A Comparative Analysis of Two Multi-Objective Evolutionary Algorithms in Product Line Architecture Design Optimization

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1. Supplementary Material

The fitness function used in the experiments takes into account conventional and specific metrics to evaluate PLA design. Metrics to evaluate basic design principles are called here Conventional Metrics (CM). Table 1 presents the CM used here. The cohesion measure H indicates to the designers the components which do not have strongly-related elements. This means that such components cohesion are weak. The size metric NumOps reveals reusability aspects of the PLA because small interfaces are, in general, easier to reuse. The other metrics refer to coupling between architectural elements.

Table 1. Conventional Metrics Suite (CM) [Wüst 2014]

Attribute	Metric	Definition
Cohesion	Relational Cohesion (H)	Average number of internal relationships per class in a component.
Coupling	Dependency of Packages (DepPack)	Number of packages on which classes and interfaces of this component depend.
	ClassDependencyIn (CDepIn)	Number of elements that depend on this class.
	ClassDependencyOut (CDepOut)	Number of elements on which this class depends.
	DependencyIn (DepIn)	Number of UML dependencies where the package is the supplier.
	DependencyOut (DepOut)	Number of UML dependencies where the package is the client.
Size	Number of Operations by Interface (NumOps)	Number of operations in the interface.

The Feature-driven Metrics (FM) [Sant'Anna et al. 2007, Sant'Anna 2008] are used to evaluate the changes caused by the feature-driven operator. They evaluate the degree of modularization of an architecture in terms of the features being realized. In addition to the negative impact on PLA reusability and maintainability, inaccurate feature modularization can lead to a wide range of design flaws, ranging from feature tangling and scattering to specific code smells, such as feature envy or god class [Figueiredo et al. 2012].

Table 2 presents the FM suite that enable NSGA-II to evaluate the feature modularization in PLA design evolved by the feature-driven operators. The metrics CDAC, CDAI and CDAO consider that a feature scattered on a high number of elements has negative impact on modularity. The feature interaction, measured by the metrics CIBC, OOBC and IIBC, happens by the presence of different features in a same architectural element. This interaction happens in three levels: component, interface and operation. Lack of feature-based cohesion (LCC) indicates that a component that addresses many features is not stable as a modification in any of the associated features may impact the others.

To evaluate the solutions, we adopted the same fitness function of Colanzi [Colanzi et al. 2014], $CM(pla)$ and $FM(pla)$, which are respectively aggregations of the CM of Table 1 and of FM of Table 2. These functions are calculated according

Table 2. Feature-driven Metrics Suite (FM) [Sant'Anna et al. 2007, Sant'Anna 2008]

Attribute	Metric	Definition
Feature Scattering	Feature Diffusion over Architectural Components(CDAC)	Number of architectural components which contributes to the realization of a certain feature
	Feature Diffusion over Architectural Interfaces(CDAI)	Number of interfaces in the system architecture which contributes to the realization of a certain feature
	Feature Diffusion over Architectural Operations(CDAO)	Number of operations in the system architecture which contributes to the realization of a certain feature
Feature Interaction	Component-level Interlacing Between Features(CIBC)	Number of features with which the assessed feature share at least a component
	Interface-level Interlacing Between Features(IIBC)	Number of features with which the assessed feature share at least an interface
	Operation-level Overlapping Between Features(OOBC)	Number of features with which the assessed feature share at least an operation
Feature-based Cohesion	Lack of Feature-based Cohesion(LCC)	Number of features addressed by the assessed component

to Equations 1 and 2, where c is the number of components, itf is the number of interfaces, cl is the number of classes and f is the number of features of a design pla. These two objectives aim at analysing if the obtained solutions (potential PLA designs) are likely to entail proper designs from the point of view of high cohesion, low coupling, reusability and feature-based modularity.

$FM(pla)$ consists on the sum of the sum of each feature-driven metric. FM were used to evaluate the feature modularization caused by the feature-driven operator. As they are co-related, when the value of one metric decreases, the values of the others decrease as well. $CM(pla)$ is compound by the sum of several conventional metrics. This sum uses the mean of DepPack for all components and the mean of NumOps for all interfaces. The metric H was counted inversely in the function because we are interested in maximizing the cohesion and minimize all other metrics.

$$FM(pla) = \sum_{i=1}^{c} LCC + \sum_{i=1}^{f} CDAC + \sum_{i=1}^{f} CDAI + \sum_{i=1}^{f} CDAO + \sum_{i=1}^{f} CIBC + \sum_{i=1}^{f} IIBC + \sum_{i=1}^{f} OOBC \quad (1)$$

$$CM(pla) = \sum_{i=1}^{c} DepIn + \sum_{i=1}^{c} DepOut + \sum_{i=1}^{cl} CDepIn + \sum_{i=1}^{cl} CDepOut + \frac{\sum_{i=1}^{c} DepPack}{c} + \frac{\sum_{i=1}^{itf} NumOps}{itf} + \frac{1}{\sum_{i=1}^{c} H} \quad (2)$$

References

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