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Introduction

Research and technology trends promote a vision of artificial systems that are able to resiliently manage themselves

Indeed, beyond the results that individual autonomous agents can carry out, a further opportunity lies in the *collab*

we provide a review of literature about autonomy and especially collective autonomy in MASs blue(s:background-rw);
we analyse the aggregate computing framework by the perspective of autonomy, by covering its positioning with respect
we exemplify the discussion through a simulated case study, investigating (i) the relationship between individual goals/a
we bluediscuss gaps in literature on programming reliable collective autonomy and delineate a research roadmap blue(s:

Experiment setup

The collective goal is to find animals in danger and rescue them. The environment consists of a continuous two-dim

Animal: an agent that needs to be rescued if it is in danger. The danger status changes are domain-specific dynamic. In
Mobile node: an agent that moves around the world and could have the capability to heal an animal.
Station: a fixed node that works as a gateway for mobile nodes.
blueIn this experiment, *Mobile nodes* can perform *tasks*, namely problems to be solved. Our characterisation of this con
ExploreAreaTask: leads agents to explore an established portion of the space.
HealTask: for which a set of agents must rescue a defined animal (and must correspondingly have "rescue capabilities").
At runtime, the program identifies agent roles (*healer*, *explorer*, *stationary*) according to the local behaviour sensed. Th
leader election is made in the stationary nodes (via —S—);
mobile nodes sense animals in danger and send the local information to the leader (via —C—);
the leader chooses what is the animal that needs to be rescued;
the leader shares its choice (via —broadcast—);
the slaves act according to the leader choice.
To be more specific, the program first tries to detect nodes' role checking how much each node has moved in a defined ti

[b] val leader = branch(isStationary) S(grain) false //(1.) leader election //.. (2.) sense animals in danger .. val noA
moves around the environment;
executes tasks. Each behaviour has an endogenous and exogenous aspect: with this program, we can specify how agent
multileader election,
animal dangers sensing, and
task selection to reduce the animal in danger in zones. With ScaFi the overall behaviour is intentionally described as:

What we want to enforce in this experiment is that individual autonomy influence collective autonomy. For exampl

In simulation evaluation, we consider whether functional and non-functional aspects. The main functional metric is

What we expect from these simulations is that selfish settings bring worse performance. Indeed, here we need a col
p: is the probability to follow the collective choice, *1 - p* is the probability to act selfishly; the bigger is p the lesser the
healer count: the nodes needed to rescue an animal. A higher value of *healer count* needs greater control on local agent
Results and discussion

Wildlife monitoring simulation screenshot. The "wi-fi" like symbol represents a *Station* node. Each *Station* has an influ

We now present the key results produced by the different simulation runs we conducted. In fig:wildlife-monitoring-g

In general, the results confirm our thesis: the more agents act autonomously, the worse the system behaves. Howev

[b]0.32 [width=]imgs/healed-4.pdf

[b]0.32 [width=]imgs/healed-6.pdf

[b]0.32 [width=]imgs/healed-8.pdf

Experiment results. blueIn each plot, the colour identifies the *p* parameter. The first column shows how many animals a

[ht!] [width=]imgs/box-plot.pdf blueAverage error (RMSE) for each combination of *p* and *healer count*. Horizontal

Final remarks blue In this experiment, we deliberately did not consider the following aspects (even if they could aff

In the following, we identify a roadmap of two research directions to unveil the full potential of aggregate programm

Expressing collective autonomous behaviour

Addressing problems at a suitable level of abstraction is key in modelling and programming. In this section, we cov

Cognitive collectives Notions like distributed cognition and group minds are often leveraged in sociology and cognit

Collective autonomy and structural organisation

One of the first works analysing the relationship between organisational structure and autonomy is by Schillo [?]. S

For instance, approaches to MAS programming based on the notion of a *team* (i.e., a sub-collective) have been prop

Reliable collective autonomy

Related to the ability of expressing collective autonomous behaviour is the extent to which specifications lead to pr

Safety and guarantees

Currently, few results are available on programming of reliable collective adaptive behaviours. In the context of agg

Norms and trust

Among the notions studied in literature to promote good cooperation between agents there are *norms* and *trust*. T

Trust can also be used as a way to reduce cooperation inefficiency and issues. An excess of individual autonomy ma

blue Applications

Multi-agent systems and technologies span various application domains [?] including e-commerce [?], health care [?]
traditional paradigms, promoting the vision of system development through integration of multiple perspectives and vie

Conclusion

In this paper, we consider the problem of programming the collective autonomous behaviour of multi-agent systems

blue The various goals described in the introduction have been addressed as follows. The literature review in s:back

We argue that it is important to *directly* address the collective dimension of MASs, rather than programming indiv

References

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