Does the Task Structure of Open Source Projects Matter? Superposition and Value Creation

Research-in-Progress

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Abstract

Collaboration through open superposition describes a process of building free (libre) and open source software (FLOSS), wherein motivationally independent layers of work is sequentially added one-on-top the other over time. This research-in-progress paper theorizes the mechanisms through which superposition influences the value of individual and organizational owned FLOSS projects. We argue for a non-linear relationship between degree of superposition and value of the FLOSS project. Moreover, we posit that the type of ownership will moderate this non-linear relationship. The moderation effect is such that – (1) organizational ownership mitigates the influence of degree of superposition on project value (2) under organizational ownership, the optimal value of degree of superposition (the point at which the project value is maximum) is lower as compared to individual owned projects. This research attempts to advance the theory of superposition and unearth the influence of task structure on the value of the FLOSS project. The findings provide insights to FLOSS researchers and practitioners as to how they can model the task structure of FLOSS projects to generate maximum value.

Keywords: open source, collaboration, motivation, task structure, IS development, superposition, value

Introduction

In the current digitally enabled collaborative environment, free (libre) and open source software (FLOSS) projects have become ubiquitous. Increasingly, both individuals as well as organizations are adopting FLOSS as a viable mode of software development because of the multifarious advantages it offers with respect to evolved coordination and motivational mechanisms. The unique coordination and motivational mechanisms that FLOSS projects offer have the ability to generate supernormal ‘value’ that can be tapped by users and businesses. For example, in a 2013 study of 750 C/C++ FLOSS projects, it was found that the quality of FLOSS projects surpassed that of proprietary software (Coverity Report, 2013). This has resulted in a need for a structured theoretical enquiry into the determinants of FLOSS project value. Though project value can be conceptualized in different ways, prior research emphasizes the need to take the user’s perspective in determining the value of the project outcome (Crowston, Annabi, & Howison, 2003; Stewart, Ammeter, & Maruping, 2006; Venkatesh, Morris, Davis, & Davis, 2003). Using this line of thought, we define value of a FLOSS projects as the significance that the project has for the end users. Prior research has examined several aspects related to FLOSS project value and has laid the groundwork.
for a deeper enquiry into the subject (e.g. Crowston, Wei, & Howison, 2012; Howison & Crowston, 2014). By building on such research, our aim is to move this salient agenda forward, which we believe will be valuable to both research and practice.

Organizations become participants in FLOSS projects by not only dedicating internal resources (programmers, infrastructure etc.) towards the projects but also by opening up the source code of their previously designed proprietary software to the public domain. For example, in November 2001, IBM embraced the open source approach by opening up the source code of several of its software tools (estimated at $40 million) to the public domain\(^1\). This officially created the Eclipse open source project (Wagstrom, 2009). As organizations embrace FLOSS, there is a need to examine FLOSS from an organizational participation perspective. Despite the salience, research on this subject especially from an organizational perspective is rather limited (Crowston et al., 2012). Specifically, there is an emergent need to study the FLOSS phenomenon from an outward perspective that can allow organizations to derive enhanced value from such projects (Fitzgerald, 2006). Motivated by Fitzgerald’s (2006) call to study the FLOSS phenomenon from an outward perspective, this research looks at the relationship between task structure and the value of the FLOSS project. Further, we also examine the influence of organizational ownership on this relationship.

The theory of collaboration through open superposition (Howison & Crowston, 2014) provides a new socio-technical lens that can be leveraged to study the influence of task structure on the value of FLOSS projects. Drawing largely from self-determination theory (SDT) (Ryan & Deci, 2000a; Ryan & Deci, 2000b) and the application of SDT to the task effort context of FLOSS projects (Ke & Zhang, 2010); the theory of superposition argues that “collaboration through open superposition is at the core of the success of community-based FLOSS projects, allowing an organization of task work that leads to the discovery of a work-breakdown that is both motivating and surprisingly coordinated” (pp. 31).

Although theory of superposition offers a unique perspective in understanding the task structure of FLOSS projects, three gaps in the research are particularly noteworthy. First, there is a need to understand theoretically and empirically if there are any limits to the value of the project to the end-users through superimposed organization of tasks. Second, because more and more organizations are adopting FLOSS, it is important to understand if formal project management approaches that organizations bring have any influence on the end-user value of the project. Specifically, is there any difference in the mechanisms that create value between individual and organization owned FLOSS projects? Third, the concept of superposition was developed through three specific FLOSS projects, which offered the necessary depth for rich theorization. But to have a greater empirical generalizability there is a need to operationalize the concept and study the relationships using secondary data. Our research aims to address these three salient gaps by addressing the following two research questions: -

**RQ1: How does the extent of superposition of tasks influence the end-user value of the FLOSS projects?**

**RQ2: How does organization owned FLOSS projects differ in terms of task superposition as compared to individual owned FLOSS projects and does it have any impact on value created for end-users?**

Through this research, we aim to make the following contributions. First, the research advances the theory of superposition by teasing out the relationship between the degree of superposition and the value of the project to the end-users. Second, we contribute to the theoretical understanding regarding the different ways in which superposition will influence project value in organizational and individual FLOSS projects. Third, we operationalize the key construct-degree of superposition, which we use for empirically validating the proposed hypotheses.

**Theoretical Background and Degree of Superposition**

**Theoretical Background**

Early research on the characteristics of FLOSS artifact indicates the importance of modular software architecture to ensure successful collaboration in FLOSS environments. For example, Baldwin & Clark

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Task Structure of Open Source Projects

(2006) show that high modularity and high option value can attract more contributors and sustain their cooperation. However, research on modularity often stops short of understanding how contributors organize the task work given a modular architecture. In order to understand how contributors coordinate their task-work, FLOSS researchers have commonly invoked coordination theory (CT) (Malone & Crowston, 1994). For example, Crowston et al. (2005) used CT to contrast coordination mechanisms in commercial and FLOSS projects. Crowston & Scozzi (2004), studied coordination mechanisms involved in the bug fixing process, finding that the tasks involved are sequential and composed of only a few steps. Other research on coordination in FLOSS projects include the study of how material artifacts impact cross-project coordination in a large open source project (Chua & Adrian, 2010), the impact of project size on the coordination mechanisms adopted (Mockus, Fielding, & Herbsleb, 2002) etc. However, this large body of research primarily looks at understanding how the organization of tasks can alleviate the problems of coordination. There has been limited discussion about the impact of task structures on motivating contribution and increasing FLOSS project value.

Research on superposition of tasks (Howison & Crowston, 2014) is one of the latest attempts at understanding the influence of task structure on the motivation and coordination of FLOSS communities. Superposition is the process through which software development occurs in a sequential manner, where changes to the software are added incrementally one-on-top the other. Each change represents a task that is independently built by a contributor and has its own functional pay-off through the improvements that it brings to the application (Howison & Crowston, 2014). The theory of superposition proposed by Howison & Crowston (2014) argues that in the case of FLOSS projects, superposition provides the most effective work break down structure that enhances the motivation to contribute and at the same time allows for the creation of complex software. In order to build a case for the above argument, the authors invoke theories of motivation and coordination. In specific, they expand the work of Ke & Zhang (2010) who apply SDT (Ryan & Deci, 2000b) and affective events theory (AET) (Weiss & Cropanzo, 1996) to show that the satisfaction of the psychological needs for competence, autonomy and relatedness will lead to contributors expending greater task effort in FLOSS projects. The authors also invoke CT (Malone & Crowston, 1994) to show that superposition not only provides the right motivational mechanism but can also overcome coordination issues while building complex software. SDT and its sub-theories postulate the existence of three innate psychological needs – competence, autonomy and relatedness – which, when satisfied yield enhanced self-motivation and result in a positive affective state (Ke & Zhang, 2010, Ryan & Deci, 2000b). AET on the other hand establishes a link between the affective state of the individual and task effort expended by the individual, arguing that a positive affective state enhances the task effort expended by the individual (Weiss & Cropanzo, 1996). Our research, tries to advance the theory of superposition by understanding the influence of superposition on the end-user value of the FLOSS project. While doing so, we study the influence of superposition on enhancing the affective state of contributors. We also study the influence of organization ownership on the relationship between superposition and end-user value of the FLOSS project.

Operationalizing Degree of Superposition:

In order to study the influence of superposition on the end-user value of the FLOSS project, we first operationalize the construct - degree of superposition. While doing so, we try to remain true to the concept of superposition introduced by Howison & Crowston (2014).

Task: A task is a unit of contribution to the FLOSS project. Howison & Crowston (2014) describe a task as a sequence of actions that leads to a change in the shared output of the project, which could be a new feature, a bug fix, updated documentation etc. The actions within a task may include – adding/deleting of code, changing files, incorporating comments, or even a review of the code. Thus, a task can begin with messages on a FLOSS community mailing list signaling a project need, continue with developments, involve peer reviews and subsequently result in a functional change to the application itself (Howison & Crowston, 2014).

Productive deferral: In the case of FLOSS projects, it is observed that the development work is undertaken overwhelmingly through individual, short episodes of work (Howison & Crowston, 2014). Since the FLOSS environment is usually not one of deadlines and time pressures, complex work tends to be deferred, rather than being broken down into smaller components to be undertaken collaboratively. That is, a contributor who has envisioned a desired task but perceives it to be too big to be implemented
individually in a short period of time, will defer the task work until code written by someone else (sometimes written for entirely different reasons) makes the envisioned task easy enough to be undertaken through relatively simple, quick, and individual work (Howison and Crowston 2014). This kind of task deferral (referred to as productive deferral) is often followed in lieu of co-work in FLOSS projects because co-work tends to reduce the autonomy afforded to the contributor (Howison & Crowston, 2014). In summary, on account of the limited time pressure and the unique motivational mechanisms (Ke & Zhang, 2010) that operate in FLOSS environments, contributors faced with complex tasks adopt superposed work structure through a process of productive deferral rather than engaging in co-work. Thus, FLOSS projects that show high levels of superposition are expected to predominantly use productive deferral to accomplish complex or big tasks. While the use of productive deferral provides the best motivational mechanism for FLOSS projects, we propose that it can also lead to inefficiencies in terms of the time it takes to accomplish the task and realize new functionalities.

**Degree of Superposition:** While theorizing collaboration through open superposition, Howison & Crowston (2014) contend that in the case of FLOSS projects, tasks are implemented by individual contributors who realize some functional pay-off from the creation of that task. Over time, these tasks are layered one-on-top of the other to incrementally build the FLOSS software. Based on this understanding, we define degree of superposition as the ratio of the total number of “versions” of the FLOSS project to the total number of “task contributions” to the project. A specific version of the project is analogous to a snapshot of the project available on a particular date. It indicates the status of the project at a given point in time in the project’s history.

Consider the example illustrated in Figure 1. Tasks A and B are added to version 0 of the project that was available on the 15th. The addition of tasks A and B results in version 1 of the project on the 17th. Task C builds on the version that was available on 17th (version 1) creating version 2 of the project. Tasks D, E and F builds on the version available on 21st (version 2) creating version 3 of the project. This example has 6 tasks and 3 versions and hence the degree of superposition is 3/6, which is 0.5.

Based on this definition, degree of superposition for a project increases as it adopts a more sequential (layered) development approach. While it decreases as projects adopts a more concurrent development approach. In other words, degree of superposition is higher for projects that tend to add new features and updates one-on-top the other rather than many at a time concurrently.

![Diagram](image)

**Figure 1: An Example for the Calculation of Degree of Superposition**
Hypothesis

**Relationship Between Degree of Superposition and End-user Value of FLOSS Project**

In the case of community-based FLOSS projects, collaboration of task work predominantly occurs through superposition. Howison & Crowston (2014) detail how superposition satisfies the three innate psychological needs of autonomy, competence and relatedness (Ryan & Deci, 2000b) creating a work breakdown structure that motivates contribution. First, superposition minimizes the interdependencies amongst contributors thereby satisfying their need for autonomy. In addition, superposition also allows complex task work to be undertaken with minimal co-work through productive deferral (Howison & Crowston, 2014). In productive deferral, a big or complex task is deferred until the work done by someone else renders the task simple enough to be completed individually. Second, superposition encourages the sense of competence in contributors because each task independently results in an improvement to the shared output of the project. Third, superposition addresses the need for relatedness as the layering of tasks on the work of others and the potential support from other contributors provides relatedness in a manner that does not undermine autonomy. Hence, by providing the aforementioned motivational mechanisms that satisfy the innate psychological needs of competence, autonomy and relatedness, superposition creates a positive motivational environment. This in-turn encourages individuals to contribute towards FLOSS projects, developing new functionalities, and eventually resulting in an increase in value for the end users. Consequently, an increase in the degree of superposition is expected to positively influence the value of the FLOSS project to the end-users. But would an increase in degree of superposition be always associated with an increase in value of the FLOSS project? To answer this question, we need to go deeper into the mechanisms that are contributing to this increase.

While superposition provides a positive motivational mechanism for individuals to contribute to FLOSS projects, we contend that there is a potential cost to adopting a superposed work breakdown structure. This cost is due to the inefficiencies involved in adopting a sequential pattern of development with very little co-work. This is especially a concern at high values of superposition where contributors tend to predominantly defer the complex or big tasks instead of engaging in co-work. This increased adoption of the productive deferral mechanism and avoidance of co-work, attributable to a high degree of superposition, may lead to frustration in the potential contributors who now need to wait until the missing piece has been executed by someone else in the FLOSS community, resulting in an arousal of negative affect (see Zhang, 2013). This is especially true if the contributors have to deal with long delays while waiting for the work of others to make the envisioned task simpler. The negative affective state caused due to frustration has been shown to reduce the task effort put forth by the individuals (Weiss & Cropanzano, 1996; Zhang, 2013), which in-turn may be instrumental in reducing the end-user value of the FLOSS project.

Hence we see that superposition has both positive and negative influences. The positive motivational environment enabled by enhanced autonomy tends to be countered by negative influence of frustration due to productive deferral mechanisms and avoidance of co-work at increasing levels of superposition. Thus we posit that the relationship between superposition and the end-user value of the project is positive until it reaches a maximum after which it starts diminishing. That is, as degree of superposition increases, value of the FLOSS project increases as it initially provides the right motivational mechanism to attract and retain contributors. But at a certain value of degree of superposition (turning point), the marginal benefit of increase in autonomy is compensated by a decrease attributable to negative affect due to frustration. Hence we hypothesize:

*Hypothesis 1: In the context of FLOSS projects, degree of superposition has a non-linear relationship with project value, such that, the value of the project to end-users increases with increase in degree of superposition until a particular value of degree of superposition (turning point). Above this optimal value of degree of superposition, any further increase in degree of superposition lowers the value of the project to the end-users.*
Moderating Effect of Owner Type on the Relationship Between Degree of Superposition and End-user Value of FLOSS Project

The organizational ownership of FLOSS projects is not only restricted to market driven (for-profit) organizations such as Google and Facebook but also nonmarket driven organizations such as Apache Software Foundation, Eclipse Foundation, and Gnome Foundation (Riehle, 2010; Wagstrom, 2009). While market driven and nonmarket driven organizations have different motivational drivers (Stewart et al., 2006), both types of organizations are capable of creating the right environment to enhance extrinsic and intrinsic motivation (Spaeth, von Krogh, & He, 2015). However, the intrinsic motivation afforded by the organization owner to its contributors differs based on its community-based credibility, openness and contributors social identification with the organization (Spaeth et al., 2015). In the case of FLOSS projects, volunteer contributors cannot be governed by traditional means of hierarchical reinforcements like employment or contracts (Teigland, Di Gangi, Flaten, Giovacchini, & Pastorino, 2014). Thus in the case of organization owned FLOSS projects there is an inherent trade off between openness (attracting external participation by increasing autonomy, stimulating innovation, creativity and organizational growth) and control (over platform activities, efficient development practices, and intellectual property right appropriation) (Engeström, 2007; Jarvenpaa & Lang, 2011). In contrast to organizational owned FLOSS projects that are managed by one or more organizations, individual owned projects are autonomous managed by private individuals who voluntarily contribute to such projects (West & O’mahony, 2008). Often these individual owned projects start when a contributor recognizes the need for a functionality or when they are motivated by intellectual curiosity, described by Eric Raymond (2005) as recognizing an “itch worth scratching”.

Fitzgerald (2006) introduced the concept of OSS 2.0, which recognized the emergence of a mainstream, commercially viable form of FLOSS development. OSS 2.0 is characterized by organizations participating and taking ownership of the FLOSS projects. As organizations invest in FLOSS projects, they introduce practices that allow them to balance a commercial profit value-for-money proposition while still adhering to the values of the open source community. Further, they bring in strategic planning initiatives and introduce project management practices for the efficient coordination and management of development activities (Fitzgerald, 2006). Similar findings have been observed empirically; in a study of 83 eclipse projects, it was found that FLOSS projects initiated by market driven organizations more actively employed both leadership and resource deployment control as compared to projects that are initiated by individuals belonging to the FLOSS community (Schaarschmidt, Walsh Gianfranco, & Von Kortzfleisch, 2015). Using the bazaar metaphor (Raymond, 1998), it can be said that the organizational ownership of FLOSS projects leads to the introduction of management practices that tends to transform the adopted model of development from a bazaar to a cathedral-like form. On the other hand, individual owned projects tend to retain the bazaar model of FLOSS development, with less formal management practices as compared to organization owned FLOSS projects.

The introduction of well-defined goals and mechanisms for coordinating and controlling FLOSS development activities can also influence the way in which degree of superposition relates to the project value. In organization owned projects, the formal practices and coordination structure tends to lay focus on more efficient development, leading to an increase in concurrent development or co-work as compared to individual owned FLOSS projects. Based on this understanding, we believe that in the case of organization owned FLOSS projects degree of superposition will play a lesser role in determining the end-user value of the project. Hence we hypothesize:

Hypothesis 2a: In the context of FLOSS projects, the ownership type of the project moderates the relationship between degree of superposition and the end-user value of the project, such that, in the case of organization owned projects, the influence of degree of superposition on the end-user value of the project is significantly lower as compared to individual owned projects

Another impact of organizational ownership of FLOSS project is the introduction of time pressure to the FLOSS project. Organizational investment in FLOSS projects creates opportunity costs, generating the time-cost of money and a pressure to see payoffs sooner rather than later (Howison & Crowston, 2014).

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² http://firstmonday.org/article/view/578/499
Because of this time-cost of money, delays due to productive deferral and avoidance of co-work has a larger negative influence on project value. Thus, in the case of organization owned projects, increased productive deferral, attributable to a high degree of superposition, may not only lead to a negative affective state in the contributors but also increase the time-cost of money. Since the negative influence of avoidance of co-work is stronger in the case of organization owned projects, we expect that the turning point is reached at lower values of degree of superposition. Hence, we contend that the value of degree of superposition at which the end-user value of the project is maximum (turning point) is significantly lower for organization owned FLOSS projects. Hence we hypothesize:

**Hypothesis 2b. In the case of organization owned projects the value of degree of superposition at which end-user value of the project is maximum (turning point) is significantly lesser as compared to individual owned projects.**

**Proposed Methodology**

In order to understand the mechanisms through which superposition influences FLOSS projects, we intend to conduct secondary data analysis of FLOSS projects. The availability of change logs for most public FLOSS projects allows us to recreate the entire history of a project and test the hypothesized relationships. However, the promises offered by the rich FLOSS datasets come with several perils. For example, Kalliamvakou et al. (2014), identified nine perils in using the GitHub data in FLOSS research. Similarly, Howison & Crowston (2004), cautioned against using data from SourceForge. We intend to take careful note of these issues before we conduct the empirical analysis.

**Measures**

The planned regression model includes the following dependent and independent variables. We also intend to identify relevant project level control variables (not included in this research-in-progress paper).

Dependent variable: Value of the project to the end-user is the dependent variable of interest for this research. Most of the FLOSS development environments (e.g. GitHub) come with integrated social features (Kalliamvakou et al., 2014) that captures elements of user satisfaction and use within the FLOSS project. Leveraging the integrated social features of the development environment, we intend to identify a suitable measure that captures the end-user value of the FLOSS project.

Independent variables: In order to study the relationship between degree of superposition and value of a FLOSS project, we employ two independent variables i.e. degree of superposition and project ownership flag. Degree of superposition is operationalized based on Howison & Crowston (2014) definition of superposition. It is measured as the ratio of total number of “versions” of the project to the total number of “tasks added” to the project (see subsection “Operationalizing Degree of Superposition”). To study the moderating impact of project ownership on the relation between degree of superposition and value of a FLOSS project, we create a project ownership flag. The project ownership flag takes a value “1” if the project is owned by an organization and “0” if owned by an individual.

Hypothesis 1 predicts that degree of superposition has a non-linear relationship with value of the project. To test this hypothesis we plan to include polynomial terms of degree of superposition and test its influence on project value. Hypothesis 2a and 2b, predicts that the relationship between degree of superposition and project value is moderated by ownership type of the project. To test these hypotheses, we plan to introduce the interactions of project ownership flag with degree of superposition in the regression model.

**Expected Contributions and Implications**

This research-in-progress paper seeks to understand how superposition affects the value of the FLOSS project and the role that ownership type plays in shaping this relationship. Two underlying motivations

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3 We thank one of the anonymous reviewers for suggesting GitHub as an excellent source of data for this research.
for the research are: (1) the need to advance the theory of superposition and understand its impact on project value (2) the desire to understand how formal project management structures introduced by organizations impact the relationship between superposition and end-user value of the FLOSS project. To gain insight into these issues, we draw on the theory of superposition (Howison & Crowston, 2014), SDT (Ryan & Deci, 2000b), AET (Weiss & Cropanzo, 1996) and the concept of OSS 2.0 (Fitzgerald, 2006). We find theoretical backing for a non-linear relation between superposition and end-user value of the project that is moderated by owner type. As a next step, we would like to test the identified relations using secondary data. We believe this research will bring major contributions that have theoretical, practical and methodological implications to the IS discipline.

Theoretical Contribution: The primary aim of our research is to advance the theory of superposition. In doing so, this research contributes to IS and organization theories in two ways. First, this research explains why superposition may exhibit a non-linear relationship with end-user value of the FLOSS project. It does so by predicting that negative affectivity due to productive deferrals and avoidance of co-work overwhelms the positive affectivity of autonomy at high values of superposition. Our consideration of the non-linear effect of superposition tries to provide a more complete explanation for the mechanisms with which superposition impacts value. Second, this research tries to integrate the theory of superposition (Howison & Crowston, 2014) and the concept of OSS 2.0 (Fitzgerald, 2006) to explain how organizational ownership of FLOSS projects alters the relationship between superposition and value of the project to the end-users. Ever since organizations started embracing the FLOSS phenomenon, there has been an interest in understanding how organizations can generate value from FLOSS projects. By finding that organizational ownership of FLOSS projects significantly alters the influence of task structure on project value, we aim to advance the understanding of organizational participation in FLOSS projects.

Practical Contribution: The paper’s main contribution to practice rests in the fact that it can help FLOSS project owners promote a work break down structure that best increases value to end-users. Organization owned FLOSS projects are faced with the challenge of motivating contribution and at the same time reducing the time-cost of money. This research argues that the above two goals are in-conflict in the case of FLOSS projects. A decrease in superposition can reduce the time-cost of money but leads to a loss of autonomy, which in-turn decreases the intrinsic motivation to participate. However, project owners could compensate this decrease in intrinsic motivation by some form of extrinsic motivation. Extrinsic motivation could be in the form of rewards for contribution or as a signaling effect of contribution (peer recognition, career prospects etc. (Lerner & Tirole, 2003)). Thus, FLOSS project owners looking at adopting a less superposed work-down structure will be well advised to provide some form of extrinsic motivation to compensate for the loss of autonomy.

Methodological Contribution: This research attempts to operationalize, validate and generalize the theory of superposition. Using secondary data sources, we attempt to provide empirical backing to the previously theorized relationships. As a first step towards this goal, we operationalize the construct – degree of superposition. We believe, this construct can help researchers to further advance the theory of superposition and unearth new relationships. Further, this construct provides a tool that allows practitioners to measure degree of superposition of their projects and study the effect of altering the same.

Conclusion

This research-in-progress paper seeks to advance the theory of superposition by identifying the relationship between superposition and value of the FLOSS project. In order to theorize the relationship, we call upon the theories of superposition, motivation and the concept of OSS 2.0. As a next step, we would like to validate this relationship using secondary data analysis. This research advances theory by understanding how superposition of tasks influences value of FLOSS project to end-users and how organizational ownership can change this relationship. The findings will lend insights to FLOSS researchers and practitioners as to how they can model the task structure of FLOSS projects to extract maximum value.

References


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