6CCS3AIN AI Reasoning & Decision-Making

Consensus Mechanisms

Week 9 – Part A – Introduction

Peter McBurney
Department of Informatics
King's College London
London

peter.mcburney@kcl.ac.uk

Week 9
30 November 2020

Consensus Mechanisms

- This week, we are going to look at some different mechanisms by which a collection of agents can reach consensus on some question.

- There are three parts to the lecture:
  - Part A is an Introduction given by me
  - Part B is Voter Models (aka Flag Colouring) given by Dr Kohan Marzagão
  - Part C is on Consensus in Blockchain, and is given by me.

- We will touch on some of the models and mathematics involved.

Image: Charley Harper

Intermission

First, I ask you to pause this presentation and look at the following video, about some small robots called Kilobots:

https://www.youtube.com/watch?v=rdM_xJkfn6k

Kilobot robots are 3.3cm tall and were developed from 2010 by Radhika Nagpal & Michael Rubenstein at Harvard University. They were intended to be low-cost robots for the study of swam robotics. They can be purchased from K-Team in Switzerland.

Image: Charley Harper

Assumptions I

- We have multiple agents or computational entities
- Each agent is programmed with the same program
- Each agent is connected to zero or more others
  - either they are linked together, or they can see each other
- So each agent has a local neighbourhood with a finite set of neighbours
- We can represent this situation as a graph
  - with agents as nodes, and "the connections" between them as edges
  - We use the terms "agent" and "node" interchangeably.

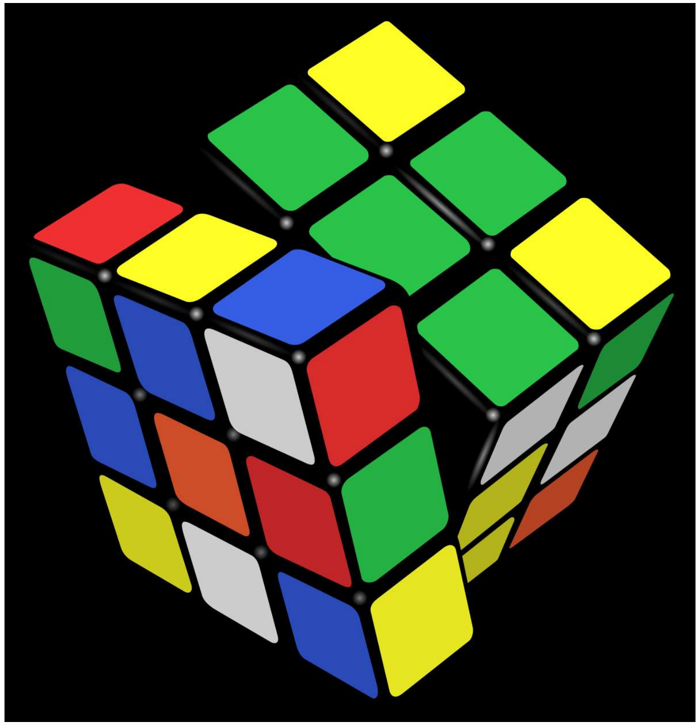
Assumptions 2

- We assume each agent can take a finite number of states (often called "colours").
  - For example, they can be either Blue or Red
- Interactions proceed in a series of rounds (or editions)
  - Each round, each agent has to decide what state (colour) to be in
  - Agents make their decision according to an algorithm (which could be random)
  - All agents are using the same algorithm
  - The algorithm may first check the colours of the neighbours in the previous round.
- We assume the agents share a common goal to achieve an overall configuration of states, eg:
  - All nodes have the same colour
  - No two adjoining nodes have the same colour
  - The colours alternate (if the nodes are in line or a circle),

Questions a computer scientist would naturally ask

- If each agent can have a finite number of colours, will they ever converge to the desired configuration?
- Is convergence possible from a random start?
- If convergence is possible, what is the probability of convergence?
- If convergence is possible, how fast will the nodes converge?
- Are deadlocks possible?
- Are cycles possible?
- Can convergence be facilitated from particular starting configurations?

A problem domain with similar questions: Rubik's Cube



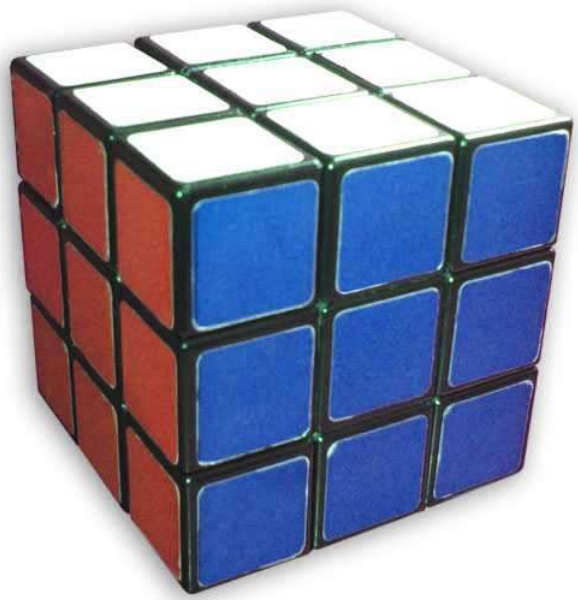


Image source: Wikipedia

Questions an agents person would naturally ask

- What happens if one or more agents are not following the common algorithm?
- For instance, what if one agent is malicious and does not wish to achieve the common goal (of a particular configuration)?
- What if one agent has the same shared goal but has buggy code?
  - It is often difficult to distinguish malice from bugs when we can only observe the agent's external behaviour
- What if one or more agents are temporarily offline?
- Can the agents protect themselves from a malicious or buggy agent? Can the other agents isolate the influence of the dissident agent? Can the other agents even identify dissident behaviour?

Applications I

- Robot bucket brigades
  - Each robot has to be either giving or receiving a bucket at each round
  - So the desired configuration is alternating colours.

Bucket Brigade, Dresden, Germany
After WW II
Source: Wikipedia

Applications 2

- Consensus in distributed systems (eg, blockchains)
  - We will talk about this in Lecture 9 Part C

- Designing and managing swarms
  - Birds in flocks and bees in swarms seem to continually adjust their speed and trajectory according to the birds they can see around them
  - We can create similar algorithms for swarms of autonomous vehicles, such as flying drones or convoys of ships or convoys of road vehicles.

Image Credit: Rolls Royce Blue Ocean

Thankyou!