. Inflow of primary resources is to be reduced.

5. Resources are to be kept in the system for a longer time.

6. Longer cycles are to be replaced by shorter cycles.

7. Replace non-renewable resources by renewable resources, in particular anorganic by organic ones, where possible.

Agent-Based Modelling and opinion dynamics

Citizens are key component in any social system, as they affect it through their actions, by voting or even just by manifesting their preferences, possibly affecting policy makers. Thus, the success of new technologies and new social systems heavily depend on the citizens' preferences on such topic.

When many autonomous agents (people, companies, countries, animals, etc.) are allowed to act independently and interact with each other, we witness the emergence of a complex system. Agent-based modelling (ABM) is a computational approach to simulate the actions and interactions of these agents in a network in order to better understand the resulting system.

Opinion dynamics is a sub-field of agent-based modelling focused on the study of public opinion. Specifically, it focuses on how opinions form and evolve over time in a population. For this reason, opinion dynamics models are extremely valuable to explore and understand how people would react to new systems such as one based on circular economy.

Tasks

The Economic model

For this project, I will explore 2 different agent-based models. The first one will model a "toy" economy consisting of agents (producers, consumers, and recyclers) in a "resource flow" system. The system will be broken down as follows:

1. The system will be set up as a graph with each node being either a Producer, a Consumer, or a Recycler.

2. The actions of each agent will depend on their role and an actions' "value" score. This value score will ideally represent how much the circular economy benefits them - and in particular, how effective is any action in the current system.

3. At each time step, the "value" scores of all agents are updated based on the actions of their neighbouring nodes.

The opinion model

In order to better understand how personal opinion may affect the adoption of a system based on circular economy, I will also explore opinion dynamics models.

As these models are often studied in a purely abstract way (i.e. without relying on real world data), the goal of this task will be to fit opinion dynamics models (e.g. the Deffuant model) to real-life data, such as climate awareness data. An example of how this can be carried out is:

1. The system is set up with N agents. each with a vector of values that associate to their beliefs from the European Social Survey (ESS) data.

2. At each timestep, two agents are randomly selected and interact according to the model's rules. This will generate a time series of simulated opinion data.

3. I will use an optimizer (such as the gradient optimizer) to find a model/parameter combination that fits the dynamic real-world data (e.g. a time series from the ESS).

Having validated models (i.e. models that have been tested against real-world data) will allow us to test how easily a population will adopt a new system such as one based on circular economy.