

Applying Stigmergy to Cognitive Agents Societies



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Abstract

- Stigmergy principles have often been employed as effective means to engineer **indirect coordination** in MASs where agents were very simple.
- We would like to extend this approach to systems populated with **cognitive agents**, i.e. agents that can reason on a symbolic stigma.
- In this presentation we will give some insights on the on-going research about artefacts to support cognitive stigmergy. In particular we will provide some examples of a middleware based on TuCSoN technology.

Stigmergy - Original Definition

- The word **stigmergie** was coined by the French entomologist Pierre-Paul Grassé in 1959
- Stigmergy refers to the **indirect coordination process** observed in termites societies while building their nests

*“La coordination des tâches et la régulation des constructions ne dépendent pas directement des ouvriers, mais des constructions elles-mêmes. **L'ouvrier ne dirige pas son travail, il est guidé par lui.** C'est à cette stimulation d'un type particulier que nous donnons le nom de stigmergie.”*

Grassé, P.P. (1959). *La reconstruction du nid et les coordinations inter-individuelles chez *Bellicositermes natalensis* et *Cubitermes* sp. La théorie de la stigmergie: Essai d'interprétation du comportement des termites constructeurs.* In *Insect Sociaux.*, 6: 41-83, 1959.

Comments on the definition

- The etymology of stigmergie derives from two Greek words
 - *stigma* → sign
 - *ergon* → work, action
- From a MAS perspective - in the original definition it's the stigma + environment that drives the agents!
- In this sense **the stigma embeds the goal** of agents...
- ... but if the environment drives completely the agents, should we still call them agents?

Agents in stigmergy

- When building system based on stigmergic coordination, agents are typically *very simple*
- In ant-based systems the actions are
 - sense pheromone field
 - put pheromone
 - pick-up food..
- If we want to have several goals we can introduce multiple pheromones...
- ... but if we are working in an open system, what will happens if we mix two ant colonies?

Extending the definition of stigmergy

- The approach of stigmergy is very appealing because of
 - indirect coordination mediated by the environment
 - positive feedback on agents
- Agents may have totally different goals, but still be willing to cooperate to increase their performance
- So what if the **stigma becomes a piece of knowledge** and agents are able to do more complex reasoning upon it?

Cognitive agents

- In social sciences an agent which has mental processes, perception, reasoning is said to be **cognitive**
- We want to study the implications of applying stigmergic coordination to societies of cognitive agents
- That's what we mean with **cognitive stigmergy**

Objection to Cognitive Stigmergy

- *But you have uncoupled agents from their environment. You shouldn't call it stigmergy anymore!*
- Yes, maybe! But think about the advantages
 1. coordination becomes simpler
 2. since agents are capable of reasoning we expect coordination to become even more efficient!
 3. we can have heterogeneous agents with different goals
 4. we can let agents migrate from a society to another one

Similar Approaches

- *It would be more difficult to show a functioning human institution that is not stigmergic, than it is to find examples of human stigmergy.*
 - H. Van Dyke Parunak. *A Survey of Environments and Mechanisms for Human-Human Stigmergy.*
- Implicitly considers the “extended” definition of stigmergy!
- Provides several examples of human stigmergy
 - path formation through vegetation, zebra crossing
 - market systems, elections
 - document editing, blogs
- How we should engineer stigmata and environment??

Conceptual Requirements

- The environment has two responsibilities
 1. a mechanism to collect symbolic stigmata by local interaction with agents
 2. evolve the stigmata over dimensions (space, time ...)
 - where are these rules located?
 - the evolution should be different for each stigma?
 - does stigmergy rules are still applicable?
- Stigmata evolution, should it be a responsibility of the environment?
- The symbolic stigma must be interpretable by agents, although they may not share the *same* ontology

Scenario - Wikipedia

- Wikipedia is a free web encyclopedia
 - www.wikipedia.org
- The knowledge stored in Wikipedia is the result of an indirect coordination/interaction process which is stigmergic
- But agents are cognitive so we would lose something if analyzing that MAS adopting traditional stigmergy point of view
- How we could better support and enhance this process?

Scenario - Wikipedia

- The simplest mechanism to achieve stigmergy is to let users put (explicitly or not) **annotations** into the shared space – Wikipedia.
- Other users can see that annotations and add their own affecting each other reasoning processes
- Annotations can be handled by the shared environment infrastructure accordingly to cognitive stigmergy processes
 - spread to near locations – i.e. articles
 - aggregate similar ones
 - fade over time
- Annotations also implicitly call for **sorting criteria!**

Scenario - Wikipedia

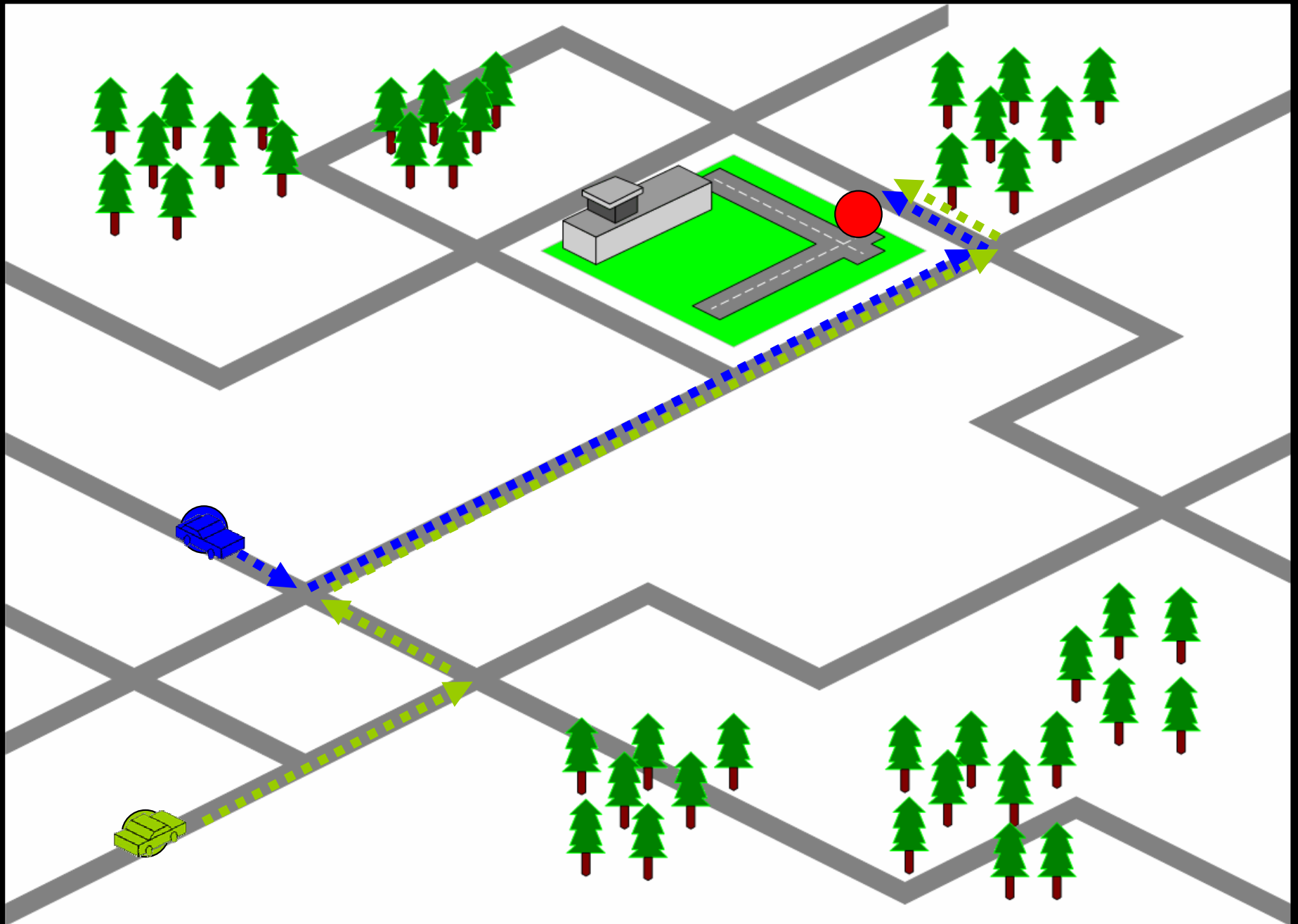
- This annotation can be used to represent several kinds of stigma, e.g.
 - **N** agents find **X** to be very useful – explicit
 - Agents that had look at **X** also had a look at **Y** implicit (e.g. Amazon online bookshop)
 - Agent **A** say “If you like **X** don’t miss **Y**” - explicit
- Also the annotation can be effectively exploited for correction/revision purpose providing a more general abstraction

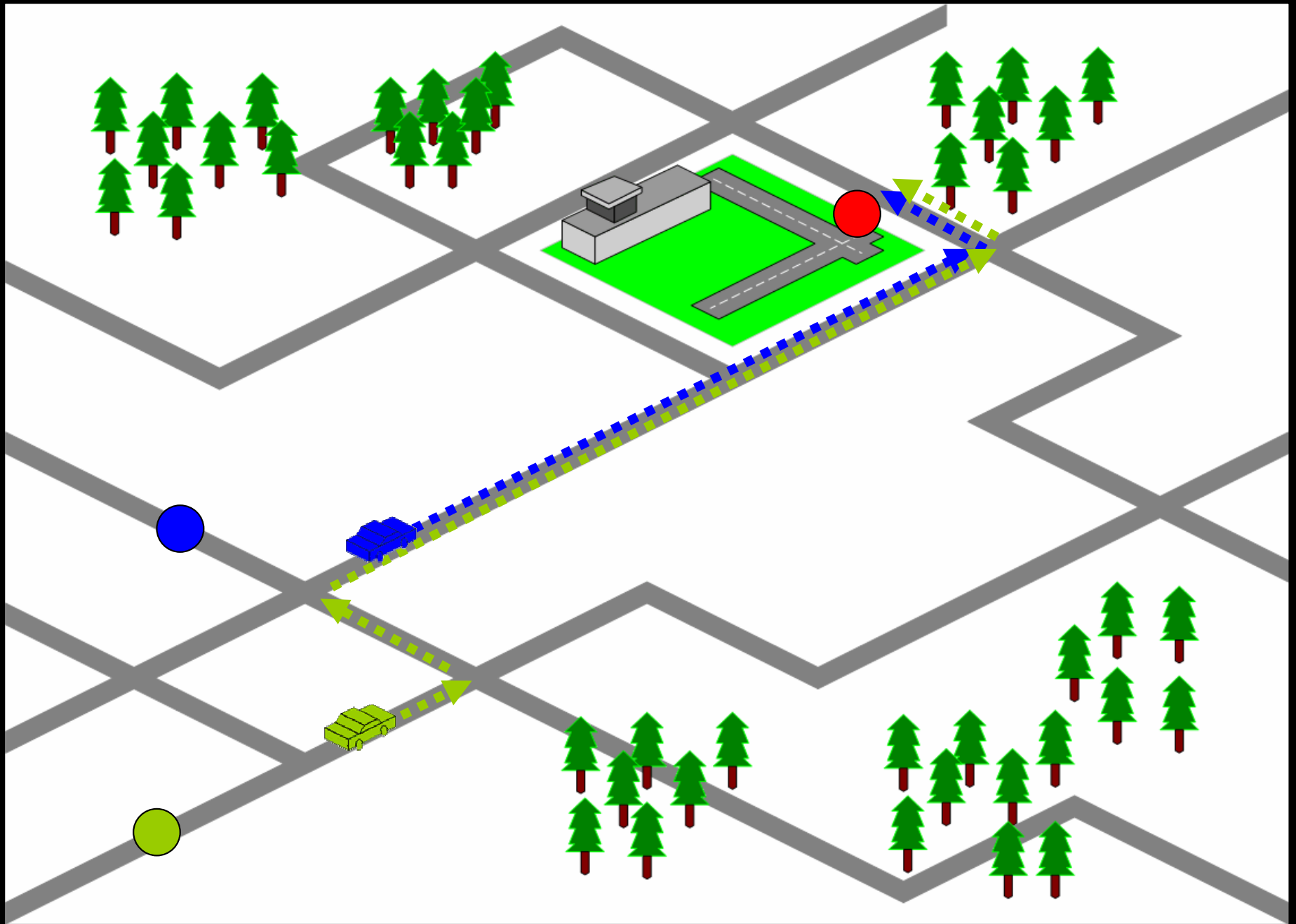
Potential Applications

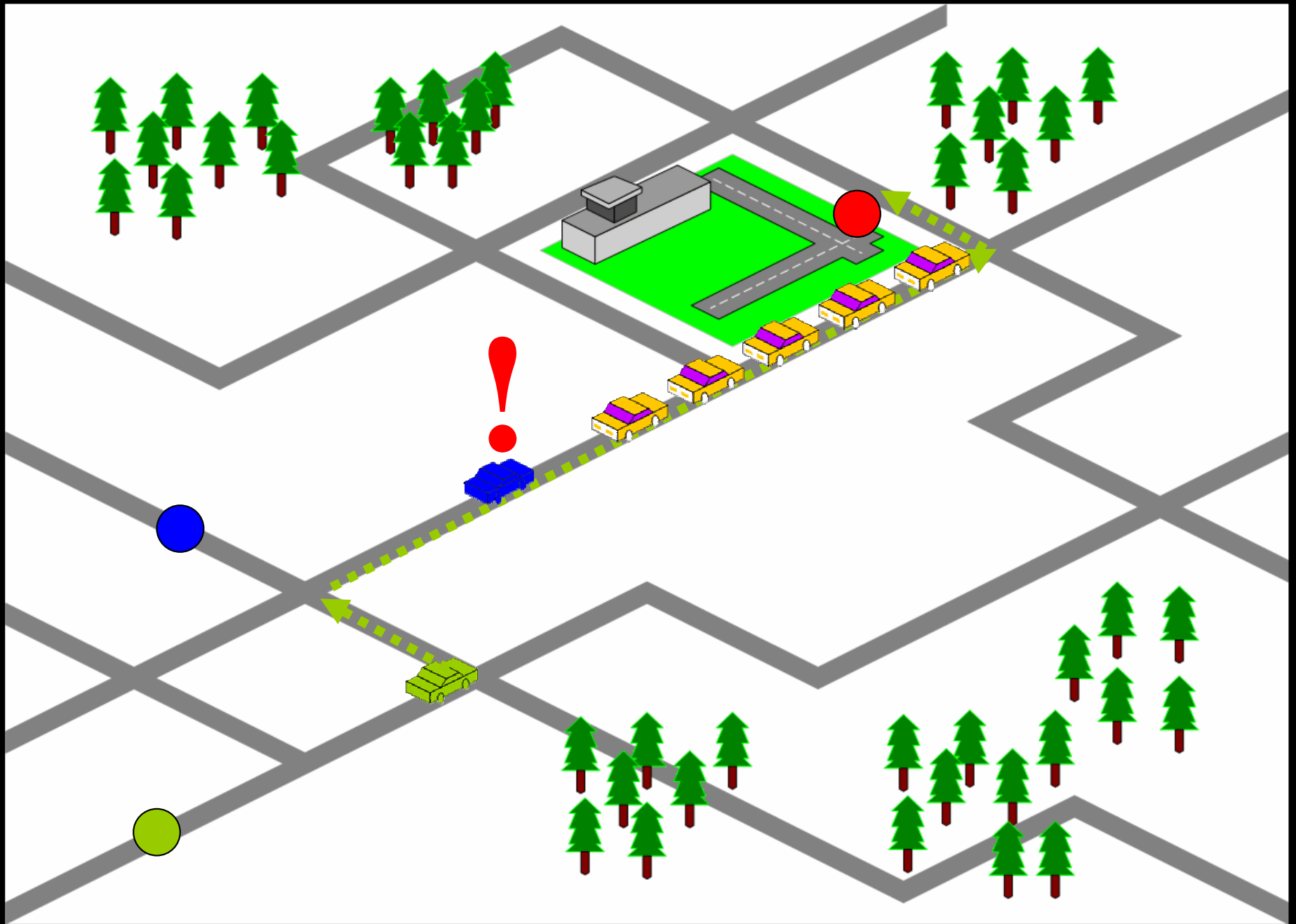
- Among the applications that could benefit of exploiting the annotation mechanism
 - e-learning
 - “if you can’t solve this ex. you may find **Y** useful”
 - e-commerce
 - “users that bought **X** also have bought **Y**” – implicit
 - “I have bought **X** and it’s doesn’t work”- explicit
 - ambient intelligence
 - “I have used this coffee machine it has stolen my money!”
 - “This restaurant is fine and it is quite cheap!”
 - traffic control
 - “Road **X** is congested all the time!”

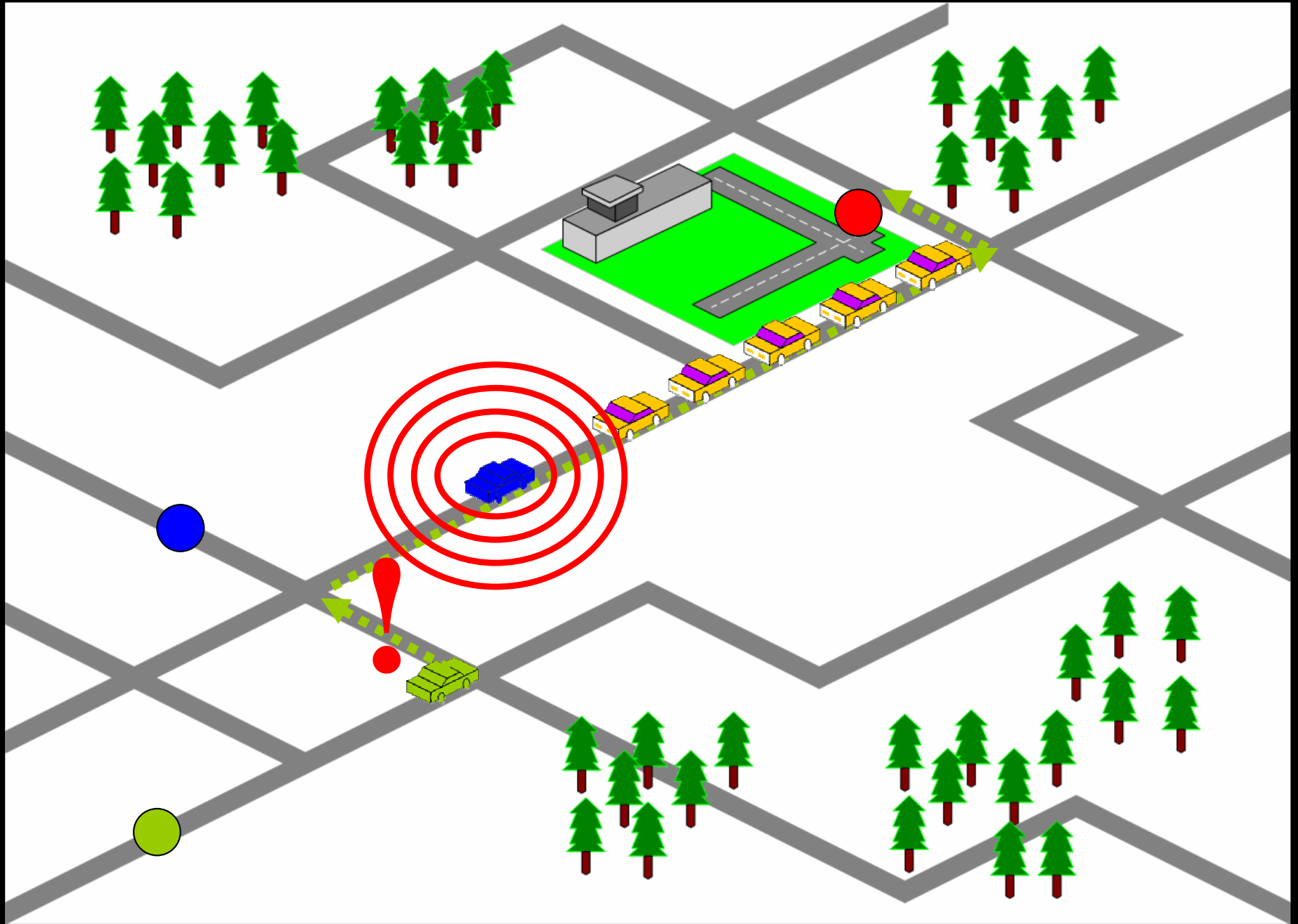
Scenario - Adaptive routing

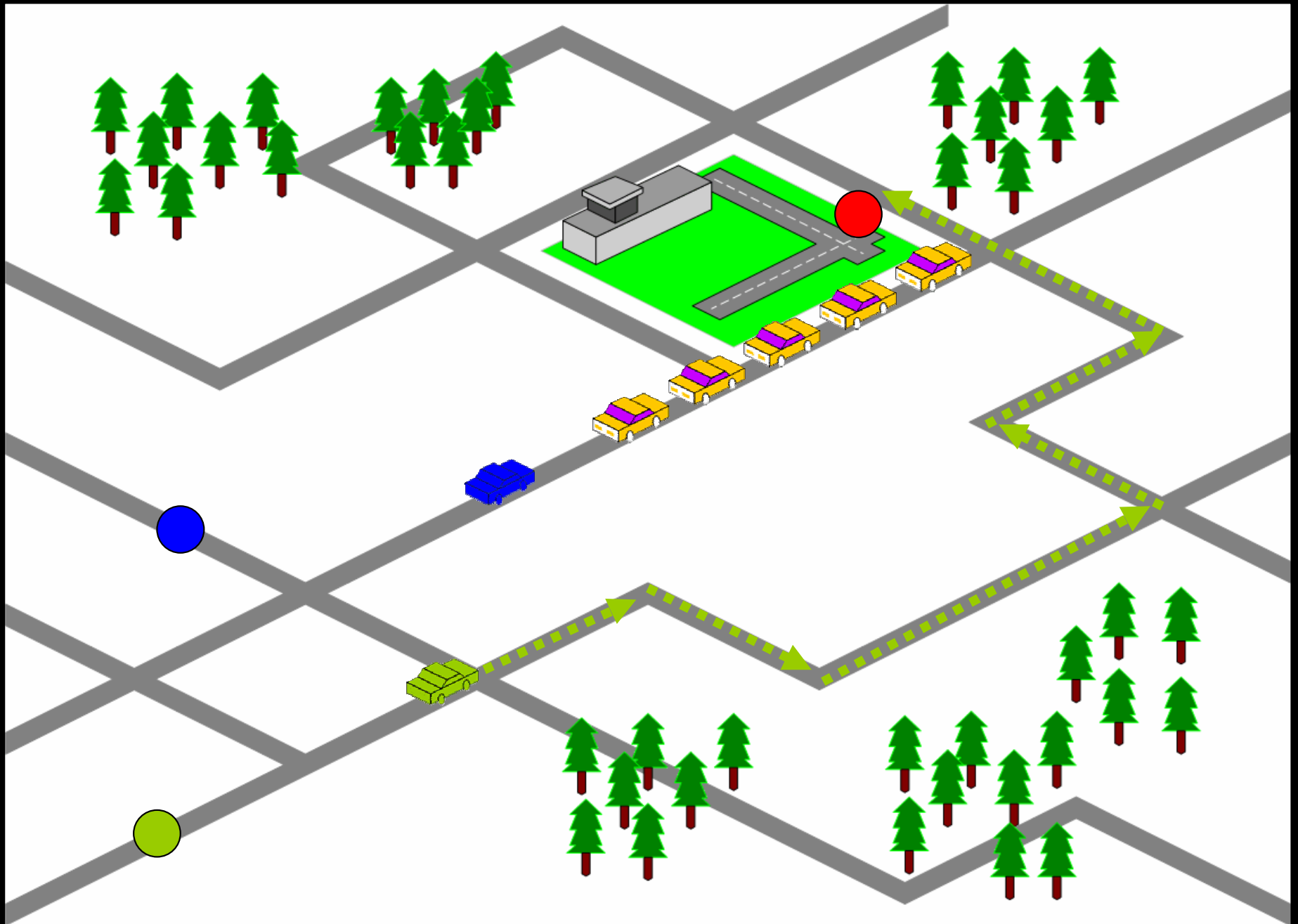
- Consider an application of adaptive routing for a business of packages delivery
- Although couriers may have a detailed roadmap, they have no real-time information about the actual traffic flow
- It could be too expensive for a single courier to gather this data
- To increase the overall performance, couriers can share annotations about real-time traffic flow
- Couriers perceiving that info can adapt their path accordingly to their strategy

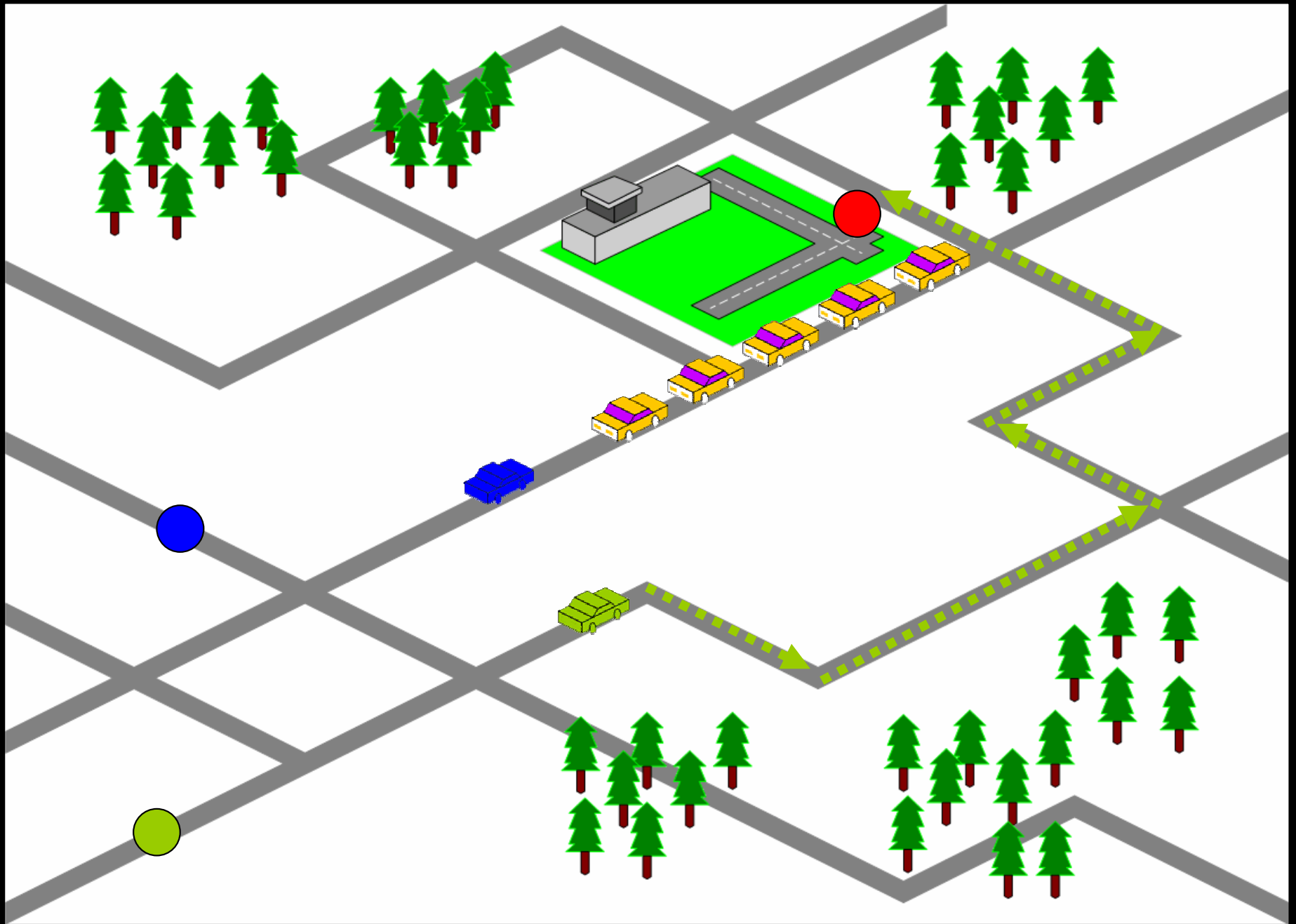






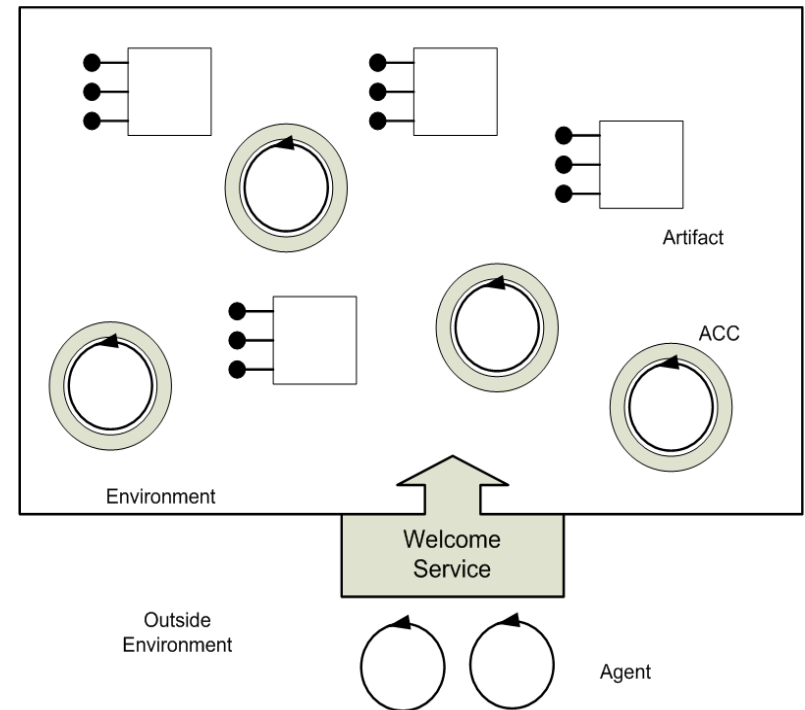






Our Vision about MASs

- We promote the idea of MASs being populated by agents and artifacts
- Artifacts – grounded on Activity Theory – are tools which may be exploited by agents for their own goals
- TuCSoN is our source of artifacts
- Tuple centres as coordination artifacts
 - Runtime abstractions encapsulating and providing a coordination service
 - Coordination Rules are specified by ReSpecT language



Stigma and Evolution Rules

- Stigma is represented by 1^o order logic tuples
- Evolution rules are encoded using ReSpecT language: the specifications might be changed dynamically
- When dealing with information there are some dimensions that are always interesting, e.g.
 - Freshness
 - Reliability
 - Relevance
- These dimensions might be quantifiable and change over time in a similar way pheromone does

Tuples Templates

- In order to build this application we have to design either agents and environment behavior
- First we must decide which is the tuple template, e.g.

`road(n1, n2, c) - persistent`
`roadrt(n1, n2, c, f, r, re) - realtime`

where n1/n2 is the first/second node, c is the cost, f is the freshness, r is reliability and re is relevance

- Then we decide how to evolve the stigma over space and time...

Rules: Freshness

- We assigned to the info a counter which decreases it over time (evaporation)
- If the same info is deposited the counter is reset to the max value (aggregation)
- If the counter reach zero the info is deleted (evaporation)

An example of stigma evolution

- Let's consider the tuple `road(n1, n2, c, f, r, re)`
- The reactions are triggered by a timer event and uses `delta(L)` parameter

```
reaction(out_r(timer), (  
    in_r(road(N1, N2, C, F, R, RE)),  
    rd_r(delta(L)),  
    F1 is F - L,  
    F1 > 0,  
    out_r(road(N1, N2, C, F1, R, RE))  
)).  
reaction(out_r(timer), (  
    in_r(road(N1, N2, C, F, R, RE)),  
    rd_r(delta(L)),  
    F1 is F - L,  
    F1 =< 0  
)).
```

Rules: Reliability

- Premise: agents cannot lie!
- Reliability depends on how many agents share the “same” info
- You can count how many agents deposited the same info (aggregation)

Rules: Relevance

- An information is relevant to you if it affects your decisions
- For example you can decide that a traffic information is no longer useful if it is X far away from its source
- So you would not spread this information from X on (diffusion)

Engineering Efforts

- Using a Java library for Operation Research problems about graphs...
- Using TuCSoN infrastructure...
- Design phase - 2 hours
- The configurator deploys and configures tuple centres given the graph topology: written in Java exploiting TuCSoN APIs - 1 hour
- Evolution rules
 - written using ReSpecT language – 2 hours
 - More debugging tools are needed 😊

Conclusions

- We are currently studying the implications of extending the definition of stigmergy to cognitive agents, to do so...
- ..we have built a middleware prototype on top of TuCSoN technology
- We have programmed artifacts to act as an active environment which evolves stigmata
- More details about theoretical framework on
 - Ricci, Omicini, Viroli, Gardelli, Oliva. *Cognitive Stigmergy: A Framework Based on Agents and Artifacts*. EUMAS 2005, 7 & 8 December 2005, Brussels - Belgium

Future Works

- We want to compare performances with a multi-pheromone infrastructure
 - But it's not all about performance it's also about architecture and methodologies!!
- We want to explore more scenarios: knowledge sharing, e-learning platforms, e-commerce..
- So we could better generalize/formalize our results..