Implementing a Risk Predictor using an Autopoietic Machine

Eng. Giovanni Morana

gmorana@auctacognitio.net - R&D Labs, Aucta Cognitio, It

The performance, the availability, the robustness of a moder, web-based, distributed application are strictly related to the performance, the availability and the robustness of each one of the its components, on the way they are deployed, the underlying hardware and the network connecting them. Those concepts, strictly related with the idea of “quality of service” of an application, are usually defined as target values (Service Level Objective - SLO) on a set of key parameters (Service Level Indicator - SLI) and stated in a document – the Service Level Agreement (SLA) – that specifies, among all the possible ones, the conditions under which the execution of an application are considered acceptable.

The ones defined in the SLA are subjective values, defined “a priori”, and identify an “equilibrium point” that establishes a specific, desired behavior -in terms of performance, robustness and cost - for the application.

During the runtime, the equilibrium stated in the SLA can be perturbated by an unexpected or excessive workload, a hardware error or a networking issue, affecting - sometimes in a persistent way - the ability to perform the application’ tasks with the appropriate level of quality.

When this happens, a set of corrective operations must be executed to bring back the application to a desired state: who decides which operations must be selected, how and when to execute them characterizes the type of control system of the application. It could be a single human operator seat in a control room or an AI-driven, autonomous, control system directly integrated with the application.

This work aims to gives an overview of a control system based on the implementation of an autopoietic machine [1,2] and focused on a control loop that aims to mitigate the risk of an SLA violation.

The decision to use a controller based on an autopoietic machine has been taken because of its ability to modify the structure of the both underlying hardware and software systems: a different structure means different sets of “equilibrium” points and, as a consequence, a higher probability to find a solution that satisfies the defined SLA.

The key component of the proposed control solution is the Risk Predictor (RP), i.e., the component used by the autopoietic machine to select the set of operations to be executed to maintain, or bring back, the system to an acceptable equilibrium point when the system is subject to fluctuations. The RP takes into account I) the current status of the application, II) the current values of inputs, III) a forecast of their values (in the immediate future), and IV) the list of parameters violating the SLA (currently or in the future as a forecast) and identifies the set of possible equilibrium points that can be reachable by the system.

The concept of reachability in this context is closely related to the concept of reachability in the context of the classical control theory but it is extended by the “autopoietic” functionality: a classical controller is able to move the controlled system from a state to a finite set of other states (from an equilibrium point to others equilibrium points in the described context) whereas an autopoietic controller, with its ability to modify the structure of the controlled systems, could rely on a larger “reachability” set.

The system composed by the controlled application and its autopoietic controller represents a complex adaptive system (CAS, as described in [1]) and its homeostatic process is driven by the corrective action selected by the rick predictor.

The autopoietic control system has been implemented using an event-based, reactive system composed of:

- simple knowledge structures to represent the relationship and behavior of each entity belonging to the software, hardware and network level;
- a control-level knowledge structure that represent the application “itself”, putting together the inter-connection among the low-level knowledge structures;
- a publish-subscribe system as an events propagator among the interconnected knowledge structures.

Each time a fluctuation occurs, i.e., a variation on one or more values stated in the SLA varies, a set of events are triggered as a consequence of behaviors associated with the related knowledge structures. The hierarchical nature of the knowledge structures composition generate a bottom-up propagation process (supported by the RP) that arrives to a higher-level, i.e., the knowledge structure representing the application. At that level it is possible to identify the current status and the set of “reachable” states under which the SLA is still satisfied.

It is important to note that some of the “reachable” states could be available only after a “structural” change of the system, made possible from the autopoietic nature of the control system: an example of this transformation is represented by the “scaling out” of one of the component of the application, which requires the ability to “create” new hardware (e.g. a server hosting the new copy of the component), the creation of the component itself (as a replica) and the “update/modification” of the networks as well as the “update” of all the info needed to keep the system up and running (e.g., location transparency – defined as infware in [1]).

The RP evaluates the risk associated with each single state and, once identified the one having the lowest risk factor, forwards this info to the controller that, in a top-down propagation, executes the needed corrective actions to move the system to the desired new state, closing his homeostatic control process.

References

[1] Burgin, M.; Mikkilineni, R; Phalke, V. Autopoietic Computing Systems and Triadic Automata: The Theory and Practice. Advances in Computer and Communication. 2020, 1 (1), p. 16-35

[2] Burgin, M.; Mikkilineni, R. From data Processing to Knowledge Processing: Working with Operational Schemas by Autopoietic Machines. *Big Data Cogn. Comput.* 2021, *5* (13). https://doi.org/10.3390/bdcc5010013