Part V – Conclusion

11 Conclusion

This chapter concludes this research work by presenting its main contributions and furthermore points to future work that could be performed to continue this research project to further extend the results obtained.

11.1 Conclusions

The current nature of the business environment of the software industry pushes the software industry organizations to be open to change, and therefore be more flexible and adaptable. A trending way that may guarantee to *"be open to change"* is demonstrated in the Agile Software Development (ASD) paradigm, which could be expended to the field of Software Product Line Engineering (SPLE). Consequently, an emerging paradigm, "Agile Product Line Engineering (APLE)", has been proposed with the aim to reduce the big upfront design, usually practiced in SPLE, and to make the development processes of the product-lines more flexible and adaptable to the current changing environment. This thesis directly addresses the core objective of *"Proposing an Agile Product Line method"*.

Evidently, there are several reasons that encourage companies and organizations to move toward the adoption of *Agile Product Line (APL) methods*. However, there are several potential challenges and risks associated with the adoption of an APL method. It was concluded that the applicability of agile methods for Application Engineering (AE) seems to be highly feasible. Nevertheless, the applicability of agile methods to Domain Engineering (DE) is still challenging and requires more effort, especially when considering traceability and challenges faced by the Product Line Architecture (PLA).

Reviewing the relevant scientific works and practical case studies in the field of APLE has highlighted the different scenarios of combining agile methods and SPL approaches. Some studies have proposed APL methodologies, in which the SPL is used as the main process; where the integration starts from SPL, and then agile practices are added. Other studies have proposed

APL methodologies in which ASD is considered as the main development process, where the integration starts from the agile method, and SPL practices are added. Moreover, the reviewed research works have acknowledged that the main advantage of the APL paradigm is that SPLE could be applied to volatile markets, where changes cannot be easily predicted. In addition, SPLE could be supported by agile methods to develop large-scale product families. The main issue related to combining ASD with SPL is to identify the right level of flexibility, according to the business objectives. The level of flexibility is, thus, a key element in determining whether the approach combines SPLE and ASD at the strategic level, or adopt SPLE at the strategic level and ASD at the tactical one. Accordingly, the APL approach can be applied to real projects only if adequate guidelines are provided on the activities, people, and work-products involved in the project. A software development methodology can satisfy this need; consequently several attempts have been made to propose practical APLE methodologies.

Through this thesis, it was aimed to define a new APL method that presents agile processes, support mechanism, and requirements engineering (RE) techniques. Where the targeted APL method takes advantage of the strengths of the studied APL methodologies and overcomes their weaknesses. When designing a new APL process, first, the basis of the new process should be selected (i.e. start with SPL or ASD). Second, if the basic process is a SPL one, the type of the SPL architecture should be selected (i.e. COPA, KobrA, FORM, etc.). Third, an agile method or a hybrid of agile methods should be selected for the combination. The proposed APL methodologies consist of two integral parts. The first one is dedicated to requirements engineering and the second one is dedicated for the development process.

In this thesis, a Feature-Oriented Agile Product Line method called “Agile Framework for managing evolving Software Product Lines – AgiFPL method” was proposed. AgiFPL targets the development process part. The proposed process consists of a set of units of work (activities, tasks, steps), guidelines, roles, and work-products that allow the people involved (experts, owners, developers, stakeholders, etc.) with the Software Product Line (SPL) to perform the development processes of Domain Engineering (DE) and Application Engineering (AE) aligned with Scrumban and Scrum practices. AgiFPL has indeed presented a Scrumban-inspired process for the DE tier and a Scrum-inspired process for the AE tier. Scrum was adopted as it is considered the mainstream method within development teams, and its practices fit the AE process by handling feedback, iterativeness, incrementally, and adaptability in a systematic way. Scrumban was adopted, as it ascribes more importance to the requirements engineering part than any other agile methodologies; it establishes a structure of limited number of “Production Lines” within its development process. It is furthermore commonly used for maintenance projects, where it helps to deal with the traceability issue in the DE tier.

For the requirement engineering part, this thesis has proposed an Integrated Requirements Engineering framework for Agile Software Product Lines, which is the part providing the syntax and semantics used for expressing the products of an APL method. The aim is to allow analysts and developers to specify requirements that precisely capture the stakeholder’s needs and intentions, as well as to manage product line variabilities.

AgiFPL method was validated and put into practice through an assessment model (i.e. AgiPL-AM), a Criteria-Based Evaluation, and an industrial case study (i.e. TranslogisTIC

project). The case study has demonstrated the applicability of the proposed Agile Product Line methodology (i.e. AgiFPL) onto the establishment of Agile Product Lines for the "Transport and Logistics" Domain. Precisely, the application of AgiFPL in Domain Engineering (DE) and Application Engineering (AE), onto the development of an Outbound Logistics Collaborative Platform, was presented. By this case study, it was shown that the Scrumban-inspired process for DE and Scrum-inspired process for AE have been highly comprehensive for the different people involved. It was observed that the continuous feedback, appropriate iterativeness, and high level of adaptability have eased the communication between the various established roles, as well as the improvement of productivity of the development teams.

The Criteria-Based Evaluation (CBE) has allowed for the identification of the anatomy of the AgiFPL method, as well as its strengths and weaknesses. The CBE has demonstrated that the AgiFPL method is a well-constructed Agile Product Line methodology and has respected almost all the principles and objectives required from an Agile Product Line methodology. However, some improvements are still required, especially for issues related to traceability, consistency management, large organizations, and support tools. Moreover, the AgiPL-AM model has allowed the evaluation of the agility level of the AgiFPL method. The result of the assessment, using AgiPL-AM, has shown that AgiFPL method is strongly agile and has successfully combined the agile principles with SPLE principles.

11.2 Main Contributions

This dissertation has contributed mainly to the field of APLE. The research project has advocated an Agile Software Product Line method in order to help professionals, especially professionals of SPLE community, as well as the ASD community as a whole. In fact, the core contributions of the research work that belong to this thesis have included:

- A multi-evaluation of the Agile Product Line Methodologies with a strong focus on their phases, optional and essential work-products, development processes, as well as the whole lifecycle;
- An adequate definition for "Agile Software Product Line Engineering" (APLE). A definition that fits the undertaken research project;
- A new Feature-Driven APL method called AgiFPL, which presents iterative and incremental development processes Software Product Lines. It furthermore presents a detailed description of the processes, practices, roles, artifacts, communication channels, etc.;
- A Three-phase approach showing how the AgiFPL approach has to be implemented incrementally. The period of implementation depends on the size or the type of the SPL Company (or organization);
- An Integrated Requirements Engineering framework for Agile Software Product Lines that allows analysts and developers to specify requirements. The RE framework was formalized and a meta-model was introduced;

- An assessment model called AgiPL-AM to assess the current situation regarding the combination of agile practices and activities with Software Product Lines. This assessment is considered as an essential step towards a successful integration of agile methods into Software Product Lines;
- The demonstration of the applicability of AgiFPL and its concepts introduced for the different development processes onto a real case study: the TranslogiTIC project.

11.3 Future Work

Future improvements and contributions could be made on the basis of this dissertation. The contributions of this thesis have presented a qualitative leap in the field of Agile Software Product Line Engineering (APLE). However, these contributions have to be completed, extended, and improved upon at different levels in further work.

- The AgiFPL method takes into account the maintenance activities. However, the established processes need to be completed by more explicit maintenance-oriented practices in future works;
- Automation of several tasks can accelerate the proposed process. It is planned in future work to develop a specific tool that ensures the integration of AgiFPL's phases, activities, tasks and work products, including market strategies and mining of legacy assets. Interesting and useful investigations for the academy and industry would be the building of this tool;
- Integrating relevant DevOps and more metrics to AgiFPL method in order to optimize its performance and to improve its applicability within SPLE and the ASD communities;
- The assessment model AgiPL-AM will be evaluated empirically and a number of members of companies will be involved in the evaluation of the applicability of AgiPL-AM; more precisely, in assessing the level of agility of companies, and in evaluating the overall findings of the assessment model;
- Regarding the Integrated Requirements Engineering framework for APLs, several future works will tackle the aim to develop a procedure to discover inconsistencies in mapping results (i.e., generated goal models and/or generated feature models). Moreover, it will be aimed to extend the validation technique in order to cover other properties, such as safe composition (i.e., for all goal models modeled within the Application Engineering (AE) tier, they have at least one correspondent feature model and vice versa);
- With the aim to perform comparative studies, several new case studies in another projects are currently being planned;
- For most of the future studies, the focus lies on capturing quantitative measurements in order to validate statistically new hypothesis, such as studies and research works that compare two methods.

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Appendix A

AgiFPL: Roles, Meetings, and Artifacts

Domain Engineering Roles

Business at domain experts

"Business Experts" play a key role in aligning business goals, prioritizing major features, and selecting business goals and market strategies Doing So, leads to the definition of the Domain Scope *Domain Experts* come from different backgrounds and they represent the users, clients, sponsors, business analysts, or any mix of these. A Domain Expert uses deep knowledge of the business to explain to the developers in various levels of details the tasks that the system must perform Business and Domain Experts represent the interests of the top management of the "Software Vendor".

Domain Sensei

"Domain Sensei" role is basically a role of supporting of the agile principles and practices for the other roles. Domain Sensei has to be present in all DE meetings that are "Planning 1","Planning 2","Daily","Review", "Retrospective", and "Andon". The Domain Sensei should has a deep knowledge about agile values and principles, as well as, the agile practices of the DE process In fact, the Domain Sensei removes obstacles of the team, guides the project members focused on the Domain Design goal According to AgiFPL, the Domain Sensei must know the value for each agile practices and activities related to DE Meetings and Production Flows.

Domain Development Team

"Domain Development Team" is a group of developers with complementary skills that perform all the defined stories and task The Domain Development Team is a cross functional group of people responsible for delivering potentially shippableincrements of reusable artifacts (at the end of every production cycle). This team perform the selection of tasks for the different product lines during the "Planning 1" and "Planning 2". The team members also pay attention to the commonalities and variabilities that have to be specified.

Domain Stakeholders

"Domain Stakeholders" are the people involved that enable the project They are only directly involved in the process during the reviews Aside from that, they may solely influence the team by discussing their needs with the product owner. Typically, the main stakeholders are external consultants, managers, customers and users related to the Domain of the Software Product Lines.

Application Engineering Roles

App i Owner

"App i Owner" is the person responsible for maintaining the "App i backlog" by representing thinterests of the stakeholders, ensuring the value of the work the development team does.

Line i Scrum Master

"Line i Scrum Master" is the person responsible for the product line i process, making sure it is used correctly and maximizing its benefits In fact, the role of the "Line i Scrum Master" is involved in all tasks that are balanced with Scrum practices. This role is a role of supporting agile principles and practices for the other roles of the "Line i".

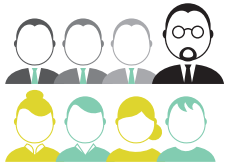
Line i Development Team

"Line i Development Team" is a cross functional group of people responsible for delivering potentially shippable increments of the App i at the end of every sprint The members of the development team have complementary skills that perform the sprint tasks.

App i Stakeholders

"App i Stakeholders" role represents the people involved that enable the project related to the "Product i". They are only directly involved in the process during the reviews Aside from that, they may solely influence the team by discussing their needs with the "App i Owner" Typically, the main stakeholders are managers, customers and users that are related to the "Product i".

Domain Engineering Meetings



Planning 1

Planning 1: The "WHAT": Whenever the product owner pulls new user stories into the selected backlog. The "Domain Analysts" holds it to select the next user stories to work on, explaining the user stories of the Features Backlog and answering open questions. After this analysis, the development team should understand the requirements Therefore, the team is able to estimate the complexity of each user story.

Planning 2

Planning 2: The "HOW" Whenever team members pull new user stories into the production flow Here, the team discusses solutions for new user stories in the SIP backlog and creates tasks for each user story accordingly.

Daily

Daily: (15 min max) A short, time boxed meeting, taking place every day at the same time Every team member answers three questions:
i. What have I done since yesterday**?**
ii. What am I planning to do today**?**
iii. What are my impediments**?**

Review

Review: (Whenever the team ships an increment) the team uses this meeting to present and review the work it has completed since the last delivery. Usually, it also includes a demonstration of the features created in the last increment.

Retrospective

Retrospective: (After any review) The "Domain Sensei" holds the retrospective to reflect on the past production cycle in order to ensure continuous process improvements. The sensei always asks two questions in the retrospective:
i. What went well during the last cycle**?**
ii. What should improve in the next cycle**?**

Andon

Andon: (Whenever a problem occurs) the "Domain Sensei" organizes an Andon meeting whenever problems in the production flow occur For example, a story is over the expected cycle time, or a task is frequently re-assigned and not yet solved Both the development Team and the product owner take place in this meeting and work on a solution to solve the open issue.

Application Engineering Meetings

Sprint Planning 1

Sprint Planning 1: (60 min per sprint week) is held to select the work to be done for the next sprint (the "WHAT"). The "App i Owner" explains the stories of the App backlog to the team and answers their question. After the planning, the team should have understood the requirements and its commits the scope for the sprint.

Sprint Planning 2

Sprint Planning 2: (60 min per sprint week) the designing phase for the selected backlog (the "HOW"). The team discusses a solution for the selected stories and creates according task for each story.

Daily

Daily: (about 15 min) short, time boxed meeting, every day at the same time Every team member answers three questions:
i. What have I done since yesterday**?**
ii. What am I planning to do today**?**
iii. What are my impediments**?**

Sprint Review

Review: (up to 60 min per sprint week) used to present and review the work that was completed and not completed during a sprint. It should include a demonstration of the realized product increment.

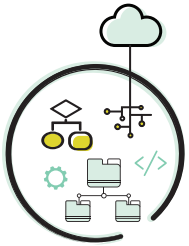
Sprint Retrospective

Sprint Retrospective: (about 45 min per sprint week) a reflection on the past sprint used to make continuous process improvements. Two main questions are asked in the sprint retrospective:
i. What went well during the sprint**?**
ii. What could be improved in the next sprint**?**

Backlog Refinement

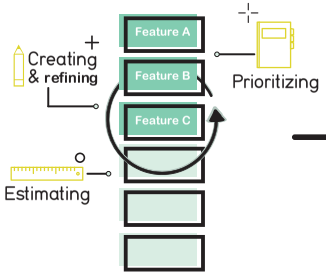
Backlog Refinement: (max 60 min) used to introduce and estimate new backlog items and to refine existing estimations as well as acceptance criteria It is also used to break large stories into smaller ones.

Domain Engineering Artifacts (1)

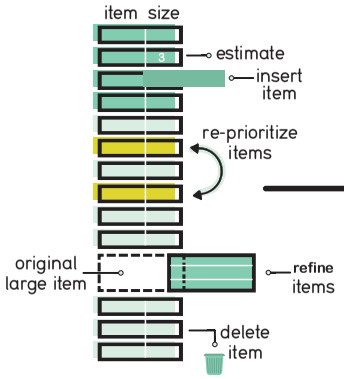


Domain Requirement Engineering (DRE): DRE aims to understand the problem space by studying the settings of the organizations related to the domain By studying a set of organizations, the emphasis is put on understanding the motivations and rationales that underline the domain requirements In fact, at this stage the reusable artifacts to be are described within its operational environment, along with relevant functions and qualities.

Domain Design (DD): At this stage, the scope of the domain and the architectures have to be determined, i.e., decide which the product line should cover products and consequently, which features are relevant and should be implemented as reusable artifacts.



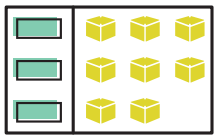
Features Backlog (FB): an ordered list of features that the team maintains for a product. At this stage, one should document requirements in 'user story' format Anyone can edit the backlog, but "Domain Analysts" are ultimately responsible for ordering the user stories Stories in the features backlog contain rough estimates of both business value and development effort.



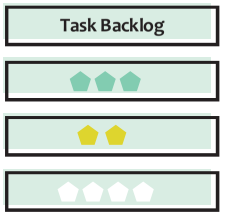
Selected backlog (SB): a list of work the development team must address next. It has a defined capacity limit. As soon as capacity is available, it is filled up with user stories or features from the top of the product backlog.

Feature: is a characteristic or end-user-visible behavior of a software system. Features are used in AgiFPL to specify and communicate commonalities and differences of the products between stakeholders, and to guide structure, reuse, and variation across all the phases of the software life cycle.

Domain Engineering Artifacts (2)



Story in Progress (SIP) Backlog: a list of user stories, which the development team currently addresses. Team members pull user stories from the selected backlog when there are no more remaining tasks in the task backlog.



Task backlog (TB): a table structured along the phases that are necessary for completing the project, e.g. design, development, and test. The development team breaks the user stories or features from the SIP backlog down into single tasks. Once a task has finished one phase, a team member from the consecutive phase eventually pulls the task to process it further.

User Story (US): a description of a certain feature or behavior, written strictly from the Domain Experts' point of view. Usually, the "Domain Experts" writes the user stories.

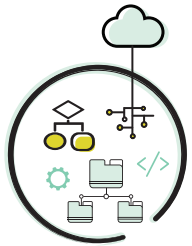
Task: a unit of work, which should be feasible within one working day or less. To implement a user story, you must accomplish all associated tasks.

Work in Progress (WIP) Limit: Limits the number of stories and tasks in each productive steps of the production flow and thus impedes work overload.

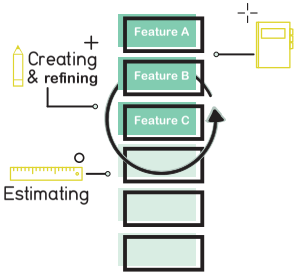
Parking lot: for tasks, which the team cannot finish due to external dependencies. For example, another team has to review a document Placing a task in the parking lot prevents the team from deadlocks, where unfinished tasks block production lines.

Impediment backlog: a list maintained by the sensei including all current impediments.

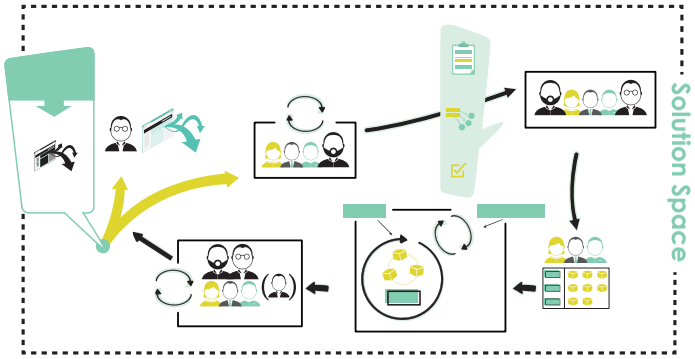
Application Engineering Artifacts (1)



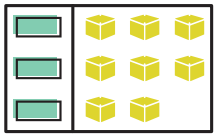
App Requirement Engineering (ARE): where the system-to-be (App to be) is described within its operational environment, along with relevant functions and qualities.



App Backlog: an ordered list of requirements that the team maintains for an application In AgiFPL approach, one should document requirements in "User Story" format. Anyone can edit the backlog, but the product owner is ultimately responsible for ordering the user stories. Stories in the App Backlog contain rough estimates of both business value and development effort.

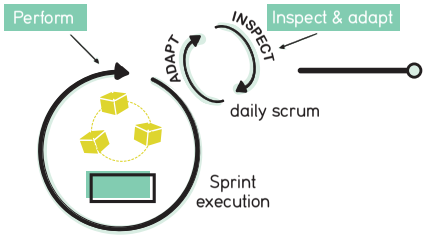


Sprints: work is performed in iterations or cycles of up to a calendar month called sprints. Sprints are time boxed so they always have a fixed start and end date, and generally, they should all be of the same duration. A new sprint immediately follows the completion of the previous sprint.



Sprint Backlog: a list of work the development team must address during the next sprint. The list is created by selecting user stories from the top of the product backlog until the development team feels it has enough work to fill the sprint, keeping in mind the velocity of its previous sprints. The stories or features are broken down into tasks by the development team. Often an accompanying task board is used to see and change the state of the tasks of the current sprint, like "To Do","In Progress" and "Done".

Application Engineering Artifacts (2)



Sprint Execution: Once the team finishes sprint planning and agrees on the content of the next sprint, the development team, guided by the Line i Scrum Master 's coaching, performs all of the task level work necessary to get the features done . "Done" means there is a high degree of confidence that all of the work necessary for producing good quality features has been completed.

User story: a description of a certain product/application feature or behavior, written strictly from the user's point of view. Usually, the "App i Owner" writes the user stories.

Task: a unit of work, which should be feasible within one working day or less. To implement a user story, you must accomplish all associated tasks.

Impediment Backlog of Line i: a list of current impediments maintained by the Line i Scrum Master.

DoD

Definition of Done (DOD): a checklist of activities required to declare the implementation of a story to be completed. The definition is determined at the beginning of the project but the team can change it at any time.

LOUVAIN SCHOOL OF MANAGEMENT
Doctoral Thesis

An Agile Feature-Driven Framework for Managing Evolving Software Product Lines

The AgiFPL Method

Hassan HAIDAR

Agile Product Line Engineering is a paradigm that has emerged as a solution for responding to the need for managing changes in requirements, reducing time-to-market, promoting product quality, and decreasing development costs in software organizations. Agile Product Line (APL) approaches are the results of combining agile methods with Software Product Lines (SPL). The main goal of this thesis is to propose an efficient APL method. In general, software development methodologies consist of two integral parts. The first one is dedicated for requirements engineering and the second one is dedicated for the development process. In this thesis, we have proposed a Feature-Oriented Agile Product Line method called "Agile Framework for managing evolving Software Product Lines – AgiFPL method". AgiFPL has been defined, designed and implemented after studying and analyzing the existent APL methodologies with the aim to take advantage of the strengths of the studied methodologies and to overcome their weaknesses. AgiFPL was proposed to address the development process part. For the requirement engineering part, we have proposed an Integrated Requirements Engineering framework for Agile Software Product Lines, which is the part that provides the syntax and semantics used for expressing the products of an APL method. The aim is to allow analysts and developers to specify requirements that precisely capture the stakeholder's needs and intentions as well as to manage product line variabilities.

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