CASA0011: Agent-Based Modelling

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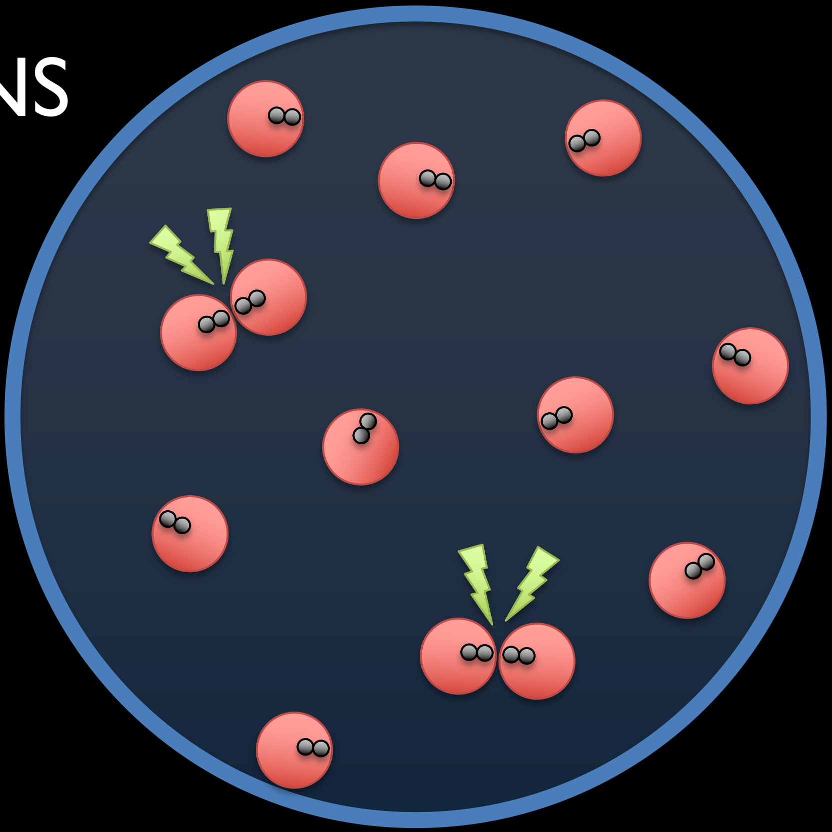


SugarScape

PRACTICAL/TUTORIAL!

Week 1: Introduction to ABMs

Week 2: Cellular Automata

Week 3: ABM Methodology

Week 4: **Agent Behaviours**

Week 5: ABMs as Research Tools

READING WEEK

Week 6: Testing ABMs

Week 7: Presenting Results

Week 8: Forecasting & Prediction

Week 9: Traffic Modelling

Week 10: Retail Markets & Gentrification

The ABM Course

Feedback

FROM MOODLE:

None!

FROM SLACK:

Cool models!

Last Week

- Consider the sort of research questions that are suitable for ABM
- Consider how ABMs can be constructed from a theoretical understanding of local processes.
- Consider different perspectives on ABMs to provide a broad range of ideas for your own projects.
- Learn how to use the ODD Protocol to plan and communicate ABMs

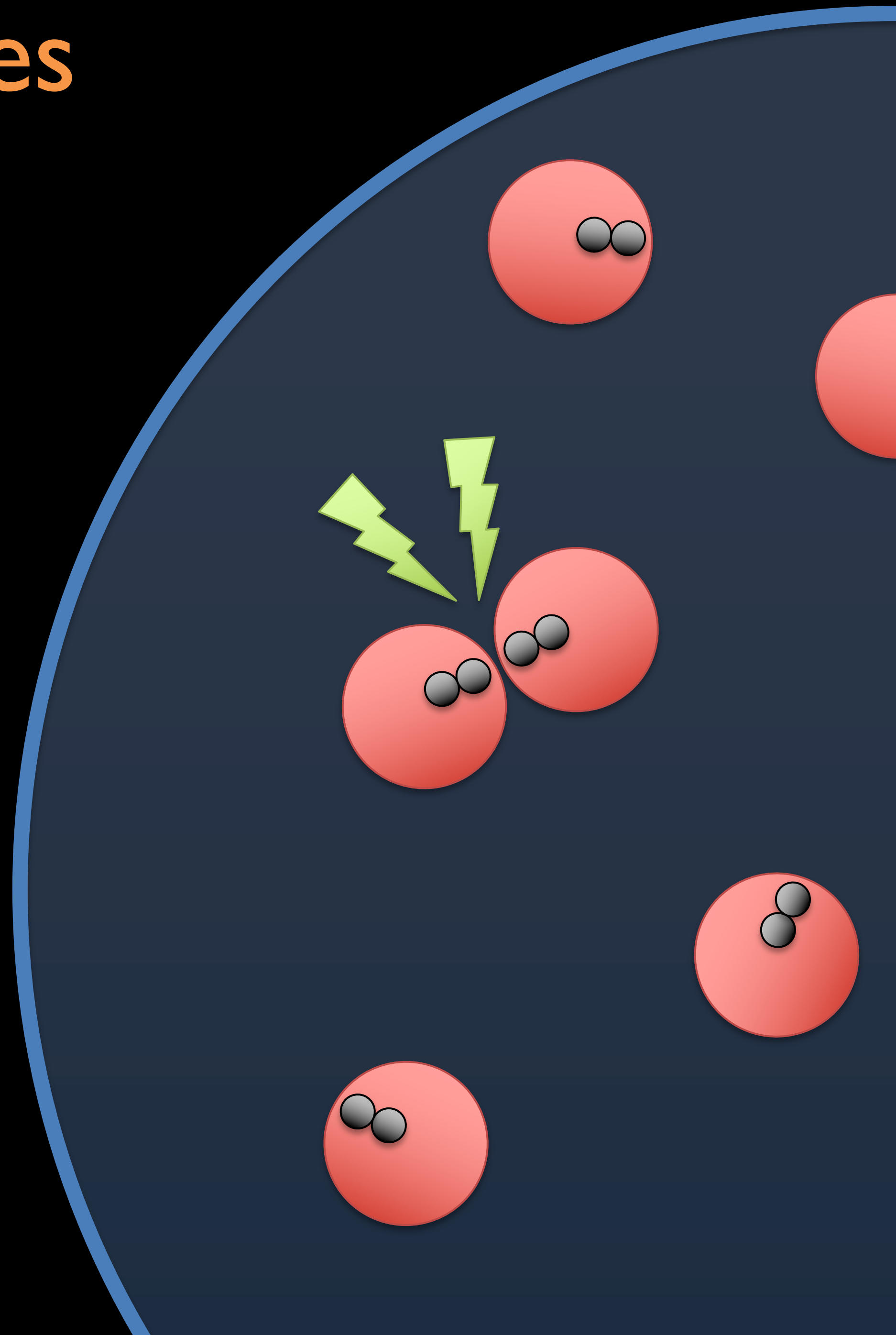
Session Objectives

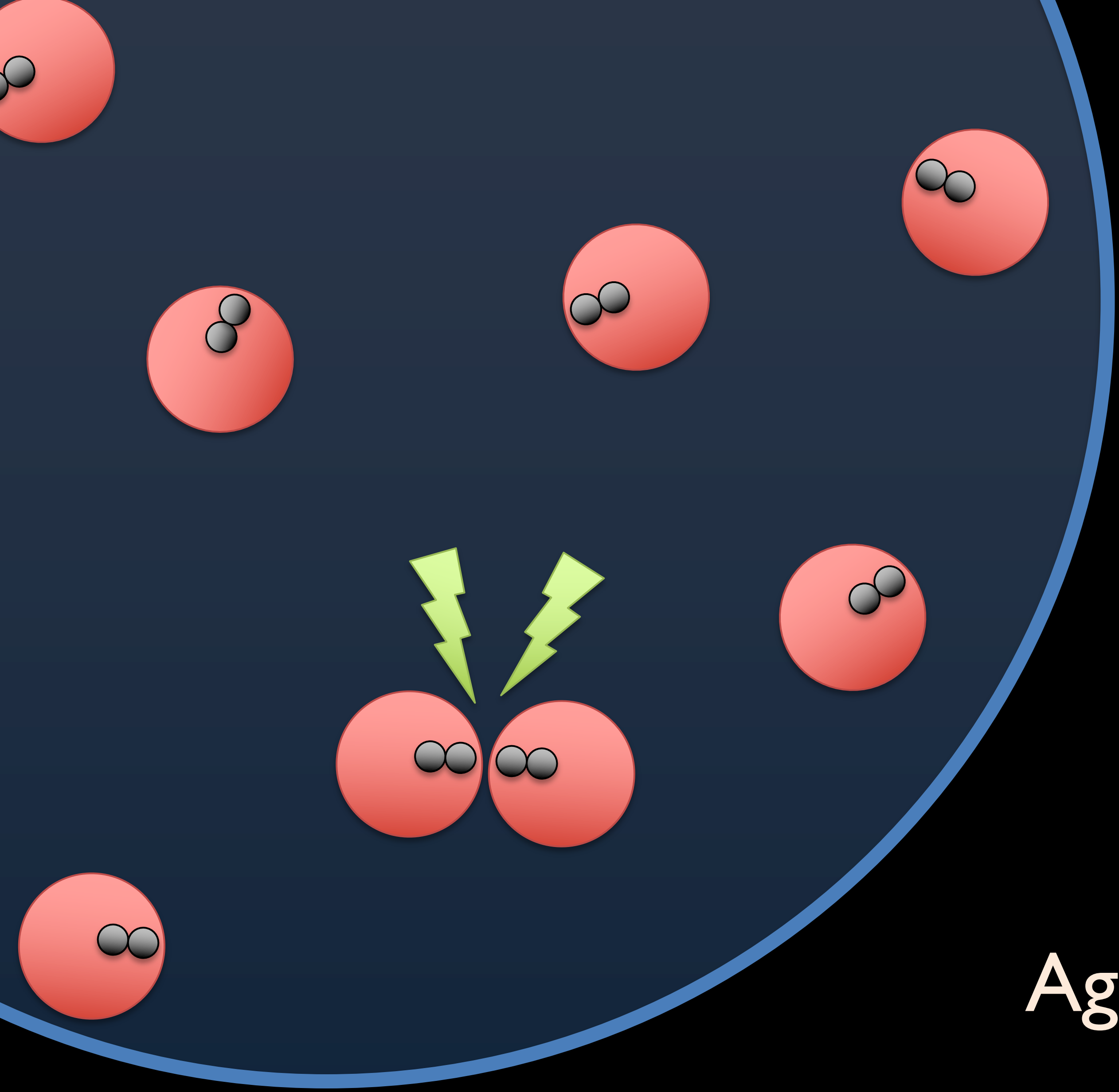
You should be able to...

Describe how learning, adaptation, and memory can influence agent behaviours

Explain different behavioural models

Describe pattern-oriented modelling and its use





LECTURE 4

Agent Behaviours

What do we mean by behaviour?

Actions taken

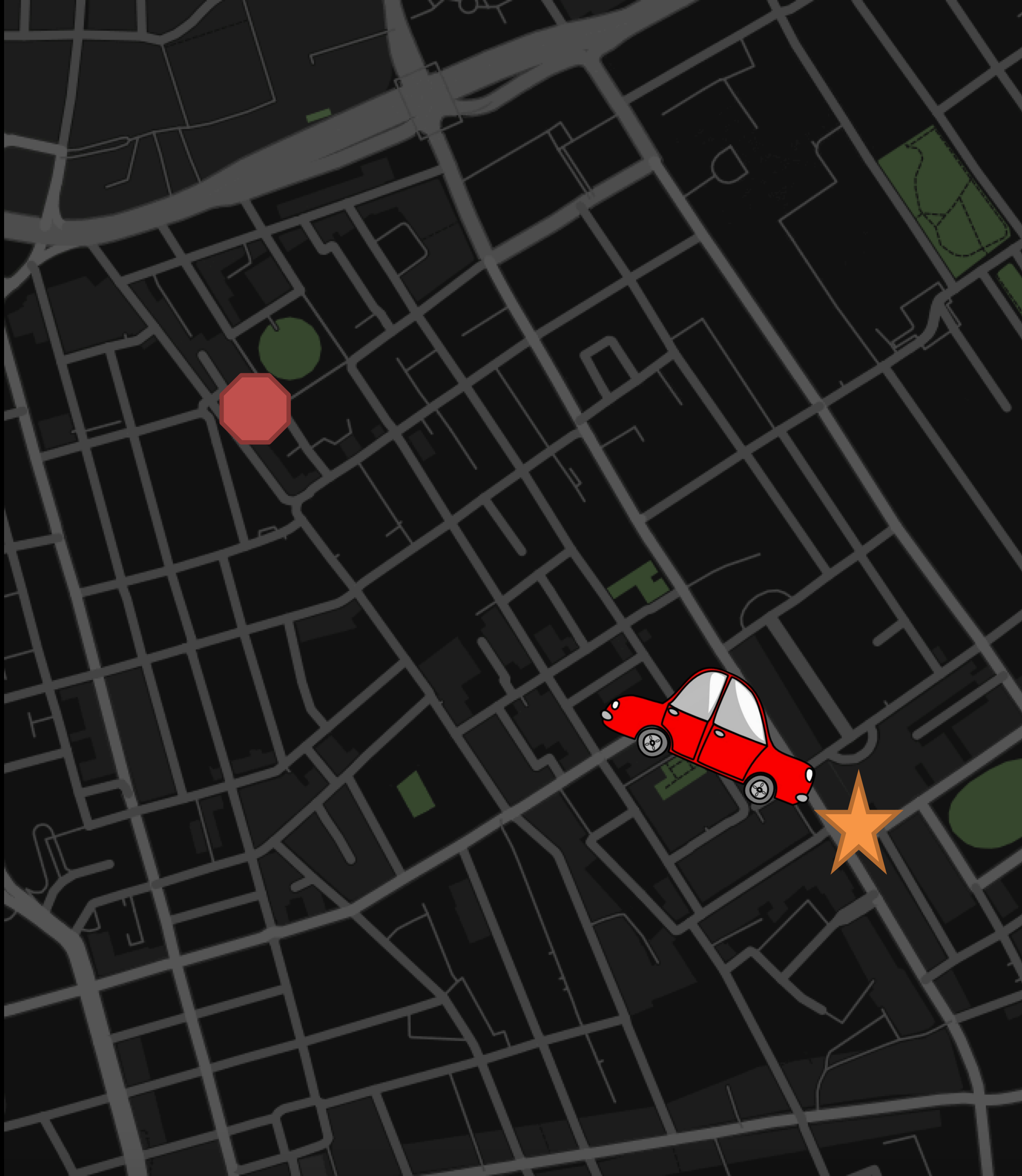
Coding definition: a method

Behaviour implies there is the potential for changes to 1+ of:

- personal attributes (e.g. wealth, knowledge, speed)
- the environment (e.g. position of agent, amount of resource)
- other agents (knowledge, position)

Things like…

- Optimising/satisficing over some set of parameters
  - heuristics versus optimisation!
- Interaction with the environment (movement!)
- Interaction with other agents
  - through environment or various networks
  - Mixing: uniform? Preferential?
- Learning/adapting



Stupid Agent

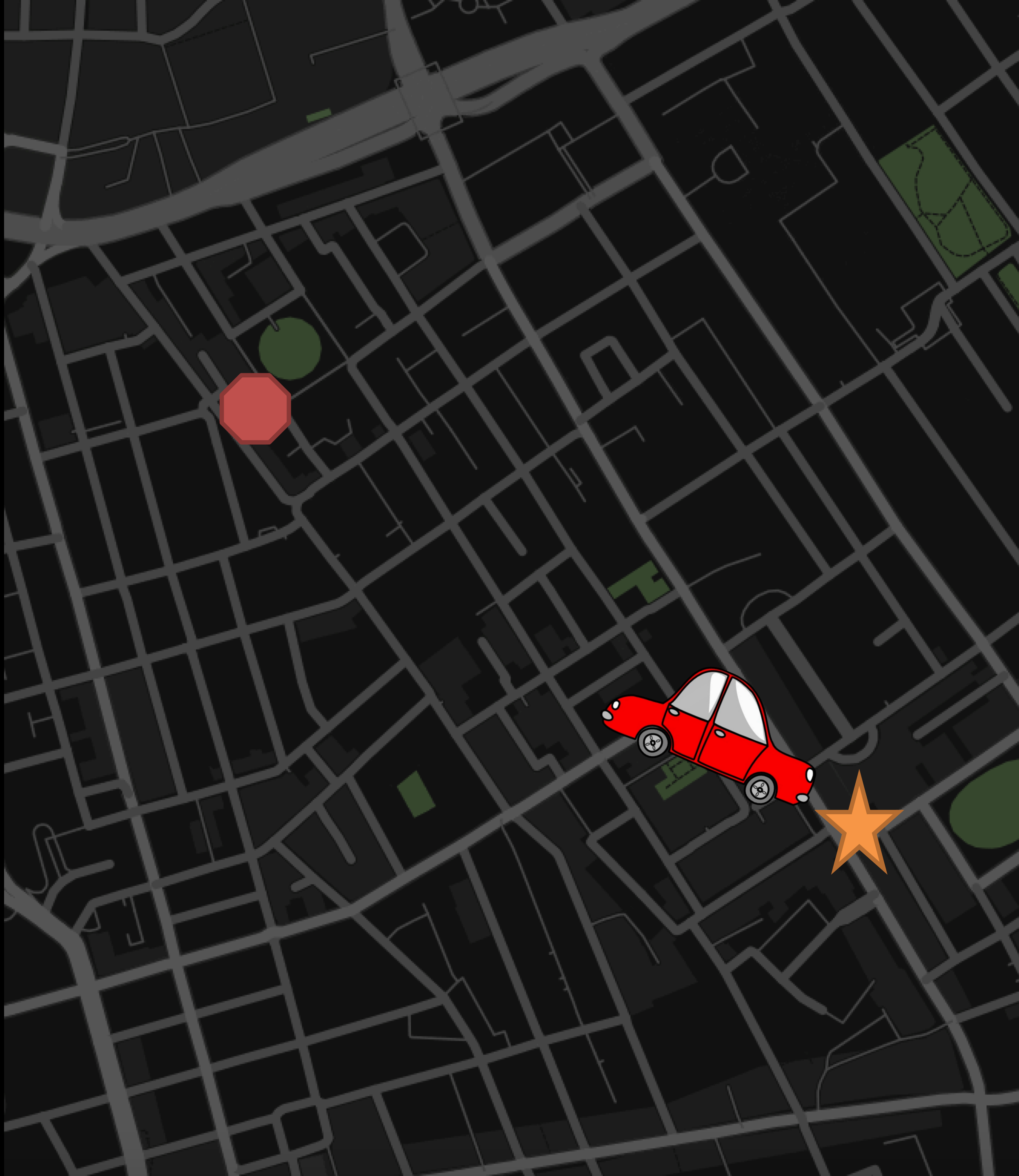
Attributes:
Current Location
Goal

Methods:
CheckIfAtGoal
TakeRandomRoad

Procedure:

Check if the agent has reached its goal.

If it has not, select a connected road at random and travel over it.



Sensing Agent

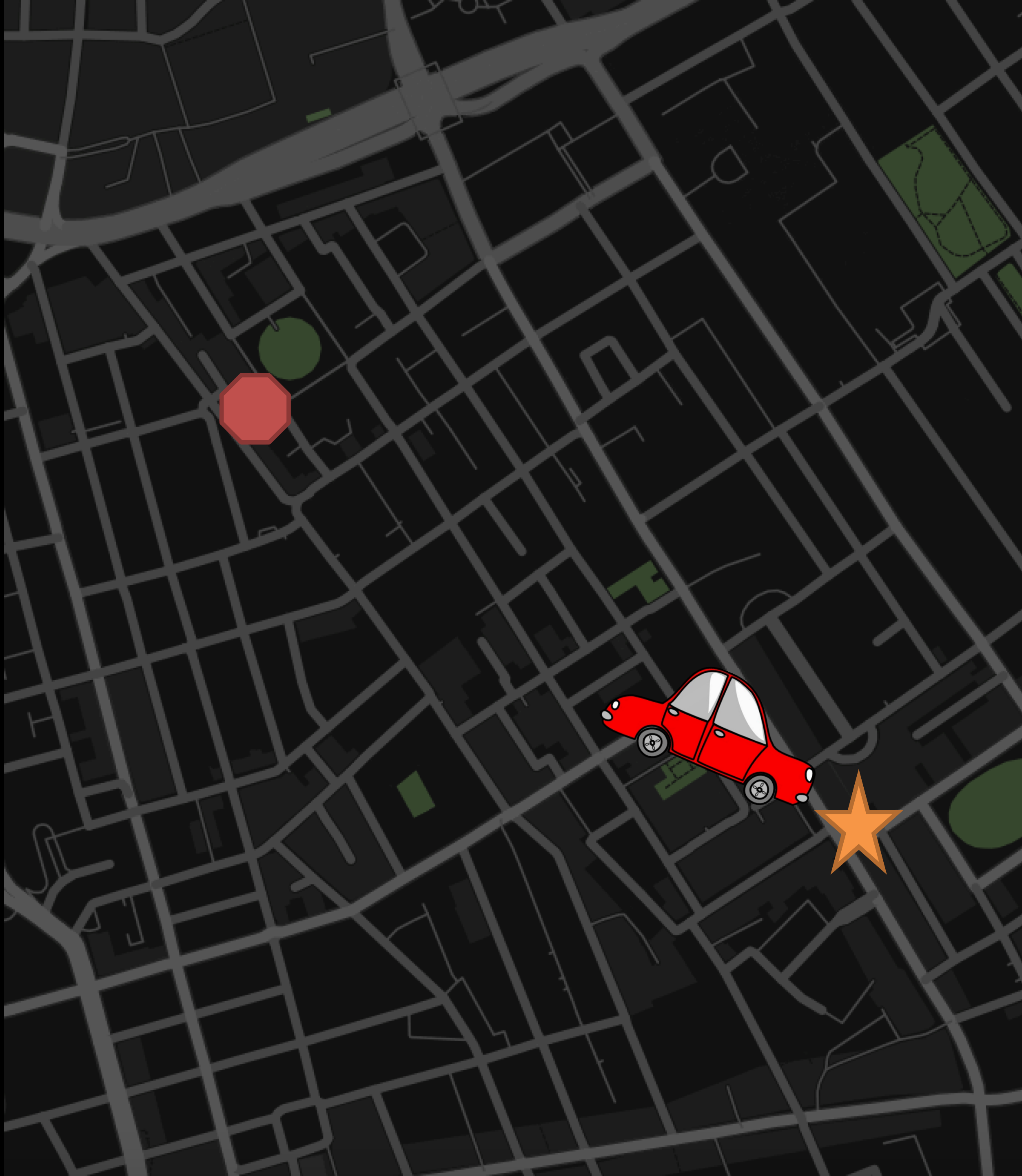
Attributes:
Current Location
Goal

Methods:
CheckIfAtGoal
TakeBestRoad

Procedure:

Check if the agent has reached its goal.

If it has not, select the road whose *endpoint is nearest* the Goal point and travel over it.



Smarter Agent

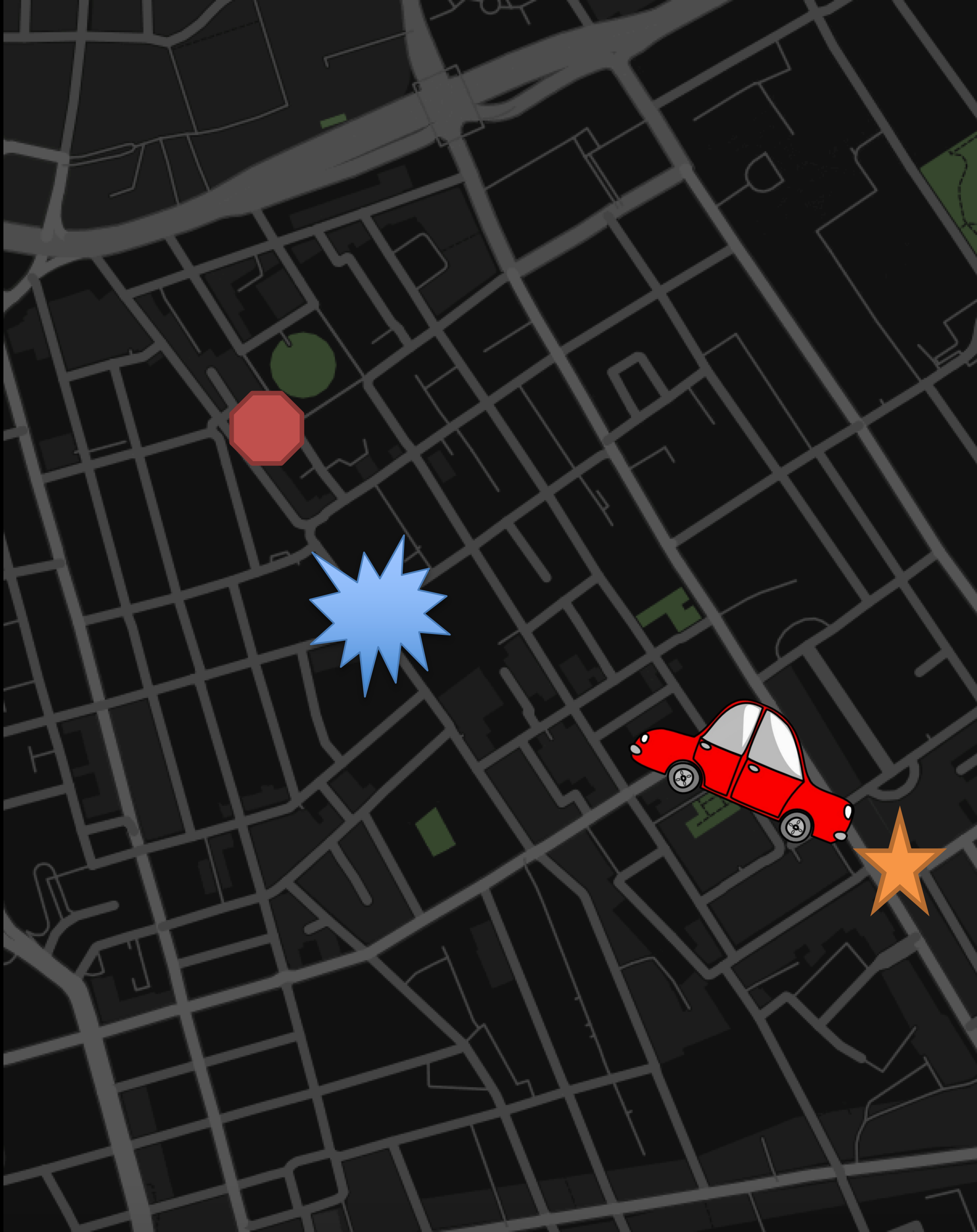
Attributes:
Current Location
RemainingPath
Goal

Methods:
CalculatePathToGoal
CheckIfAtGoal
Move

Procedure:
Check if the agent has reached its goal.

If not, if the remaining path has a road in it, take that road.

Otherwise, if the remaining path is empty, calculate a path.



Roadblock Agent

Attributes:

Current Location
RemainingPath
KnownBlockages
Goal

Methods:

CalculatePathToGoal
CheckIfAtGoal
Move (returns false if blocked)

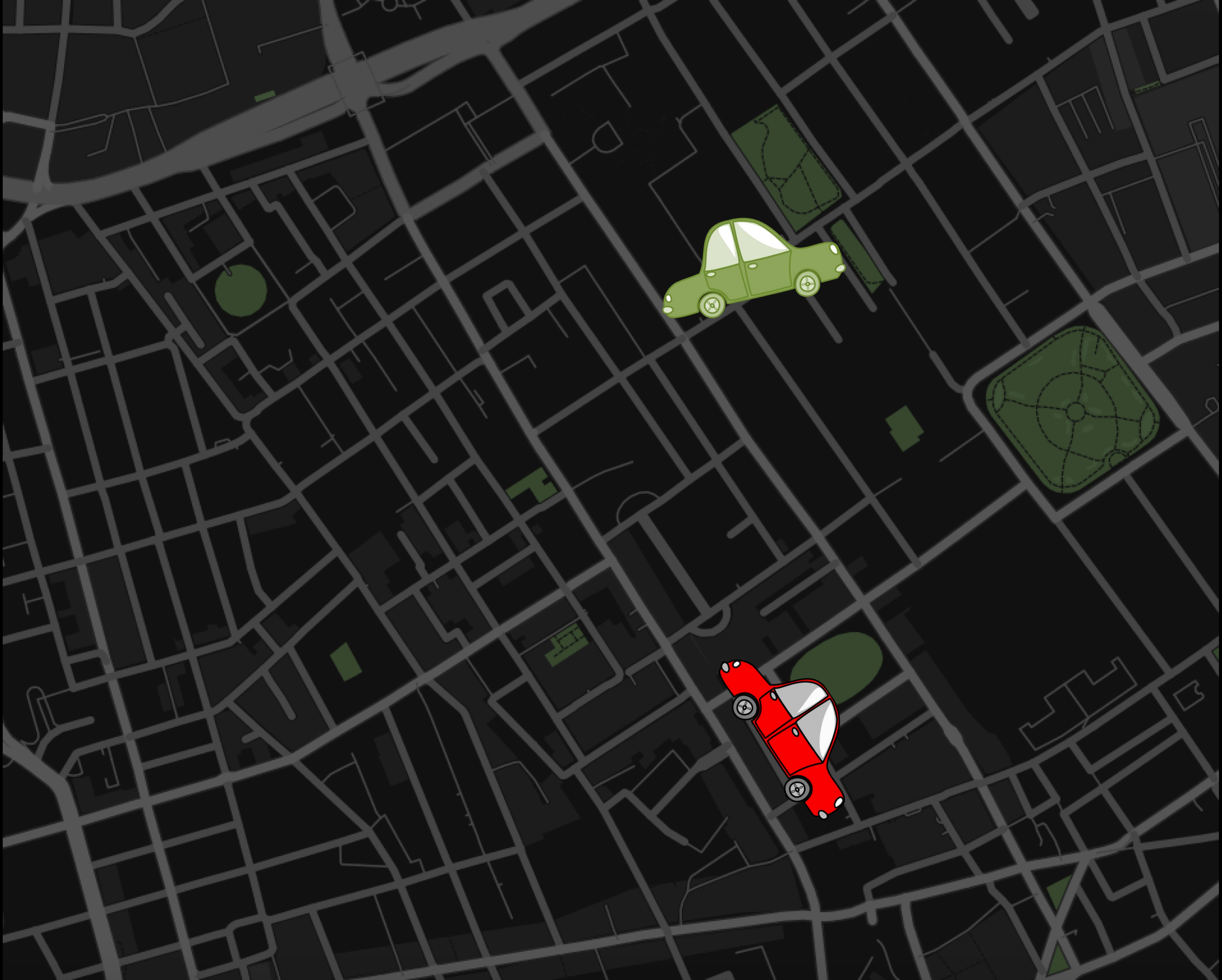
Procedure:

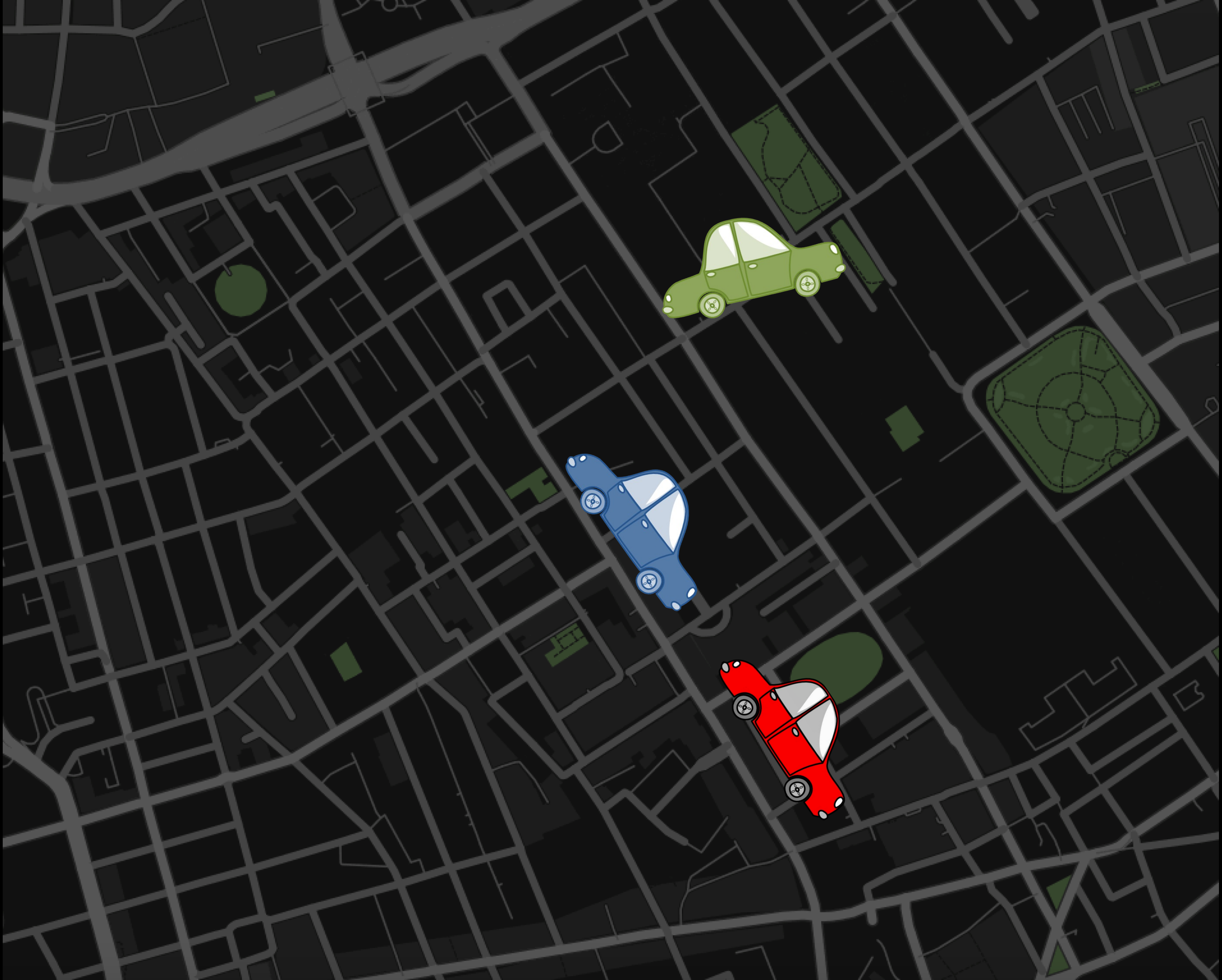
Check if the agent has reached the goal.

If not, if the remaining path has a road in it, take that road.

If the road is blocked, stop moving, record the blockage, and set the path to empty.

If the remaining path is empty, calculate a path. **If that path is null, return an error!**





Some Other Factors to Consider

- Knowledge and its representation
  - bounded rationality
  - memory/history
  - how complex do you want to go?
- Impact of individual attributes on behaviours
  - heterogeneity
  - agent roles?
- Activation order

BEHAVIOURAL MODELS

How Do We Model Behaviour?

Three approaches: mathematical, cognitive frameworks, and cognitive architectures

Kennedy, 2012

- **Mathematical:** simple but brittle; low-level
  - Granovetter's Thresholding (1978)
  - Gode and Sunder (1993) randomly choose a behaviour
- **Cognitive Frameworks:** conceptual way to structure your work
  - Belief, Desires, and Intentions (BDI) - Rao & Georgeff (1991) possible worlds model
  - Physical, Emotional, Cognitive, and Social factors (PECS) – Schmidt (2002) model of self and environment, memory, motives
  - Fast and Frugal - Gigerenzer & Goldstein (1996) heuristics based on data
- **Cognitive Architectures:** modelling cognitive functioning
  - Google DeepMind (https://www.deepmind.com/)
  - ACT-R: all memory is declarative or procedural (https://act-r.psy.cmu.edu/)
  - Soar: fixed computational building blocks (https://soar.eecs.umich.edu/)

Example of Mathematical: Utility Functions

Basic idea: production increases with

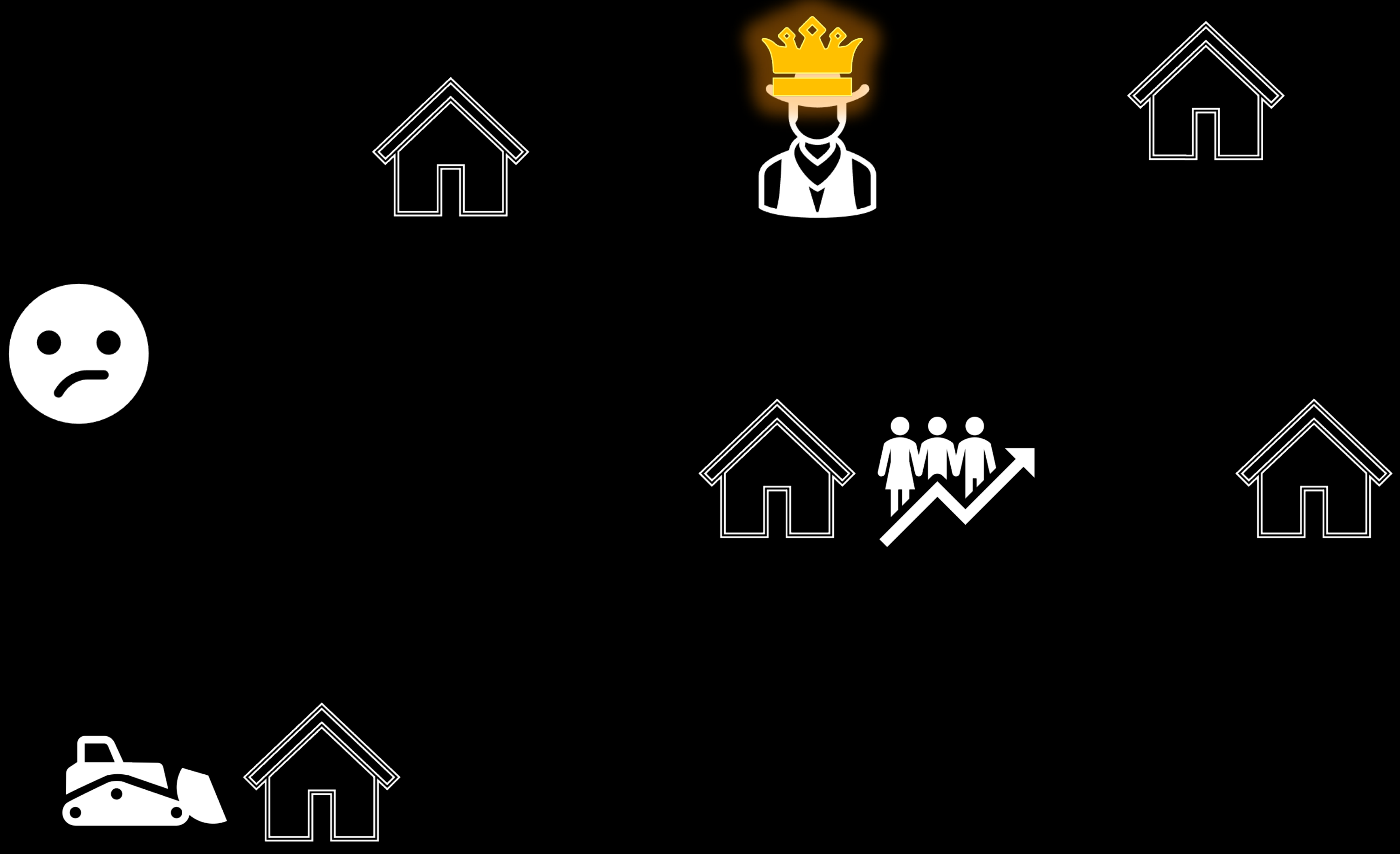
- Capital
- Labour

Example of Mathematical: Utility Functions

The bandits **take** resources, based on how big their group is and how far they have to travel.

Attacks also decrease labour!

Example of Mathematical: Utility Functions



Example of Mathematical: Utility Functions

Bandits

choose where/whether to plunder/tax

s = size of group

d = distance to village

R = resources of village,

r_e = rate of plundering efficiency

r_t = rate of taxation

Cost of movement: $C_m = f(s, d)$

Cost of attacking: $C_{att} = f(r_e, R)$

Cost of taxation: $C_{tax} = f(r_t, R)$

Village

produce based on resources

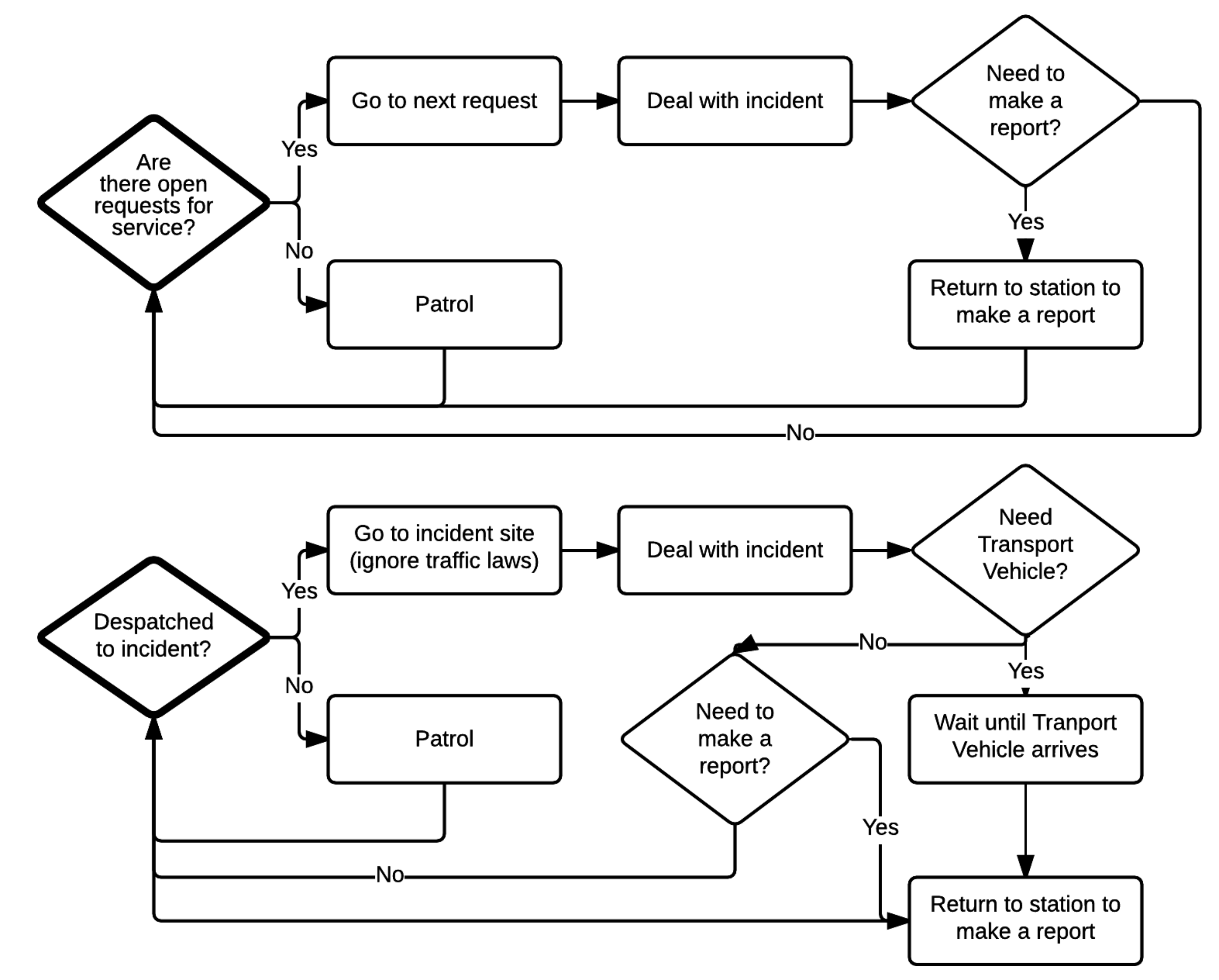
K = capital

L = labour

α = weighting of importance

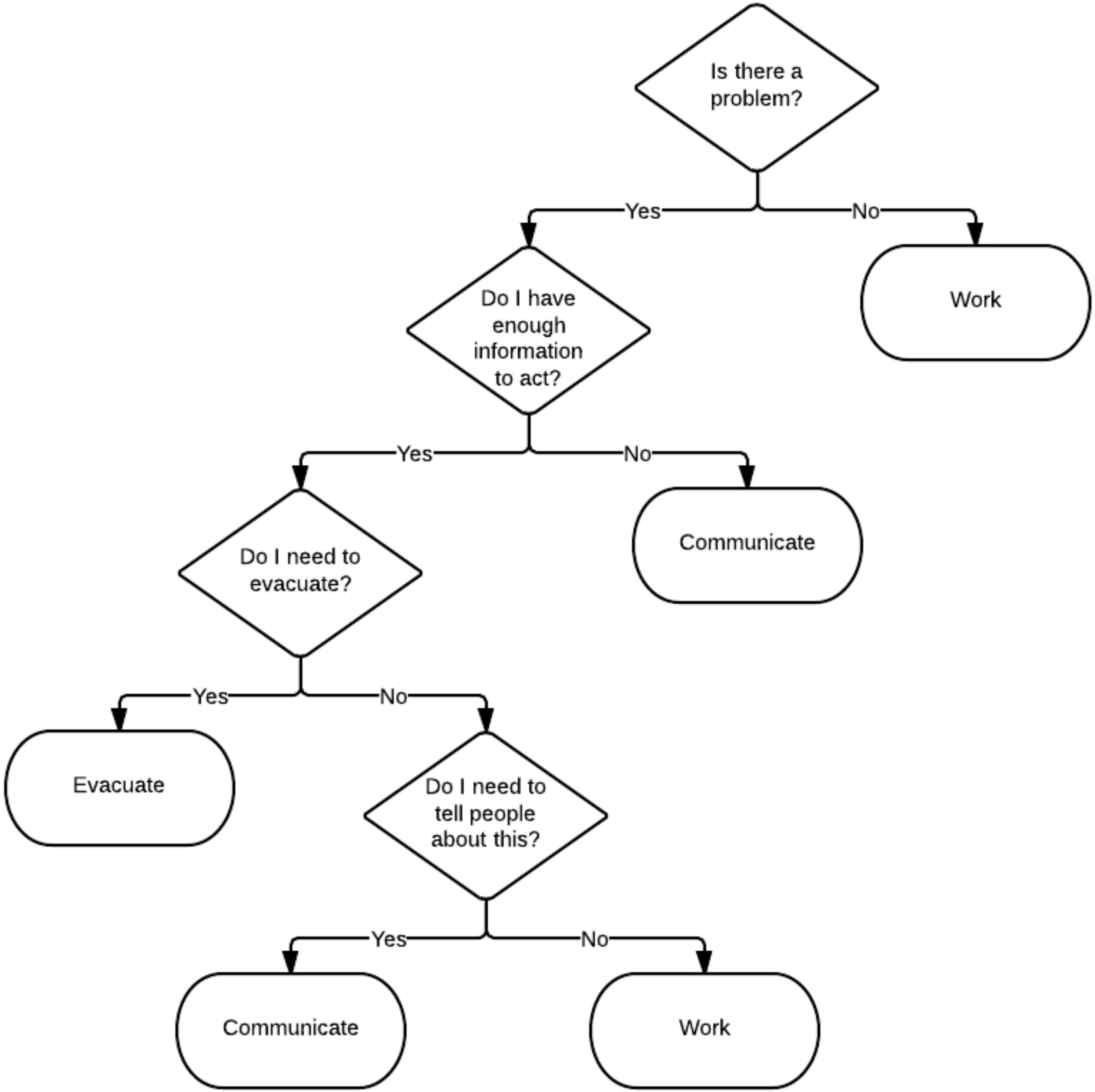
Production $P = K^{\alpha} L^{1-\alpha}$

Flowchart



Go to next request
Deal with incident
Need to make a report?
Are there open requests for service?
Yes
No
Patrol
Yes
Return to station to make a report
No
Go to incident site (ignore traffic laws)
Deal with incident
Need Transport Vehicle?
Despatched to incident?
Yes
No
No
Yes
Patrol
Need to make a report?
Wait until Tranport Vehicle arrives
Yes
No
Return to station to make a report

Fast and Frugal



PATTERN-ORIENTED MODELLING

What is Pattern-Oriented Modelling?

Researchers can "use multiple patterns as indicators of a system's internal organisation"

- Railsback & Grimm, p 228

Using “patterns” to:

- design the model's structure
- develop and test theory for agent behaviour
- find good parameter values

In essence: making sure a system works across a range of different dimensions!

Defining Patterns

A pattern is "**anything beyond random variation**"

R&G, p 228

"**stylised facts** are broad…generalisation of empirical observations and **describe essential characteristics** of a phenomenon"

R&G citing Heine et al. 2007, who are in turn citing Kaldor 1961

- strong vs weak patterns - e.g. distinct cut-off versus parameters staying within a range as system responds in characteristic ways
- The hard part: **definition** of criteria for when a pattern is matched!

Designing A Model Structure

- Formulate model: minimally necessary entities, state variables, and processes. (Should "seem too simple to possibly be useful”)
- Identify set of observed patterns you believe to characterise system **relative to the problem at hand**
  - 3-4 normally, 2-6 at extremes
  - maximise **independence** of patterns
  - rank patterns by **importance of characterising** the system
- Define pattern-matching **criteria**
- Review draft model to ensure it's possible for characteristic patterns to emerge from it. Confirm:
  - any processes driven by things not in the model?
  - new variables, outputs needed to observe whether patterns are reproduced?
- Build and calibrate model - THEN test matching of patterns!!

discipline: system	question	patterns used	use of patterns	major insights
behavioural ecology: goose foraging in farm fields [23]	how is the decision to forage in groups affected by the foragers' information on habitat quality and on group benefits?	seasonal difference in flock size increasing number of geese foraging on wheat from mid-April seasonal changes in differences between roost and foraging sites higher exploitation of rice fields that are farther away from the roost seasonal pattern in the rate of fat deposition	model selection (four alternative submodels for decision making)	the submodel assuming incompletely informed foragers with benefits of group foraging best reproduced all five patterns
landscape ecology: elk foraging and habitat selection [24]	what are the effects of roads on the distribution and foraging movement of elk?	proportion of elk observations occurring within 11 road proximity intervals and six general classes of vegetation	model selection (four alternative movement models)	elk responses to growing road networks are nonlinear, exposing thresholds for road density effects
microbiology: cyanobacteria in laboratory cultures [25]	what are the biochemical mechanisms driving the circadian clock of a unicellular cyanobacterium, and how does the clock affect fitness?	time series of the concentration of 20 different types of molecules, under a variety of growth conditions	parametrization (manually and by visual inspection)	unrealistic model output led to the identification of a missing process
population ecology: European eel populations [26]	how can watershed management increase the biomass of spawning eels?	silver eel production in a watershed is not unlimited decreased recruitment leads to changes in sex ratios, favouring females eel abundance in rivers decreases exponentially with distance from the sea sex ratio changes in favour of females with distance from the sea sex ratio changes with increasing recruitment, from purely female to purely male (related to second pattern)	model design model selection parametrization	recommendation for management to concentrate mitigation efforts on the downstream part of the watershed
plant ecology: treelines (ecotones) [27]	does the array of processes underlying tree line formation vary among sites, or do local heterogeneities and site idiosyncrasies dominate over prevailing mechanisms?	density of seedlings, adults and krummholz individuals mean height of individuals (excluding krummholz) at different locations along the treeline transect (data from field studies on four sites)	parametrization (using summary statistics, likelihood functions and Monte Carlo Markov Chain methods) model selection (based on Aikaike Information Criterion)	variation in tree line physiognomy observed at four sites reflects changes in the relative importance of certain nonlinear responses
community ecology: stream fish communities [28]	how do patterns of fish diversity emerge in river networks?	local species richnesss (LSR) in different geographical regions which directly drain to a group of streams (mean LSR as a function of topological distance to outlet; frequency distribution of LSR)	model design model selection (dispersal kernel) parametrization	neutral theory, implemented via meta-community models, can reproduce biodiversity patterns of stream fish in dendritic river networks (if appropriate dispersal kernel and local capacities are assumed)

(*Continued.*)

Grimm & Railsback, 2012

QUESTION: how can watershed management increase the biomass of spawning eel?

1. silver eel production in a watershed is not unlimited
2. decreased recruitment [i.e. # of new eels arriving in the watershed] leads to changes in sex ratios, favouring females
3. eel abundance in rivers decreases exponentially with distance from the sea
4. sex ratio changes in favour of females with distance from the sea
5. sex ratio changes with increasing recruitment, from purely female to purely male (related to #2)

Lambert, P. & Rochard, E. 2007 Identification of the inland population dynamics of the European eel using pattern-oriented modelling. Ecol. Model.206, 166 – 178.(doi:10.1016/j.ecolmodel.2007.03.033)

Why Bother?

R&G's argument: **weak and qualitative** patterns can be taken from a **diverse** spread of model outputs and used to confirm that the system is being captured, when the data from a **strong** pattern would be **impossible to obtain**

- Gathering data is **hard**, and might be **limited** by cost, privacy, time, logistics, inaccessibility in space or time, etc.
- By focusing on the subsystems, we ensure that the model fits at every level, at least to some level – no inbuilt false assumptions!
- Marriage of verification and validation