Self-Organization Algorithms for Autonomic Systems in the SelfLet Approach

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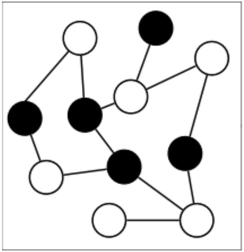
Reading Group

Outline

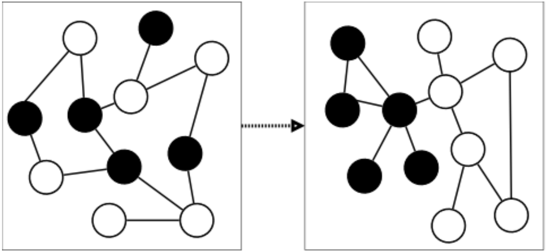
Motivating Example (1)

- What we have:
  - A generic network of interconnected nodes;
  - Every node is a piece of software that is able to execute a particolar task;
  - Nodes that are able to execute the same type of task have the same color.



Motivating Example (2)

- What we want:
  - Reconfigure this network in response to the needs of its nodes;
  - Solving Load Balancing problems;
  - Creating collaborative groups in order to solve complex tasks.



Motivating Example (3)

- Constraints:
  - The solution must be independent as much as possible from the size of the network;
  - Each node has only information about its direct links (neighbors);
  - Removal, insertion, or random/selfish behaviors of some nodes should not impact the achievement of our goals.
- Possible Solution: Biologically inspired self-organization algorithms.

Approach

Definition

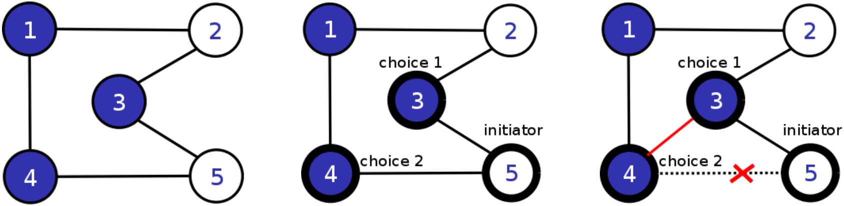
A self-organization algorithm is defined as an algorithm capable of making a spontaneous formation of well-organized structures, patterns, and behaviors without central control.

- We consider Autonomic Systems as networks of interconnected nodes called Autonomic Elements.
- Characteristics of Autonomic Elements:
  - They have only partial knowledge of the system;
  - Indirect achievement of the high-level goals of the system;
  - Simple operations at element level constitute the building blocks for more complex operations at system level.
- Examples of self-organization algorithms: Autonomic Clustering algorithms to solve the aggregation problem.

Clustering Algorithm Idea

Simplification of the CASCADAS (Saffre et al., 2007) Clustering Algorithms

1. Election of an initiator node: random in *Passive* mode, requested by a neighbor in the *Active* mode;
2. The matchmaker chooses two neighbors that share the same type and creates a connection between them;
3. The matchmaker removes a link between itself and one of the chosen neighbors.



Example

Creation of link 3-4 and removal of link 4-5.

From Autonomic Elements to SelfLets

- Clustering Algorithms have been validated using mathematical models and simulations.
- How to put them in practice: the *SelfLet*[1] model:
  - *Internal Autonomicity*: changing internal state and behavior in response to events (*IBM approach*);
  - *External Autonomicity*: achieving high level goals through interations between different elements of the system (*AntHill approach*).

[1] SelfLet model is based on the ACE model of CASCADAS.

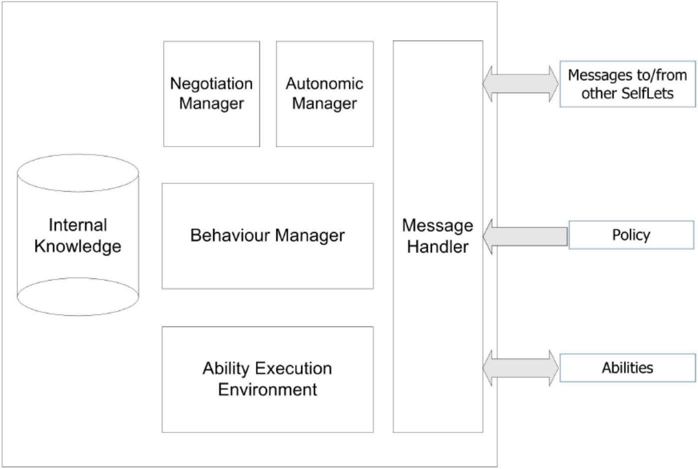
SelfLet Definition and Model

Definition

A *SelfLet* is a self-sufficient piece of software which is situated in some kind of logical or physical network, where it can interact and communicate with other *SelfLets*.

- Characteristics of a SelfLet:
  - it is characterized by a unique ID, one or more types and a location;
  - it may provide services called Abilities that can be executed locally or remotely;
  - it may request and offer goals to other SelfLets;
  - its execution is managed by one or more Behaviors, represented as FSMs;
  - it has Autonomic Rules that can modify the Behavior in response to changes in the internal state or in the environment.

SelfLet Internal Architecture



SelfLet Life Cycle

1. Definition of a Behavior:
   - Design of a StateChart that defines the actions that the SelfLet will execute;
   - Definition of how it can be modified in order to support application dependent self-configuration.
2. Definition of Actions and Goals:
   - Actions involve the execution of application-dependent services called Abilities;
   - Goals can be achievable or needed and they usually refer to the possibility to install and run Abilities.
3. Definition of an Autonomic Policy:
   - A high-level specification of the system goals that will be converted into Autonomic Rules that may install/execute Abilities or change Behaviors.
4. Deployment.

Self-Organization as Ability

- Self-Organization algorithms can be used to solve this problem: they can be integrated as Autonomic Abilities.
- Examples of self-organization Clustering and Reverse-Clustering Algorithm Applications:
  - Load Balancing: when the load of a SelfLet passes a certain threshold and requires to delegate some tasks;
  - Fault Tolerance: recreate a group of SelfLets when some of the members of the group are unavailable;
  - Cooperative Grouping: when a SelfLet is not able to reach autonomously some complex goals.

Distribution Issues

Initialization and Termination

When self-aggregation ability is invoked on a SelfLet, it will propagate the algorithm initialization on other SelfLets following a domino approach. Termination is triggered by an Autonomic Rule when the SelfLet's group remains stable.

- Distribution Issues:
  - Preventing network saturation: self-adaptive iteration frequency;
  - Synchronization: use of lock primitives;
  - Error and timeout management: rollback of incomplete iterations.

Performance Indexes

- *Exchanged messages* and network *homogeneity*.

Definition

Homogeneity $= \frac{\sum_{i=1}^{N} v(i)}{L}$ (Saffre et al., 2006)

- N is the number of nodes, $v(x)$ is the number of neighbors of x that has the same type of x, L is the total number of links of the network.

- Simulations:
  - use of a simulation framework that runs a SelfLet (*Manager SelfLet*) with a centralized initialization and analysis tool as ability;
  - the experiments involved the use of Active and Passive (reverse) clustering on a network of 100 nodes and 1000 links and 5 types randomly distributed.

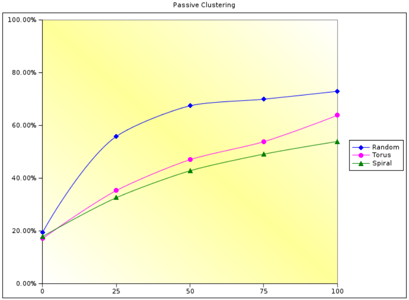
Analysis Results

Number of Messages vs execution time in clustering algorithms

	Normal	Active	Passive	**Reverse**	Active	Passive
Topology	Time	Msg $\times 10^3$	Msg $\times 10^3$	Time	Msg $\times 10^3$	Msg $\times 10^3$
Random	25s	19	19	1s	3.0	2.9
	50s	35	36	5s	5.1	5.6
	75s	50	52	10s	5.8	9.2
	100s	64	66	20s	6.5	15.8
Torus	25s	21	19	1s	2.9	2.8
	50s	37	36	5s	5.6	5.4
	75s	55	51	10s	8.9	9.0
	100s	72	68	20s	11.8	15.8
Spiral	25s	20	19	1s	2.9	2.9
	50s	36	34	5s	5.7	5.3
	75s	55	51	10s	9.2	8.9
	100s	72	67	20s	13.1	15.6

Analysis Results

Normal clustering *Homogeneity* vs algorithm completion time

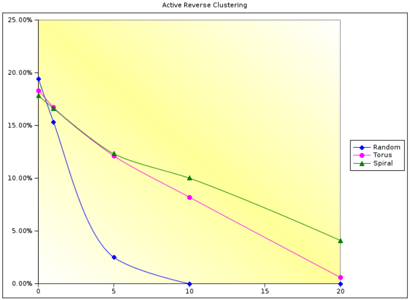


Comparison

The algorithm is successful in increasing the homogeneity with all the different initial topologies we have used.

Analysis Results

Reverse Clustering *Homogeneity* vs algorithm completion time



Comparison

The algorithm shows better performances in all cases, but it is particularly good in the Random topology.

Conclusions

- Summary
  - We have presented a comprehensive model of autonomic system called SelfLet that addresses some of the limitations of existing autonomic system models.
  - We have seen how self-organization algorithms integrate into the SelfLet model in the building of SelfLets neighborhoods.
  - Finally we have investigated their effectiveness using a distributed simulator framework based on the SelfLet model.
- Future Work
  - Clustering algorithms can be made adaptive by considering changing environment and goals.
  - Clustering algorithms can be generalized to cluster similar types and to deal with nodes with multiple types.
  - Finding a better solution to the initialization/iteration/termination problem in order to reduce the number of exchanged messages.