Chapter 6

CONCLUSION AND FUTURE WORK

“If we can really understand the problem, the answer will come out of it, because the answer is not separate from the problem.”

Jiddu Krishnamurti

6.1 Background

Separation of concerns and modularity are two fundamental principles that drive the research in software engineering since the early days. A lot of techniques exist in literature which follows these fundamental principles of software engineering. Some success in this direction has been achieved. But, still complete separation of concerns is not achieved even in today’s most popular programming paradigm like object-oriented programming. In these traditional techniques, some concerns may be easily encapsulated with their building blocks such as classes, modules, procedures etc. But, same is not possible for another. They are non-modular and spanning over multiple classes, modules, or procedures in a software system and are therefore called crosscutting concerns. Several empirical studies provide evidence that crosscutting concerns degrade code quality because they negatively impact internal quality metrics such as program size, coupling, and separation of concerns [MAR 08].

The problems that motivate advanced separation of concerns approaches are becoming more pressing and more widely recognized, and computer science has evolved enough that we have a realistic hope of addressing them. The area is young and poses many open research issues and practical challenges.

AOSD [ELR 01] is another step towards achieving it and aims at alleviating the problems of scattering and tangling. It aims at addressing crosscutting concerns by providing means for their systematic identification, separation, representation and composition [RAS 03]. Crosscutting concerns are encapsulated in separate modules, known as aspects, so that localization can be promoted. It later uses composition mechanism to weave them with other core modules at loading time, compilation time, or run-time [BAN 06]. This results
in better support for modularization hence reducing development, maintenance and evolution costs.

A lot of work also has been carried out at the design level mainly through extensions to the UML meta-model e.g. [CLA 01; SUZ 99]. Research on the use of aspects at the requirements engineering stage is still immature. Handling crosscutting concerns in the early stages of software development is beneficial rather than handling them in later stages of software development because it not only makes the design simpler, but also helps to reduce the cost and defects that occur in the later stages of development.

Aspect-Oriented Requirements Engineering (AORE) [RAS 03] is an early phase in AOSD that supports separation of crosscutting concerns at requirements level. It not only aims to provide improved separation of crosscutting concerns during requirements engineering, but also to provide a better means to identify and manage conflicts arising due to tangled representations of crosscutting concerns. Since during requirement phase, a more direct contact is maintained with stakeholders [NUS 00], which assists negotiation and decision-making among stakeholders. Such means of early conflict resolution help to establish critical trade-offs even before the architecture is derived [KHA 05].

Over the last few years, several research efforts have been devoted for handling crosscutting concerns at the early phases of software development especially at requirements level. These efforts are meaningless unless all the crosscutting concerns are properly identified. Many approaches only consider non-functional concerns as crosscutting concerns. However, crosscutting concerns may also be functional, such as auditing, or validation [MOR 02; RAS 06]. Further, several research efforts have been devoted to resolve conflict in AORE but, still a lot of work is needed. The use of fuzzy logic to conflict resolution is an emerging area that will incorporate one domain in other.

6.2 Significant Contribution

Four major contributions made in this thesis are briefly described as follows:

- **Cognition and Analysis of AORE Literature**

  The *first contribution* made in this thesis is to cognition and analysis of AORE literature. This is achieved by presenting an extensive AORE literature which helped
to set the context and the background for this research work and also to understand some core key terms. We have also discussed some traditional requirements engineering approaches that provide good support for identification and treatment of requirements. But, they all fail in handling the crosscutting concerns clearly and motivated to invent AORE approaches to remove some of the flaws encountered in traditional requirements engineering approaches which is presented in Section 2.1.4 of this thesis.

Over the last few years, several research efforts have been devoted for handling crosscutting concerns at the early phases of software development especially at requirements level. These efforts are meaningless unless all the crosscutting concerns are properly identified. After presenting a critical analysis of AORE approaches exists in literature (discussed in Section 3.2) we are able to say that many AORE approaches only consider non-functional concerns as crosscutting concerns. However, crosscutting concerns may also be functional, such as auditing, or validation [MOR 02; RAS 06].

Based on the above discussion, we have presented a roadmap to our research which is discussed in Section 3.3 of this thesis.

- **Development of Integrated AORE Process Model**

The flaws encountered in traditional requirements engineering approaches should be avoided by AORE process models. A lot of work in the area of AORE has been done with some success, but this work is not sufficient to handle all the flaws encountered. Some AORE process models still need to avoid the tyranny of dominant decomposition because they are extensions of existing requirements engineering approaches; need to improve the ability to identify and specify both functional and non-functional crosscutting concerns because most of the approaches consider only non-functional concerns as crosscutting; and need to offer a systematic method to handle conflicts in AORE. Thus, the main motivation factor behind this research work was the analysis of existing AORE approaches and incorporating their strengths into a single integrated approach.
The second contribution in this thesis is made by proposing an Integrated AORE Process Model which is integration of [ARA 03; BRI 04; JOS 10]. This model is divided into four main activities: identify concerns, specify concerns, identify crosscutting concerns, and compose concerns. The model supports the identification of concerns, specification of concerns, identification of crosscutting concerns (both functional and non-functional), and composition of concerns. This model also supports conflict resolution that could emerge at requirements level. To validate the model, it is illustrated with a case study.

- Development of Fuzzy Interval Based Approach to Handle Conflict in AORE

A conflict occurs among two or more concerns when one of them tries to vary in a way that is totally opposite i.e. contribute negative to others [AMR 12]. In AORE, a conflict occurs when two or more crosscutting concerns i.e. aspects having the same priority contribute negatively to each other, need to be composed in the same match point. A match point identifies specific locations in the base concerns where other concerns’ behaviour should be composed, or satisfied. Conflict resolution is a process that establishes a critical trade-off among such kind of aspects. So, the conflict resolution process is a compulsory process [SAM 07] and need to achieve it.

In last few years, many researchers contributed their significant work for resolving conflicts but most of them have used simple reasoning techniques based on intuitive that do not allow a rigorous engineering approach to the problem. These efforts were briefly discussed in section 5.2.

The third contribution in this thesis is made by proposing a fuzzy interval based approach to handle conflicts in AORE. This approach is an extension to already existing approach [RAS 03] and [HAM 08] for handle conflicts in AORE. Here, we have applied the concept of fuzzy intervals, which are more appropriate than traditional classical numbers, because fuzzy numbers depict the physical world more realistically than single-valued numbers. To validate the approach, it is illustrated with a case study.
Establishment of Comparison Criteria to Evaluate Proposed Approach Against Other Approaches Existing in Literature

The forth contribution in this thesis is made by establishing the comparison criteria to evaluate proposed approach against other approaches existing in literature. The comparison criteria was based on the specific criteria for assessing requirements engineering approaches proposed in Chitchyan et al. [CHI 05] and Khan et al. [KHA 05]. Following these comparison criteria, the proposed model was evaluated with some AORE approaches already exist in literature. As per evaluation results, the integrated AORE process model appears as the best model for advanced separation of concerns because it not only supports four systematic activities for separation of concerns (identify concerns, separate concerns, represent concerns, and compose concerns) but also supports modularization, conflict resolution, and traceability. The illustration of the proposed model with a case study validates it to some extent and indicates that this approach reaching some maturity.

6.3 Future Work

The main motivation factor behind this research work was the analysis of existing AORE approaches and incorporating their strengths into a single integrated approach to improve the ability to identify and specify both functional and non-functional crosscutting concerns, and to handle conflicts. As expected, an integrated AORE process model was proposed in this research work. The model supports the identification of concerns, specification of concerns, and identification of crosscutting concerns (both functional and non-functional). This model also supports conflict resolution that could emerge at requirements level. In order to enhance the acceptability of the developed process model, experimental validation has been carried out using a case study.

The research work is a step towards advanced separation of concerns during early stages of software development especially at requirements phase and requires lots of concentrations. The proposed model is still considered to be in its beginning stage and there are many opportunities for improvement as future extensions. Future work includes:
• **Industrial Experimental Validation**

During this research work, the proposed integrated AORE process model and the fuzzy fuzzy intervals based approach to handle conflicts in AORE are implemented on a case study. In order to enhance the acceptability of these proposals, it is required to implements these on large scale industrial projects. Collection of industrial project’s data itself requires lot of efforts, time, and manpower which was not feasible during this research work. However, implementation on industrial projects has its own importance for validation. Therefore, this model should be applied on industrial projects.

• **Establishment of Software Quality Metrics for Quantitative Evaluation**

In this research work, qualitative evaluation is performed by establishing the comparison criteria to evaluate proposed approach against other approaches existing in literature. The comparison criteria was based on the specific criteria for assessing requirements engineering approaches proposed by Chitchyan *et al.* [CHI 05] and Khan *et al.* [KHA 05].

Since quantitative measurements are essential in all sciences, so it is needed to evaluate the proposed approach against the software quality metrics. The metrics were originally proposed to requirements engineering for Object-Oriented approaches and then were adapted to AOSD. However, these metrics are much related to specific artefacts, for example classes, which cannot assess accurately the AORE artefacts of the different approaches. Therefore, these metrics had to be extended for AORE and new ones had to be established.

• **To Extend Réquirements Management in AORE**

A requirement can be thought of as a dynamic concept that changes and evolves throughout the software development lifecycle. It can be enhanced, taken away from, added to, dropped from the scope altogether, split into multiple requirements, or aggregated with other requirements. Research shows that requirements can and do change throughout the duration of a project. For example, one of IBM’s labs reports that 25% of requirements on an average system being developed within the company will change [NEA 01].
Requirements management is the set of disciplines and activities concerned with the capture, formulation, organization, versioning, publishing, tracing, analysis, and change of requirements. Many people mistakenly believe that requirements management is something that takes place during the definition stages of a project and is then complete. In fact, requirements exist in some form at virtually every stage of development. Indeed, requirements play a vital role in the many stages of testing, even those at the end of the development process.

We believe that changing requirements may cause side effects on identified concerns especially on crosscutting concerns because if requirements are modified or elaborated then they definitely affect the respective concerns, resulting some new concerns as crosscutting concerns and vice versa. So, to avoid or minimize these side effects, there is an area of future work to extend the requirements management in AORE approaches.

- **To Define Compositional Rules**

Our approach partially supports composition of concerns as it lacks in defining the compositional rules. A composition rule defines the order and how in which concerns will be applied in a particular match point. Composition rules need to be handled from two different perspectives: the order in which required concerns will be composed with the base concern that defines the match point and, for each particular required concern, how its behaviour will be integrated into the base concern. Hence, there is an area of future work to introduce the notions of composition rule to promote a more rigorous and systematic composition activity.

Other important future work will be investigating how requirement documents should be built so that crosscutting concerns can be localized and their influence over other concerns can be specified explicitly. Instead of identifying crosscutting concerns from existing software requirement specifications, crosscutting concerns can be addressed upfront when requirements are being compiled and software requirement specifications are being formed.
6.4 Conclusion

In this thesis, we have presented main concepts and approaches concerning AORE. The main focus placed primarily on cognition and analysis of AORE literature, proposing an Integrated AORE Process Model, proposing a fuzzy interval based approach to handle conflicts in AORE, and establishing the comparison criteria to evaluate proposed approach against other approaches existing in literature.

In this thesis, we have discussed many AORE approaches to deal with crosscutting concerns at early stages of software development. As compared with traditional requirements engineering approaches like use cases, viewpoints, and goals; AORE approaches are too young and still need to: avoid the tyranny of dominant decomposition because they are extension to traditional requirements engineering approaches, improve the ability for identifying both functional and non-functional crosscutting concerns because most of the approaches consider only non-functional concerns as crosscutting, and to handle conflicts because most of researchers have used simple reasoning techniques based on intuitive that do not allow a rigorous engineering approach to the problem.

Thus, the main motivation towards integrated AORE process model was the analysis of existing AORE approaches and incorporating their strengths into a single integrated approach to solve all these problems. The proposed model which is integration of [ARA 03; BRI 04; JOS 10] supports the identification of concerns, specification of concerns, and identification of crosscutting concerns both functional and non-functional. This approach also supports conflict resolution that could emerge at requirements level.

In this thesis, we also have presented an approach to resolve conflicts in AORE, which is an extension to already existing approach in [RAS 03] and [HAM 08]. Here, we have applied the concepts of fuzzy intervals for conflict resolution in AORE which will prove to be a powerful tool for decision-making in human reasoning, and to handle and manipulate imprecise data because fuzzy numbers depict the physical world more realistically than single-valued numbers.
But, still we need more efforts on these approaches to realize them as valid approaches. Our future work will focus on improving the proposed approaches by incorporating all the aspects which are left here.