

Optimization Approaches for Self-Adaptive Systems

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1 Introduction

2 Classification of Self-Adaptive Systems

There are different approaches on how to classify and describe Self-Adaptive Systems, which all focus on different usages, the three approaches that will be highlighted by this paper are:

- FORMS from Weyns et al., 2012 [5]
- Raibulet's, 2018 taxonomy for self-* properties [3]
- Krupitzer's et al., 2015 taxonomy for Self-Adaptive Systems [2]

In their 2012 paper FORMS [5] Weyns et al. propose a formal reference model for describing Self-Adaptive Systems. By composing a Self-Adaptive System from different levels of components called subsystems, where each level can adapt the level beneath, FORMS models the self-adaptive process using reflection. The bottom level is populated by base-level computations, base-level subsystems and domain models. On top of these base-level components are reflective computations, reflective subsystems and reflection models.

The goal of FORMS is to provide a well defined basis for talking and reasoning about Self-Adaptive Systems. This is achieved by providing a definition of FORMS, which classifies Self-Adaptive Systems, using Z notation.

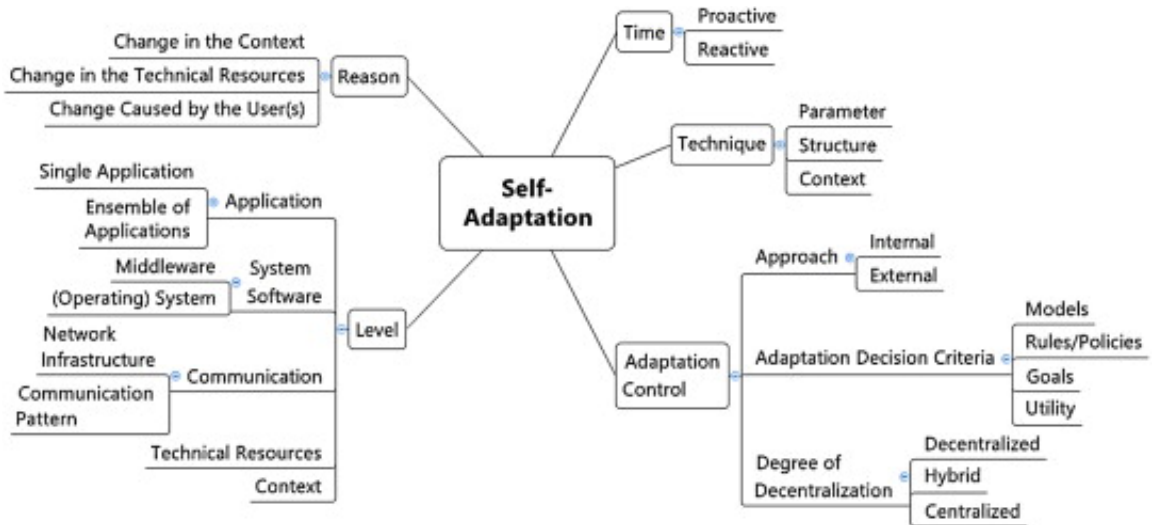


Figure 1: Taxonomy for Self-Adaptive Software by Krupitzer et al., 2015 [2]

The taxonomy for Self-Adaptive Systems by Krupitzer's et al., 2015 [2] in Figure 1 is based upon the 5W+1H questions by Salehie and Tahvildari, 2009 [4]. These questions are: Where, When, What, Why, Who and How. Each of these questions is responsible for a different aspect of Self-Adaptive Systems and corresponds to a dimension of the taxonomy.

First there needs to be a reason for a Self-Adaptive System to adapt. Why an adaptation should be performed is answered by the Reason dimension. According to the taxonomy

reasons for an adaptation can be changes in either the context, a technical resource or changes caused by the user.

The question of where asks on which level of the system changes need to occur. The different levels on which changes can occur include:

- Different levels of applications from the operating system to a user application.
- How systems communicate with each other.
- The technical resources that are needed by the system.
- The context in which the system operates.

While the original When-Question by Salehie and Tahvildari tries to understand all temporal aspects of Self-Adaptive Systems, including how frequently changes should occur and if they happen continuously, the taxonomy only answers the question when changes should be performed. For this purpose the Time dimension differentiates between systems that perform changes proactively or reactively.

In addition to the question of where and when changes should occur, it is also important to know what changes should occur. There are different techniques, that can be used. The Technique dimension of the taxonomy differentiates between systems that change parameters, their structure or their context.

After answering where, when, what and why changes should be performed, it is necessary to select who is responsible for these changes. According to Salehie and Tahvildari it is also important to establish if the changes can be performed fully autonomous or if the involvement of human operators is necessary. The taxonomy does not directly address all of these concerns but states that: "N/A (nature of a SAS leads to an automatic type of adaptation)" (Krupitzer et al., 2015 [2]).

Lastly, after determining the where, when, what, why and by who, there needs to be a way to perform the required changes. This is answered by asking how the changes should be performed and corresponds to the Adaptation Control. The three main factors of the Adaptation Control are the degree of decentralization, the adaptation decision criteria and the approach taken by the system, which divides Self-Adaptive Systems into those where the adaptation logic is part of the application logic and those with separated adaptation and application logic.

3 Proposal for classification of optimization approaches

When thinking about how to classify optimization approaches for Self-Adaptive Systems, one must realize that an optimization approach for Self-Adaptive Systems is really just a Self-Adaptive System of a Self-Adaptive System.

Because of this the proposed classification for optimization approaches for Self-Adaptive Systems should be based upon the same principles as the classification for Self-Adaptive Systems and it should use the same terminology.

Following Krupitzer's et al, 2015[2] taxonomy for Self-Adaptive Software, a classification for Optimization Approach of SAS should answer the 5W+1H questions by Salehie and Tahvildari, 2009[4]. These questions are:

- Where is the need for change?
- When should a change occur?
- What should be changed?
- Why should something be changed?
- Who should change something?
- How should something be changed?

The process of optimizing Self-Adaptive Software can be split into multiple parts using the MAPE-K (Monitor-Analyze-Plan-Execute with Knowledge) feedback loop by Kephart and Chess, 2003[1]. Each part of the MAPE-K feedback loop can be mapped to the process of optimization in the following way:

- Firstly the optimization approach has to constantly monitor the Self-Adaptive System and its context.
- The data gathered from monitoring can then be analyzed to decide whether or not an optimization is necessary and what should be optimized.
- After deciding that something should be optimized, there needs to be a plan on how to optimize.
- Lastly the planned optimization can be executed.
- For all of this the optimization approach requires knowledge about the Self-Adaptive System and its context.

Location Where in the system is an optimization necessary?

- Adaptation control
- Level
- Technique
- Time

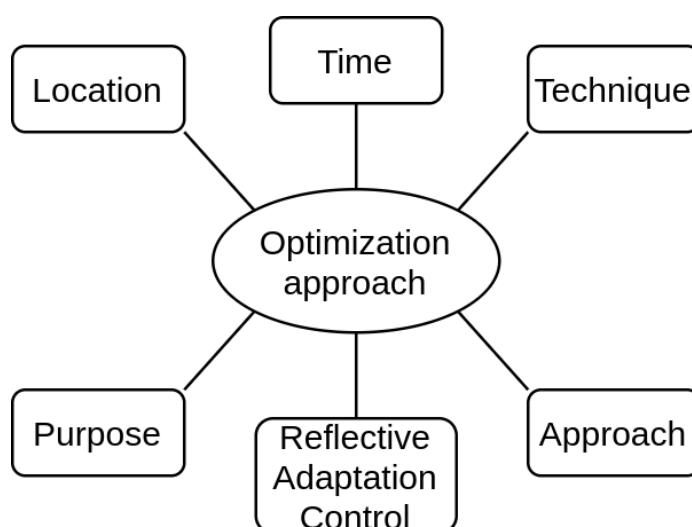


Figure 2: The proposed classification for Optimization Approaches for Self-Adaptive Systems

Time When are optimizations performed?

Similarly to SAS, Optimization Approaches can be differentiated by comparing when they perform optimizations. There are three different phases during the lifetime of a Self-Adaptive System where optimizations can occur. These are:

- at the runtime of the system
- during the design time of the system
- while training the system

The training phase can happen in parallel to the run and design time of the system. Examples for this would be when the initial parameters for a Self-Adaptive System are chosen by training a domain model or when generating a new model for the system by training an updated domain model parallel to the running system.

Technique What gets changed to perform the optimization?

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Purpose Why should an optimization occur?

The most important question for any optimization is: What influences the need for an optimization. Just like with Self-Adaptive Systems this can be caused by changes in context, the system itself or updated requirements for the system. Additionally an optimization might be necessary if for example the system detects that its current adaptation control can be improved.

- Changes in context, the system itself or requirements for the system.
- Detection of suboptimal adaptation logic.

Approach Who is responsible for performing the optimization?

- An internal component of the system
- An external actor

Reflective Adaptation Control How is the optimization applied to the system?

Just like the Self-Adaptive System can be described by its Adaptation Control, which is responsible for applying changes to the system, an optimization approach can also be described by how it applies its optimizations to the system. In reference to FORMS by Weyns et al., 2012[5], which uses reflective operations to change components in the system, the Adaptation Control of the optimization approach will be called Reflective Adaptation Control.

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MAPE Mapping

MAPE	OA
Monitor	
Analyze	
Plan	Technique
Execute	Reflective Adaptation Control

5W+1H Mapping

5W+1H	OA
Where	Location
When	Time
What	Technique
Why	Purpose
Who	Approach
How	Reflective Adaptation Control

4 Classifying existing optimization approaches

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- Location:
- Time:
- Technique:
- Purpose:
- Approach:
- Reflective Adaptation Control:

5 Conclusion

References

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