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Trustworthy Resolution of Requirement Conflicts at Runtime

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Abstract

As software systems become increasingly autonomous, trust has emerged as a critical factor that directly influences users' acceptance and adoption of these systems. However, trust is challenged by conflicting system requirements, as they can lead to unexpected and potentially unwanted system behaviour. Particularly in autonomous systems that operate in dynamic and uncertain environments, conflicts are likely and need to be managed in a way that preserves and positively impacts the user's trust. This thesis investigates how conflicting requirements can be managed at runtime in a way that maintains user trust. The resulting contributions aim to establish guidelines for trustworthy conflict management that ensure that conflict resolution is both effective and aligned with user expectations.

CCS Concepts

• **Software and its engineering** → *Software evolution*.

Keywords

Requirement Conflict, Conflict Resolution, Trust, Runtime, Requirements Engineering

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1 Background and Research Problem

Systems today are becoming more autonomous and often operate in dynamic and uncertain environments, which has made trust between the system and user a central factor to consider [2, 21, 26]. How trustworthy users perceive a system to be plays a crucial role in their acceptance and adoption of it [9, 19]. However, higher levels of system autonomy can negatively impact trust due to reduced user control, as well as a perceived lack of predictability and transparency [5, 10, 21]. Therefore, trust needs to be carefully managed in autonomous systems to ensure users accept them despite having limited control in certain situations [18].

Another factor that challenges the user's trust in a system is requirement or goal conflicts [13, 25]. Requirement conflicts arise

when a set of requirements is incompatible and cannot be satisfied simultaneously [23]. An example of a conflict could be between a security requirement that requires a certain level of data encryption, which can lead to slower data transmission, and a safety requirement for the brakes in a car that requires real-time data communication with minimal lag. Another example from the human-robot interaction domain is a conflict between the human's need to maintain a certain distance from the robot for safety and the robot's need to complete a task that requires moving closer to the human.

With autonomous systems that operate in dynamic environments, the risk of conflicts increases, particularly at runtime [3, 11], due to unexpected changes in the internal state of the system or its environment, such as changes in user goals or preferences. At runtime, these conflicts need to be resolved in a more adaptive and often more autonomous manner. However, as discussed earlier, systems with higher autonomy can challenge trust due to users' perceived lack of control or lower system interpretability, which makes it difficult for humans to understand and follow the system's decision-making [10, 28]. Higher levels of automation can also lead to misuse or disuse of technology due to too high or too low trust from human users [8, 14, 22].

Consequently, one question that arises is how conflicting requirements can be managed at runtime while maintaining the user's trust in the system. To address this issue, it is necessary to gather more insights into what is essential to effectively resolve conflicts in runtime contexts and how humans need to be supported during conflict resolution to enable adequate levels of trust, especially for solutions where a higher level of autonomy is needed, such as in conflict resolution at runtime. Having a better understanding of how the resolution mechanisms should involve humans to inspire trust plays an important factor in promoting safety and efficiency in human-automation collaborations [8].

Therefore, the overall aim of this thesis is to provide solutions for the trustworthy resolution of conflicting requirements at runtime. The proposed solutions can help provide guidelines for effective conflict resolution, which promote and support users' trust with, for example, the right degree of human involvement in the resolution, the right amount and type of explainability, or adequate assurances of the resolution's effectiveness and outcome satisfaction.

2 Related Work

Several conflict resolution approaches have been proposed in previous works [4, 16, 20, 27, 32] for conflicts in runtime contexts or autonomous systems. However, these solutions often do not consider the impact on trust in relation to conflict resolution, as well as how the human should be considered in this process to maintain their trust. While there is previous research [6, 7, 35] in the software engineering domain that has proposed solutions to resolve requirement or goal conflicts with some consideration of the human in the

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process through human-in-the-loop approaches, these approaches are generally aimed at design time resolution of conflicts and would be ineffective for resolving conflicts in autonomous systems. Other aspects of trust such as explainability have also been explored with more autonomous conflict resolution [30, 31]. Increasing the understandability of a system with explanations represents one critical dimension of trust. However, future research needs to consider a more holistic view that takes other aspects into account as well, particularly as in some conflict contexts, explanations are not sufficient to build or maintain trust [33].

In other domains, such as in human-robot interaction, several solutions [12, 13, 15, 24] have been proposed to resolve goal conflicts between humans and robots. However, there are also relatively few studies [1] that explore the impact on trust in this process. Similarly, previous research related to autonomous vehicles [17, 36, 37] has proposed solution frameworks for conflict resolution, but the direct impact on trust remains relatively unexplored, with only a few current works investigating this issue [29].

Gaining a better understanding of how conflict resolution affects users' trust represents a significant gap, where further research can help improve interactions between autonomous systems and users, especially in more complex situations and environments. To the best of our knowledge, no existing studies examine how real-time conflict resolution strategies directly influence human trust or how such conflicts should be managed to preserve it. This dissertation therefore aims to provide solutions such as guidelines and frameworks to conceptualise and integrate trust-awareness in autonomous conflict resolution, particularly when human-system goal conflicts emerge at runtime.

3 Research Approach and Preliminary Results

The general aim of this thesis is to identify and create solutions for trustworthy resolution of conflicting requirements at runtime. To achieve this aim, our approach is based on two parts:

Domain Exploration. We need a better understanding of requirement conflicts and conflict management, as well as how trust is impacted by conflict management, such as which factors are critical for maintaining trust during conflict resolution.

Solution Design. Based on our findings from exploring the domain of requirement conflict management and trust, we aim to propose solution guidelines in the form of concrete recommendations and potentially a framework that can conceptualise and guide the promotion and maintenance of trust in requirement conflict resolution, particularly in autonomous system contexts.

The two parts are described in more detail below.

3.1 Domain Exploration

In order to provide solutions for effective requirement or goal conflict resolution that can maintain users' trust in autonomous systems, we need more insights into conflict management in practice and how trust is affected during conflict resolution.

In our previous work [34], we explored the types of conflicts that occur in practice and how they are managed. We performed an interview study with ten practitioners from eight different companies. Our findings highlighted the context-dependent nature of requirement conflicts, as we found multiple different conflict types,

causes, and corresponding solutions that are typically applied to resolve a certain conflict situation. This study highlights the need to consider the conflict cause in the resolution process. Taking a more rationale-driven approach could potentially enable more effective conflict resolution and is therefore a key insight to build upon when developing solutions for dynamic conflict situations.

Furthermore, to gain more insights into conflict resolution and trust, we evaluated the impact of different conflict resolution settings on trust, with a specific focus on two dimensions: automation level, i.e., human involvement in conflict resolution, and explainability level [33]. We conducted a 2x2 within-subjects experimental study with 20 participants, where we simulated a requirement conflict between a human and a robot. The impact on the participants' trust was measured through surveys and a short interview. Automation level had a statistically significant effect on trust, whereas explanations did not. Based on the interviews, we found that the impact of explanations on user trust depends on different contextual factors, such as the type and timing of the explanation. Moreover, the type of conflict also appears to have a strong impact on this aspect in relation to trust.

In future work, the aim is to further explore trust in the context of conflict resolution, such as studying the impact of automation and explainability with different types of conflicts to enable more generalisable results.

3.2 Solution Design

In this thesis, the aim is to provide solutions such as concrete guidelines and a framework that conceptualises trustworthy conflict resolution at runtime. Previous frameworks and models on trust in automation, such as [8], will be used as the foundation, along with current solutions for dynamic conflict resolution in the autonomous system context. Moreover, the insights generated in our work so far, as well as in the next studies, will be used as the basis for the solution design.

The proposed framework will be validated with experts in the autonomous systems domain through interviews and surveys, as well as further evaluated with practitioners and end users through experiments. Creating an initial version of this framework is currently ongoing.

4 Expected Contributions

With the proposed approach in this dissertation, we aim to contribute new strategies for resolving requirement conflicts at runtime in a manner that supports and promotes trust. The thesis will provide new insights into and solutions for intelligent conflict resolution in autonomous systems that interact with users without negatively impacting their trust. This thesis will further contribute to research on trust in software engineering and increase the consideration of user trust in requirements management at runtime.

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