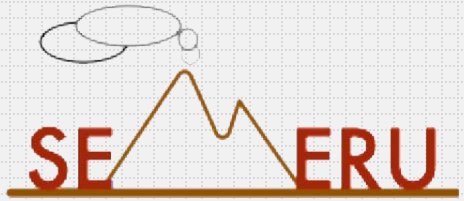
How Do Developers Document Database Usages in Source Code?

Mario Linares-Vasquez, Boyang Li, Christopher Vendome, and Denys Poshyvanyk



Database-centric application (DCA)

DCAs are software systems that rely on databases to persist records using database objects.

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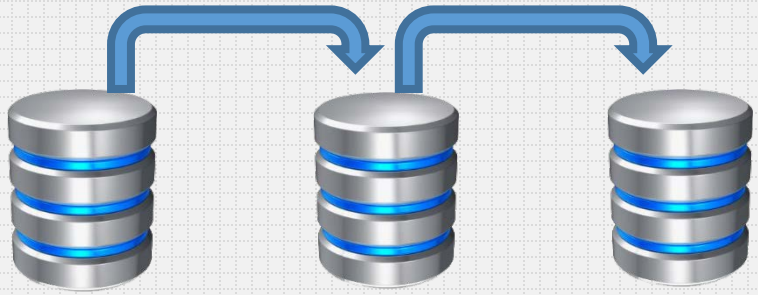
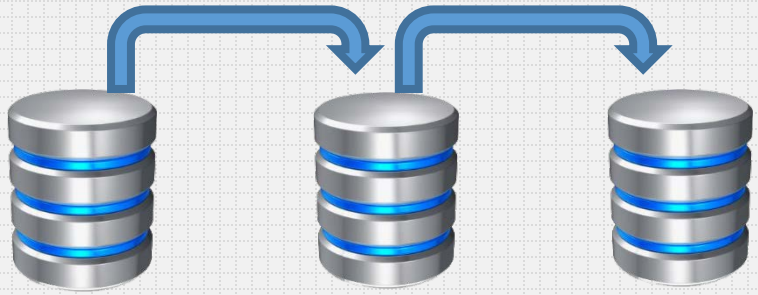
Challenges



Challenges

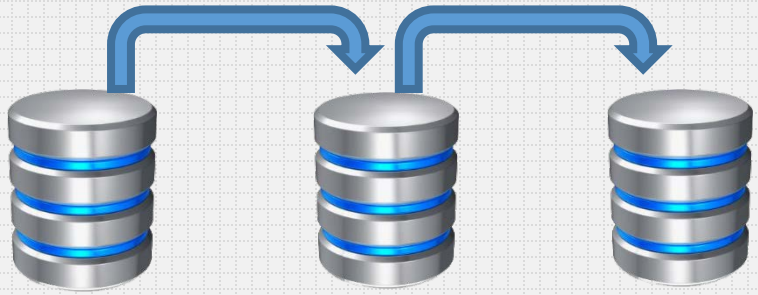


STUDENT

ID	Num	PWD	Gender	Address	Year	…
…		…	…	…	…	…
…		…	…	…	…	…

DBManager.getAllInfoByStudentID ()

Challenges



STUDENT

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ID	Num	PWD	…
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…	…		…

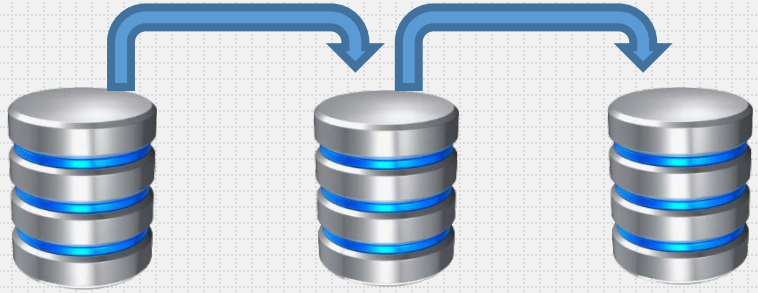
ST_LOGIN

ID	Gender	Address	Year	…
…	…	…	…	…
…	…	…	…	…

ST_DETAILS

DBManager.getAllInfoByStudentID ()

Challenges



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DBManager.getAllInfoByStudentID ()

getSTLogin()

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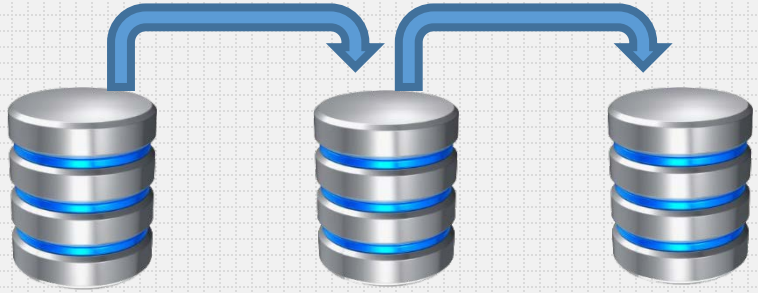
Challenges



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…		…	…	…	…	…

ID	Num	PWD	…
…	…		…
…	…		…

ST_LOGIN

ID	Gender	Address	Year	…
…	…	…	…	…
…	…	…	…	…

ST_DETAILS

UI.student.buttonClickShowAllInfo()

UI.student.quaryAllInfoByID ()

DBManager.getAllInfoByStudentID ()

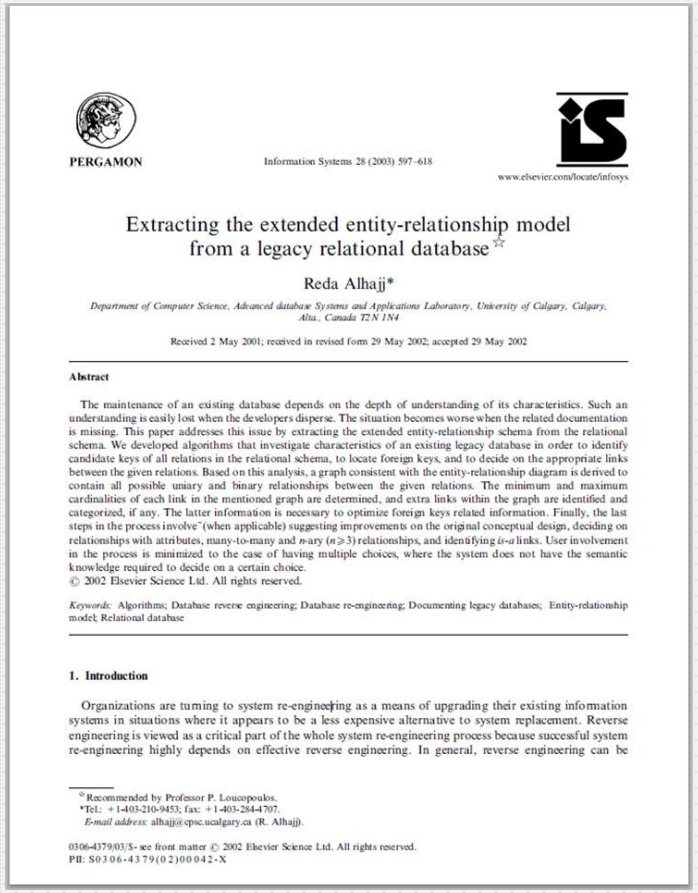
getSTLogin()

getSTDetails()

Challenges

- How the model is described by a schema
- How the database is used in the source code

Related works



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Extracting the extended entity-relationship model from a legacy relational database ☆

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Keywords: Algorithms; Database reverse engineering; Database re-engineering; Documenting legacy databases; Entity-relationship model; Relational database

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An Empirical Analysis of the Co-evolution of Schema and Code in Database Applications

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ABSTRACT

Modern database applications are among the most widely used and complex software systems. They constantly evolve, responding to changes to data, database schemas, and code. It is challenging to manage these changes and ensure that everything co-evolves consistently. For example, when a database schema is modified, all the code that interacts with the database must be changed accordingly. Although database evolution and software evolution have been extensively studied in isolation, the co-evolution of schema and code has largely been unexplored.

This paper presents the first comprehensive empirical analysis of the co-evolution of database schemas and code in ten popular large open-source database applications, totaling over 160K revisions. Our major findings include: 1) Database schemas evolve frequently during the application lifecycle, exhibiting a variety of change types with similar distributions across the studied applications; 2) Overall, schema changes induce significant code-level modifications, while certain change types have more impact on code than others; and 3) Co-change analyses can be viable to automate or assist with database application evolution. We have also observed that: 1) 80% of the schema changes happened in 20-30% of the tables, while nearly 40% of the tables did not change; and 2) Referential integrity constraints and stored procedures are rarely used in our studied subjects. We believe that our study reveals new insights into how database applications evolve and useful guidelines for designing assistive tools to aid their evolution.

Categories and Subject Descriptors

H.2.7 [**Software Engineering**]: Distribution, Maintenance, and Enhancement; H.2.1 [**Database Management**]: Logical Design—*Schema and subschema*

General Terms

Language, Measurement

Keywords

Co-evolution, database application, empirical analysis

ESEC/FSE'13, August 18–26, 2013, Saint Petersburg, Russia

1. INTRODUCTION

A database application is a software system that collects, manages, and retrieves data, which are typically stored in a database managed by a database management system (DBMS) and organized *w.r.t.* database schemas. For example, most online services are powered by database applications. Wikis, social networking systems (SNS), Web-based content management systems (CMS), mailing systems, enterprise resource planning systems (ERP) are all database applications. As Figure 1 illustrates, a program needs to obey the structure of the data organization defined by a schema when it accesses the data. Namely, a schema is a mediator that manages the interactions between code and data, bridging their gap.

Software systems are subject to continuous evolution due to modified system requirements; database applications are no exception. Cleve *et al.* [5] observe that little work exists on understanding the evolution of database applications considering both data and code. Different from traditional applications, the evolution of database applications is more complex. For example, consider a system that uses a table USER to store both user authentication information and other personal data. Now the system requirements change, and the system needs to store user authentication information and personal data separately. Thus, the original table USER must be split into two new tables, say USER_LOGIN and USER_DETAILS. Data and application code must be synchronized to be consistent with the new schemas. First, the original data organization should be migrated to the new one defined by USER_LOGIN and USER_DETAILS. Second, the original application code that accesses data in USER must be modified to correctly access the newly organized data in USER_LOGIN and USER_DETAILS.

Figure 1 illustrates these two types of co-evolution in database applications: 1) data co-evolve with schemas, and 2) code co-evolves with schemas. The first type of co-evolution involves three main tasks: i) predicting and estimating the effects before the proposed schema changes are performed; ii) rewriting the existing DBMS-level queries to work on the new schemas; and iii) migrating data to the new schemas. The second type involves two main tasks: i) evaluating the cost of reconciling the existing code *w.r.t.* the new schemas before any schema changes; and ii) locating and modifying all impacted code regions after applying the schema changes.

The database community has addressed the first co-evolution problem gracefully to support automatic data migration and DBMS-level query rewriting to operate on the new schemas [6, 7]. However, little work has considered the second co-evolution problem. Its difficulties are twofold. First, query updates and data migration for the first problem are done by DB Administrators (DBA), who have the domain knowledge. In contrast, the application developers, who have different level of database knowledge, may not precisely capture the whole evolution process of the database structure. In

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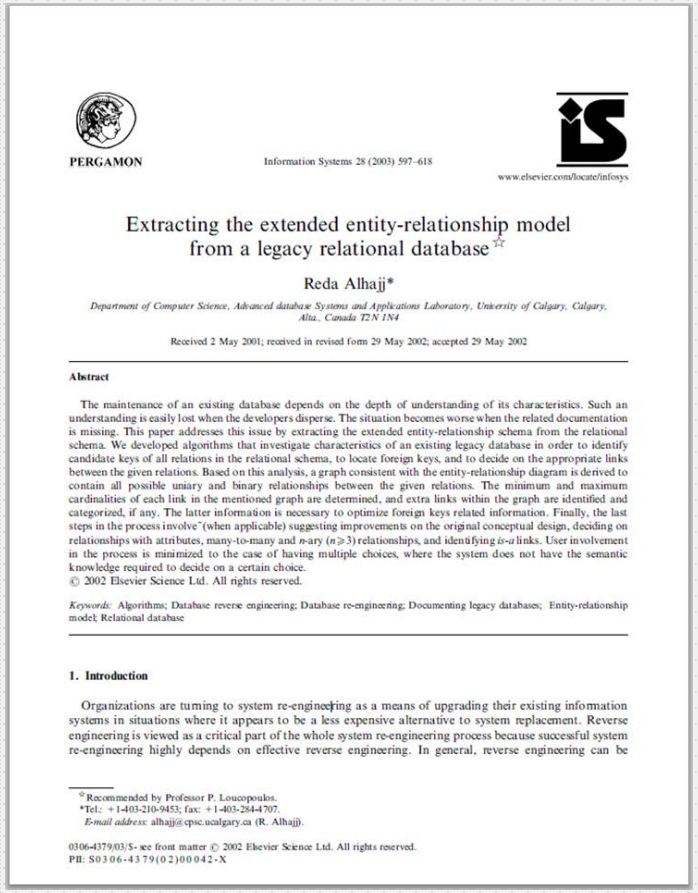

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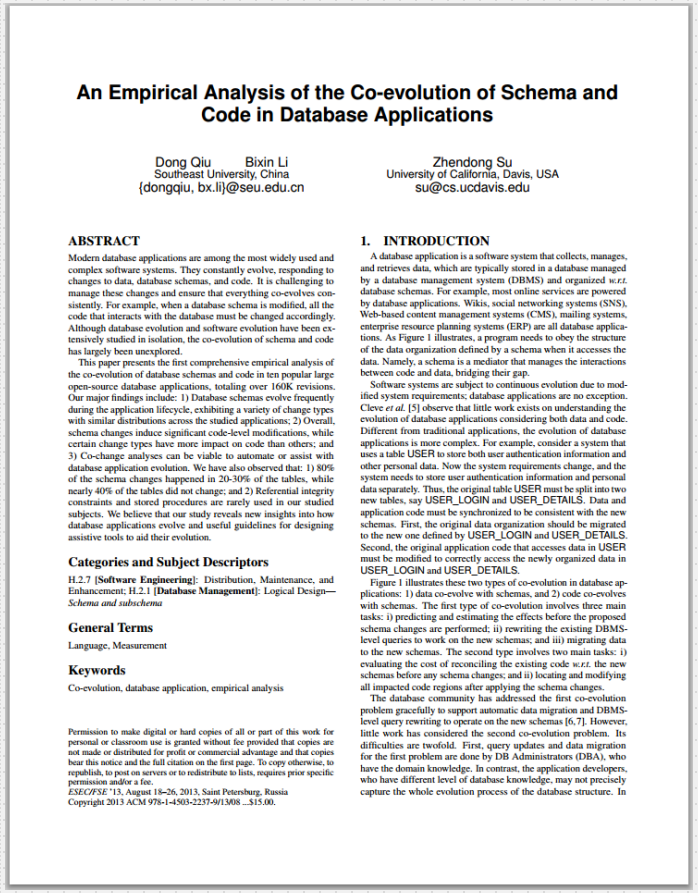

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ABSTRACT

Modern database applications are among the most widely used and complex software systems. They constantly evolve, responding to changes to data, database schemas, and code. It is challenging to manage these changes and ensure that everything co-evolves consistently. For example, when a database schema is modified, all the code that interacts with the database must be changed accordingly. Although database evolution and software evolution have been extensively studied in isolation, the co-evolution of schema and code has largely been unexplored.

This paper presents the first comprehensive empirical analysis of the co-evolution of database schemas and code in ten popular large open-source database applications, totaling over 160K revisions. Our major findings include: 1) Database schemas evolve frequently during the application lifecycle, exhibiting a variety of change types with similar distributions across the studied applications; 2) Overall, schema changes induce significant code-level modifications, while certain change types have more impact on code than others; and 3) Co-change analyses can be viable to automate or assist with database application evolution. We have also observed that: 1) 80% of the schema changes happened in 20-30% of the tables, while nearly 40% of the tables did not change; and 2) Referential integrity constraints and stored procedures are rarely used in our studied subjects. We believe that our study reveals new insights into how database applications evolve and useful guidelines for designing assistive tools to aid their evolution.

Categories and Subject Descriptors

H.2.7 [**Software Engineering**]: Distribution, Maintenance, and Enhancement; H.2.1 [**Database Management**]: Logical Design—*Schema and subschema*

General Terms

Language, Measurement

Keywords

Co-evolution, database application, empirical analysis

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1. INTRODUCTION

A database application is a software system that collects, manages, and retrieves data, which are typically stored in a database managed by a database management system (DBMS) and organized *w.r.t.* database schemas. For example, most online services are powered by database applications. Wikis, social networking systems (SNS), Web-based content management systems (CMS), mailing systems, enterprise resource planning systems (ERP) are all database applications. As Figure 1 illustrates, a program needs to obey the structure of the data organization defined by a schema when it accesses the data. Namely, a schema is a mediator that manages the interactions between code and data, bridging their gap.

Software systems are subject to continuous evolution due to modified system requirements; database applications are no exception. Cleve *et al.* [5] observe that little work exists on understanding the evolution of database applications considering both data and code. Different from traditional applications, the evolution of database applications is more complex. For example, consider a system that uses a table USER to store both user authentication information and other personal data. Now the system requirements change, and the system needs to store user authentication information and personal data separately. Thus, the original table USER must be split into two new tables, say USER_LOGIN and USER_DETAILS. Data and application code must be synchronized to be consistent with the new schemas. First, the original data organization should be migrated to the new one defined by USER_LOGIN and USER_DETAILS. Second, the original application code that accesses data in USER must be modified to correctly access the newly organized data in USER_LOGIN and USER_DETAILS.

Figure 1 illustrates these two types of co-evolution in database applications: 1) data co-evolve with schemas, and 2) code co-evolves with schemas. The first type of co-evolution involves three main tasks: i) predicting and estimating the effects before the proposed schema changes are performed; ii) rewriting the existing DBMS-level queries to work on the new schemas; and iii) migrating data to the new schemas. The second type involves two main tasks: i) evaluating the cost of reconciling the existing code *w.r.t.* the new schemas before any schema changes; and ii) locating and modifying all impacted code regions after applying the schema changes.

The database community has addressed the first co-evolution problem gracefully to support automatic data migration and DBMS-level query rewriting to operate on the new schemas [6, 7]. However, little work has considered the second co-evolution problem. Its difficulties are twofold. First, query updates and data migration for the first problem are done by DB Administrators (DBA), who have the domain knowledge. In contrast, the application developers, who have different level of database knowledge, may not precisely capture the whole evolution process of the database structure. In

No previous work has been done to understand database documentation practices at source code level.

Goal

How Do Developers Document Database Usages in Source Code?

Methodology

GitHub

381,161 projects

Methodology

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Identified the projects using SQL

18,828 projects

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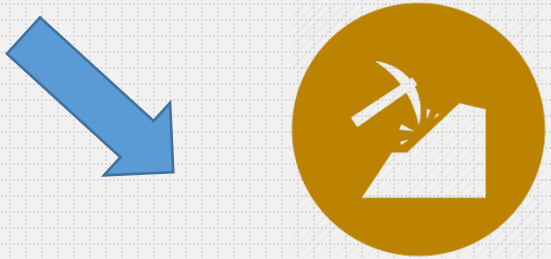
3,113 projects

Methodology

A survey

GitHub

3,113 projects



A mining-based analysis

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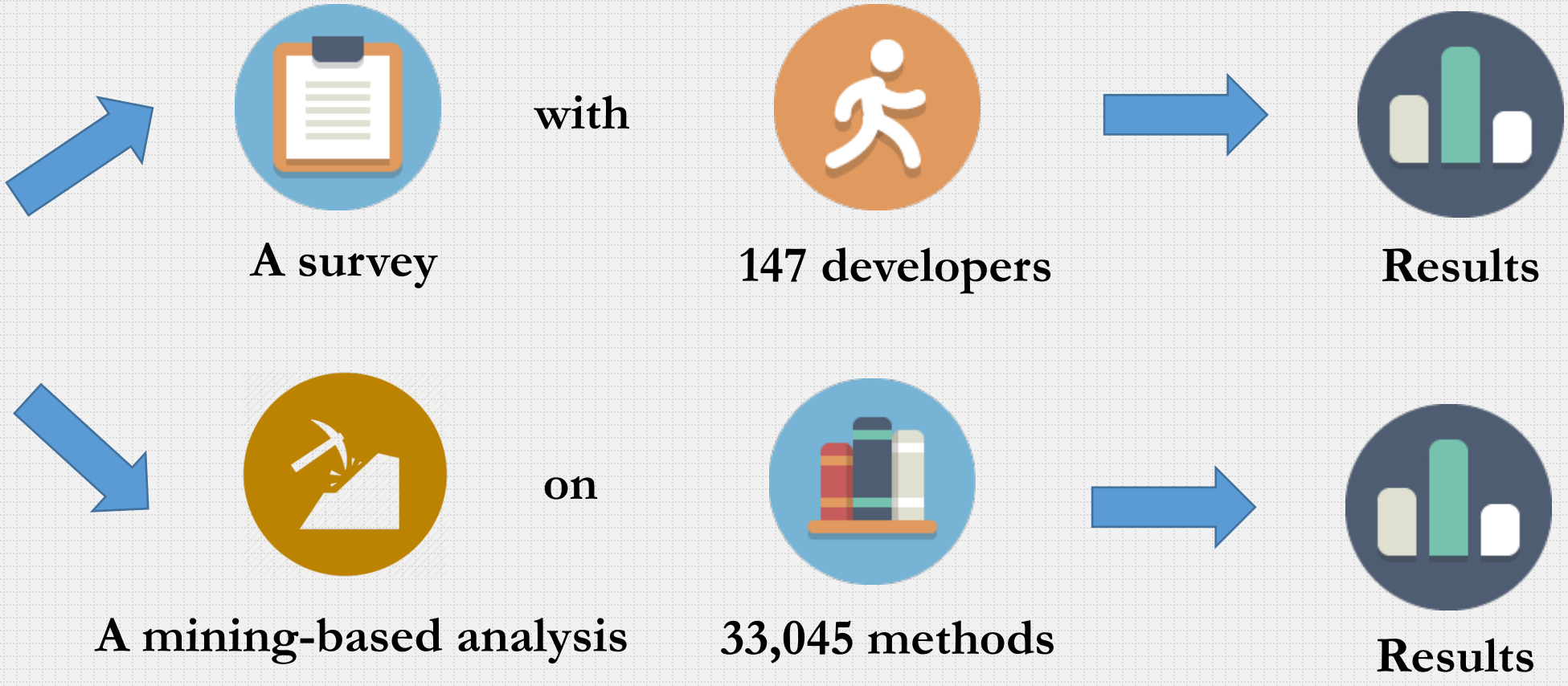


Research Questions

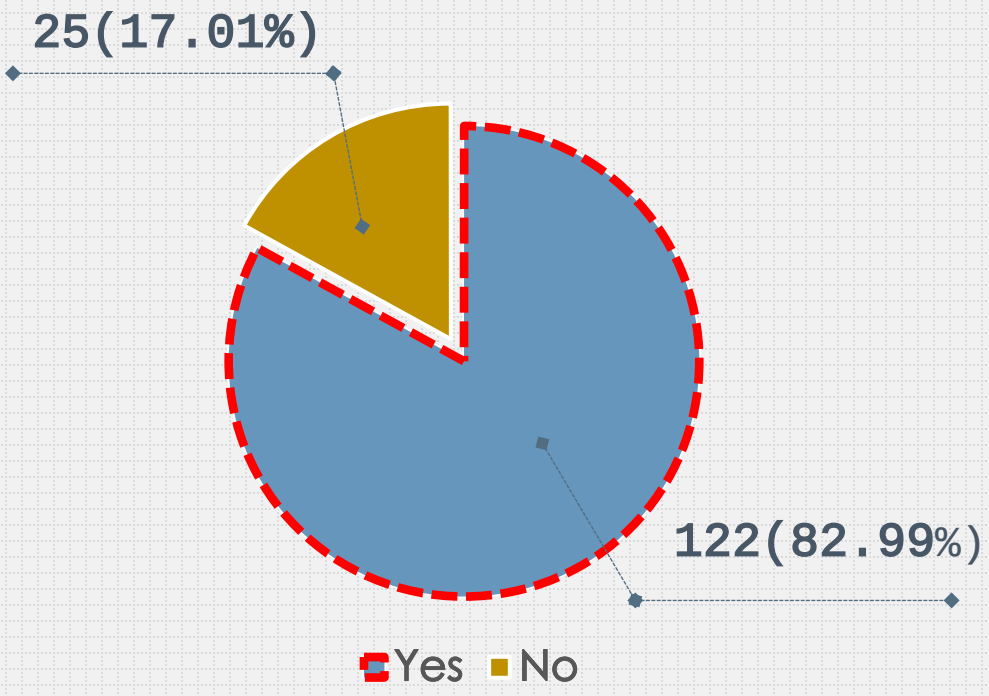
RQ1. Do developers document database-related methods

RQ2. Do developers update comments for database-related methods

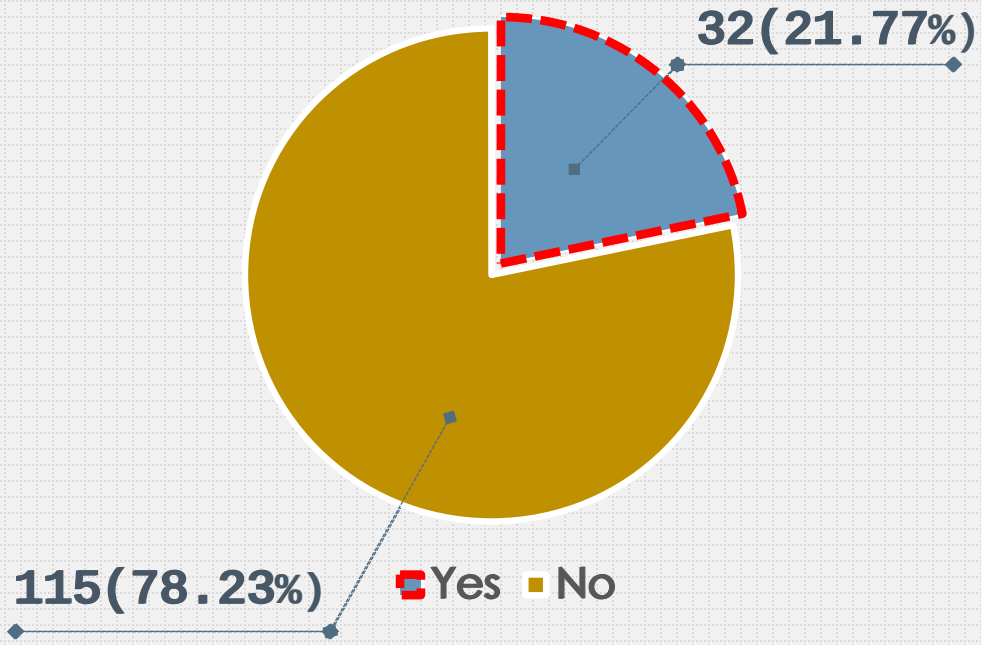
RQ3. How difficult is to understand the database schema constraints along call-chains

RQ1. Do developers comment methods in source code that locally execute SQL queries and statements?

SQ1. Do you add/write documentation comments to methods in the source code?



SQ2. Do you write source code comments detailing database schema constraints?



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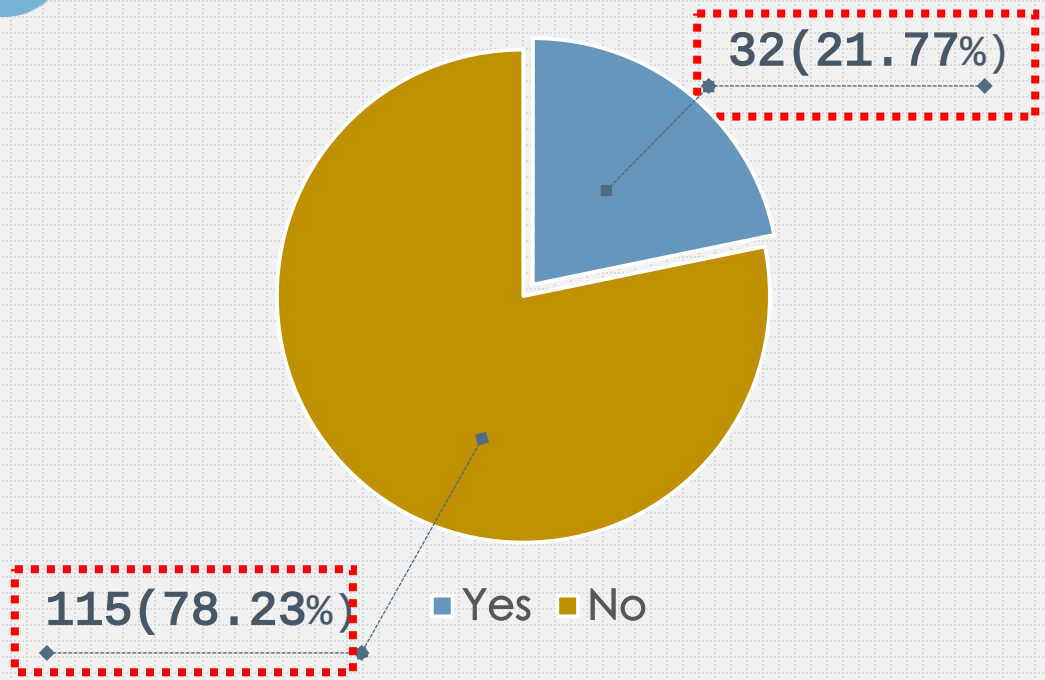

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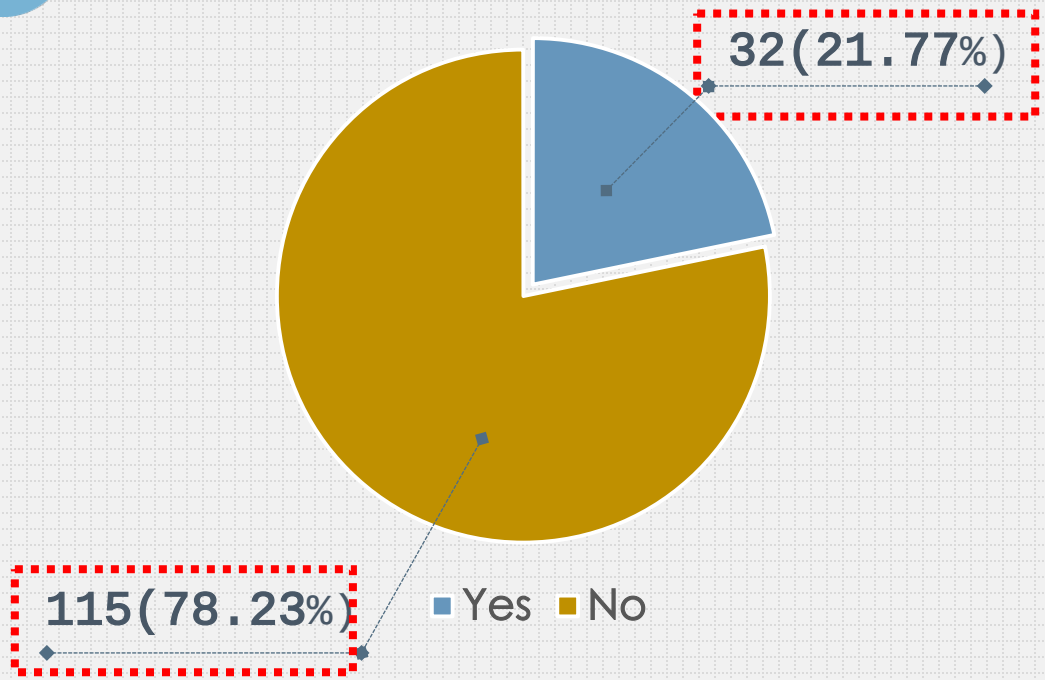

> *"The database schema and documentation takes care of that. I can always look at the table definition very easily."*

> *"Comments related to the database schema and its constraints I consider to be irrelevant to the code using it. The schema, its details, and any quirks about it should be outlined in a separate document."*

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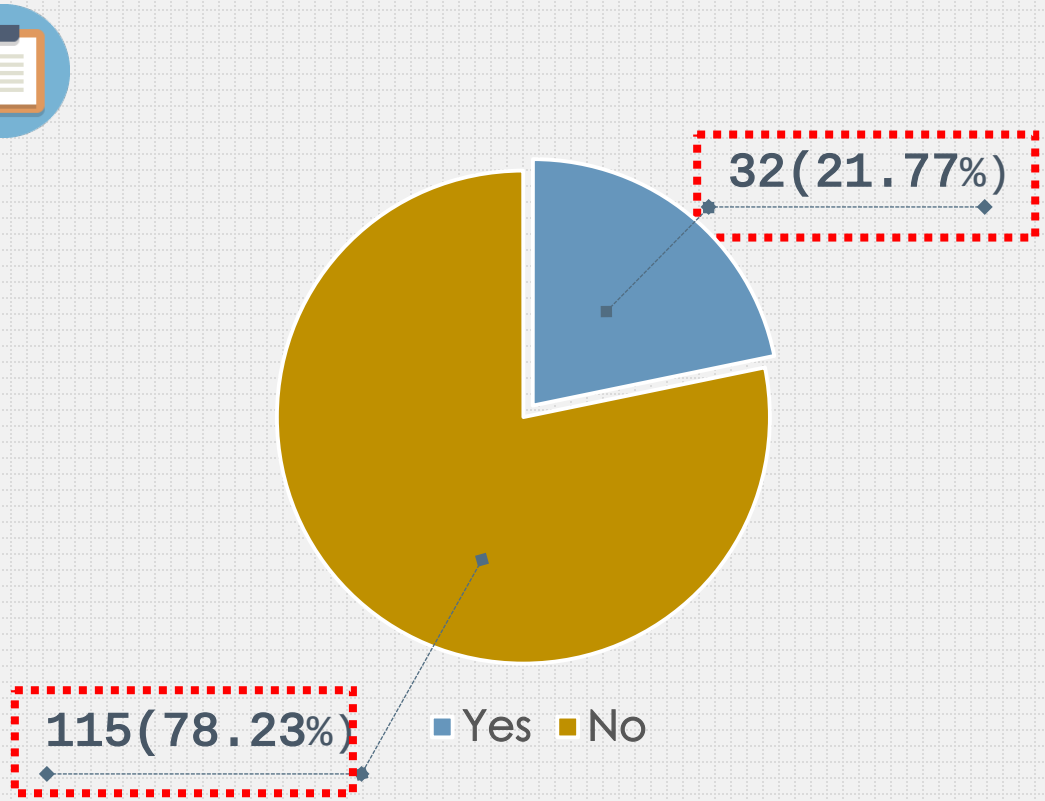
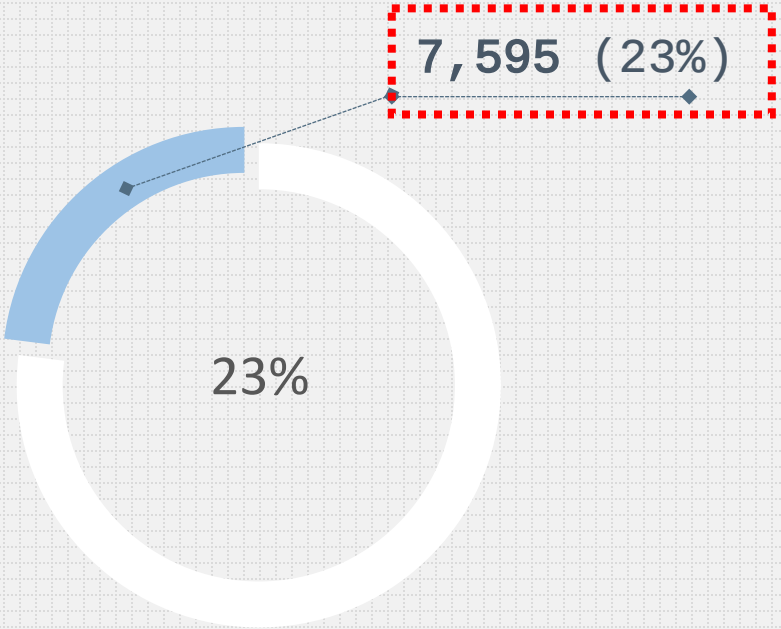
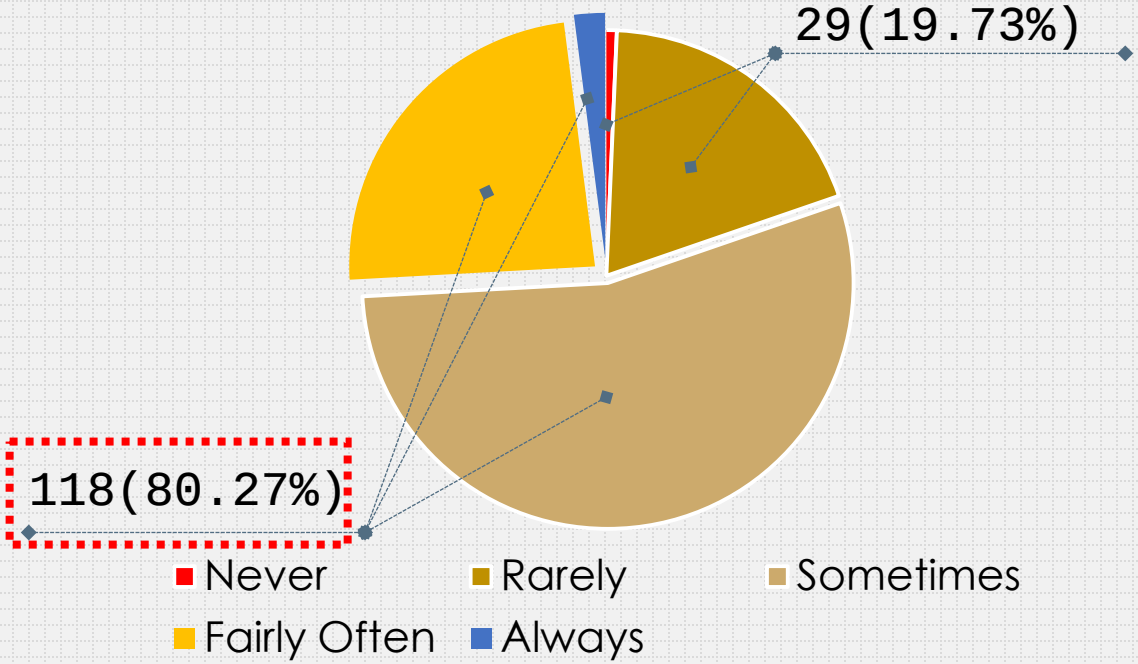




In the 3,113 projects, we identified a total of 33,045 methods invoking SQL ueries/statements.

RQ2. Do developers update comments of database-related methods during the evolution of a system?

SQ3. How often do you find outdated comments in source code?



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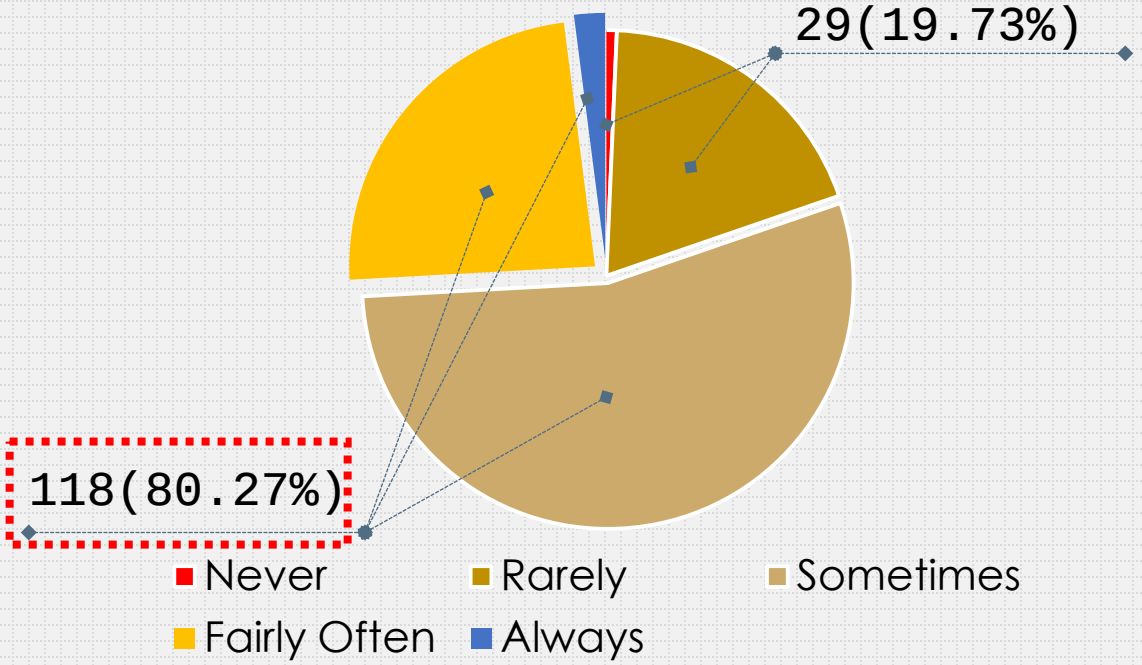

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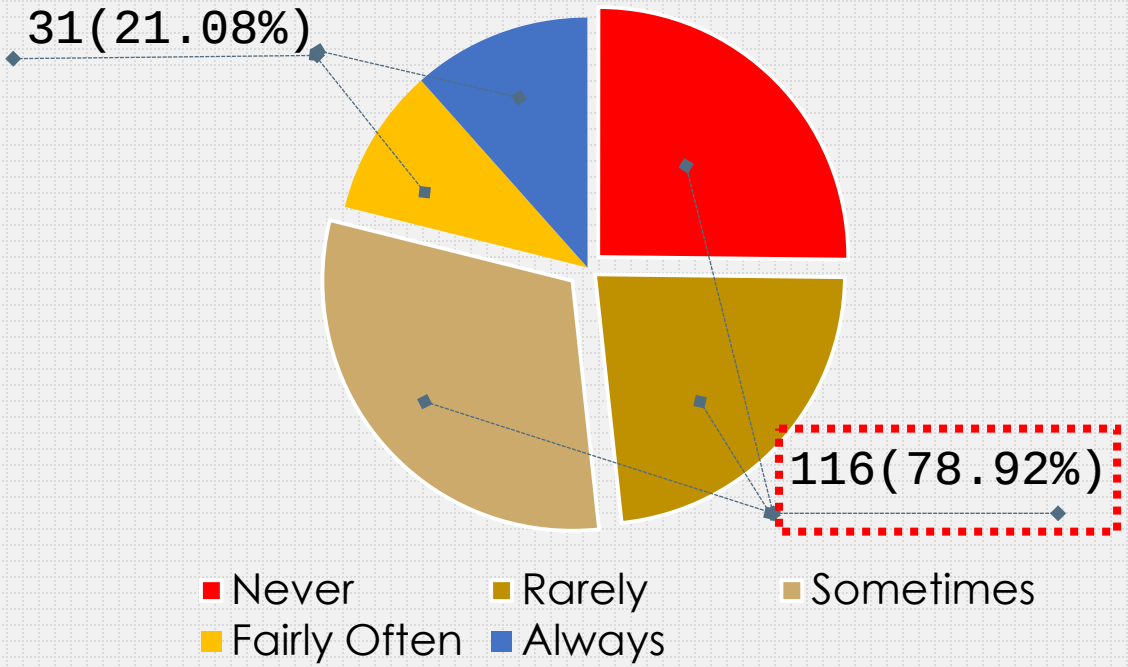

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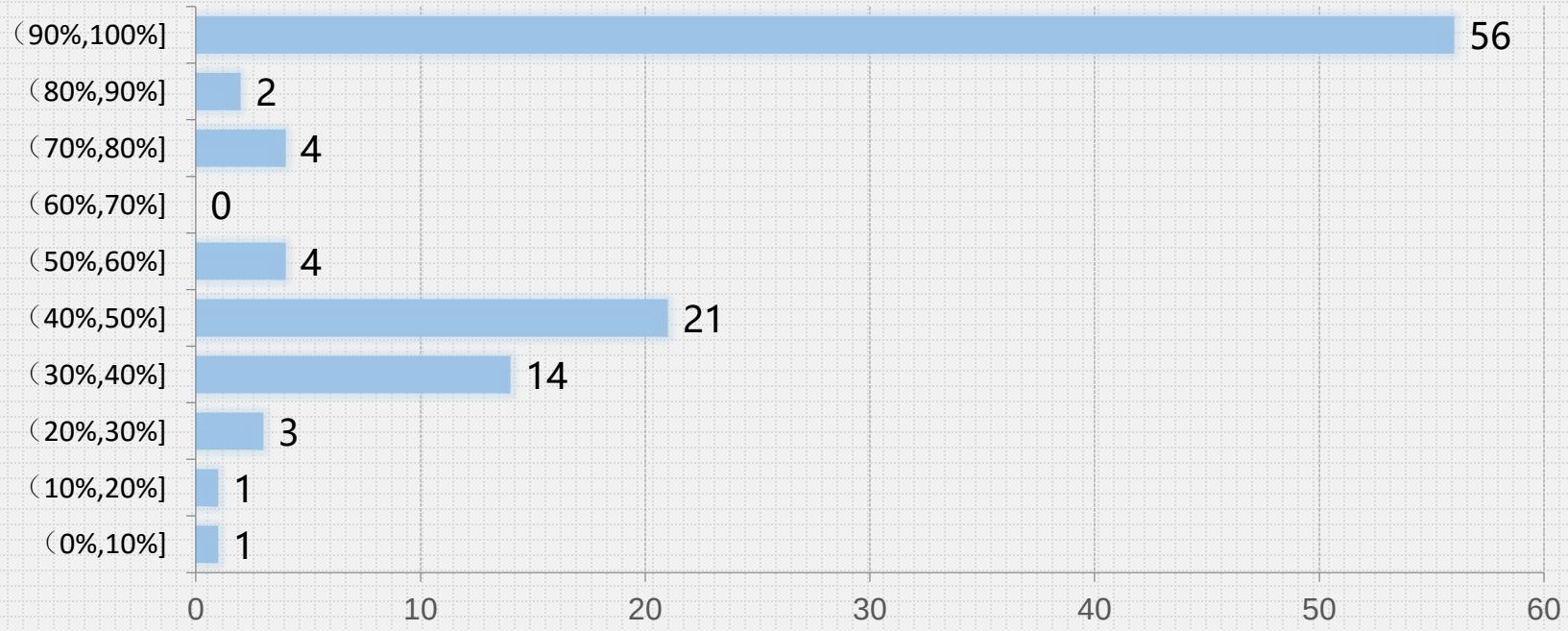

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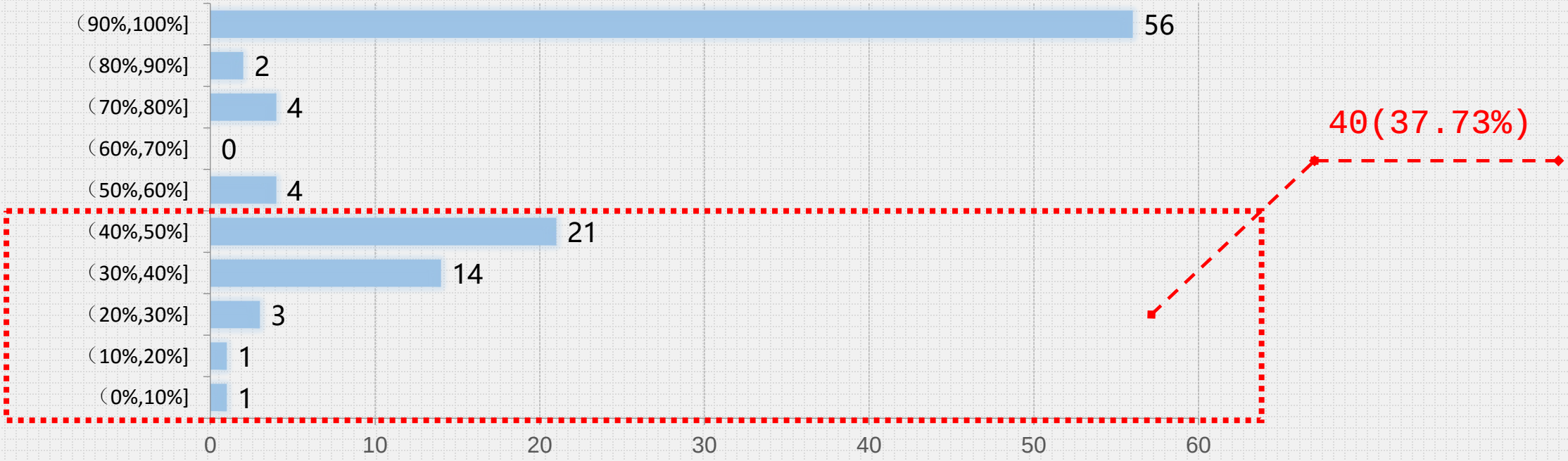

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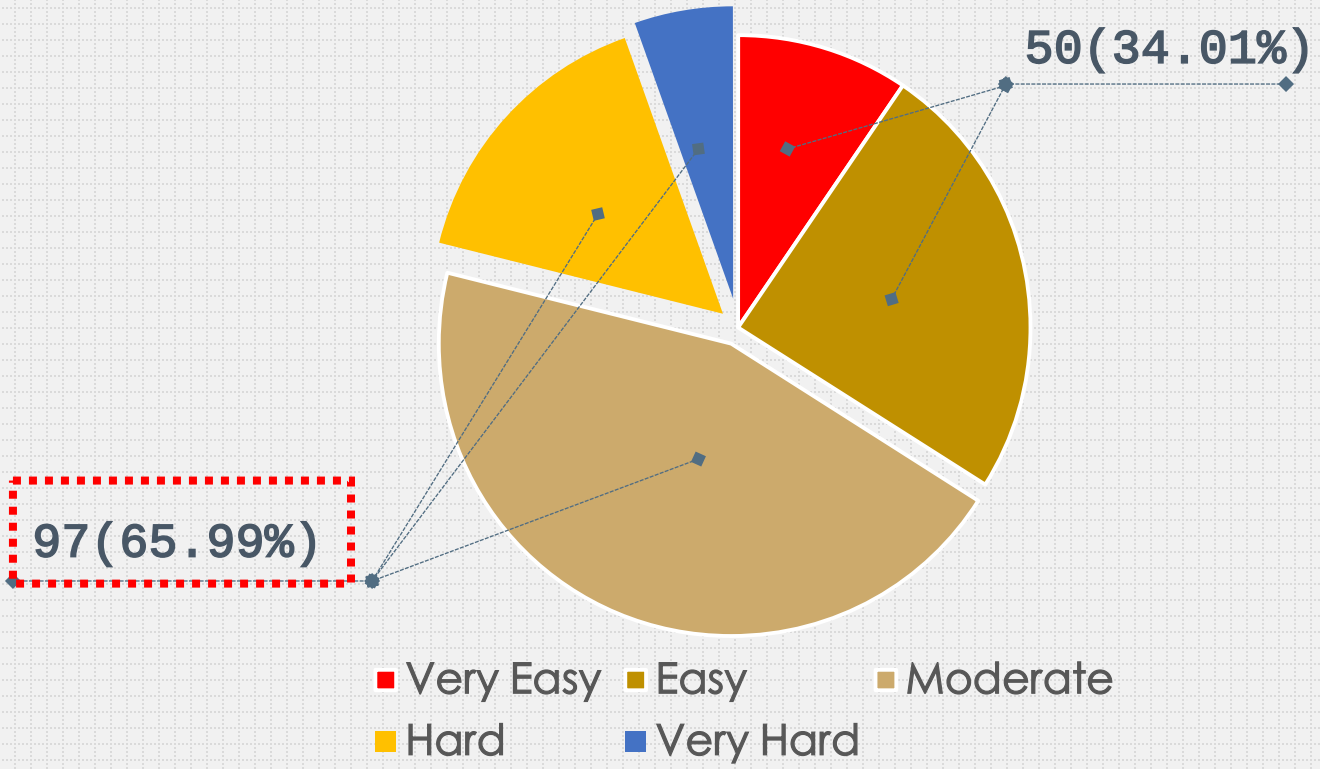
RQ3. How difficult is it for developers to understand propagated schema constraints along call-chains?

SQ5. How difficult is it to trace the schema constraints (e.g., foreign key violations) from the methods with SQL statements to top-level method callers



Lessons learnt

(i) Documenting database usages and constraints is not a common practice in source code methods

(ii) Developers do not update comments when changes are done to database-related methods

(iii) Tracing schema constraints through call-chains in the call graph is not an easy task in most of the cases

Lessons learnt

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Documentation

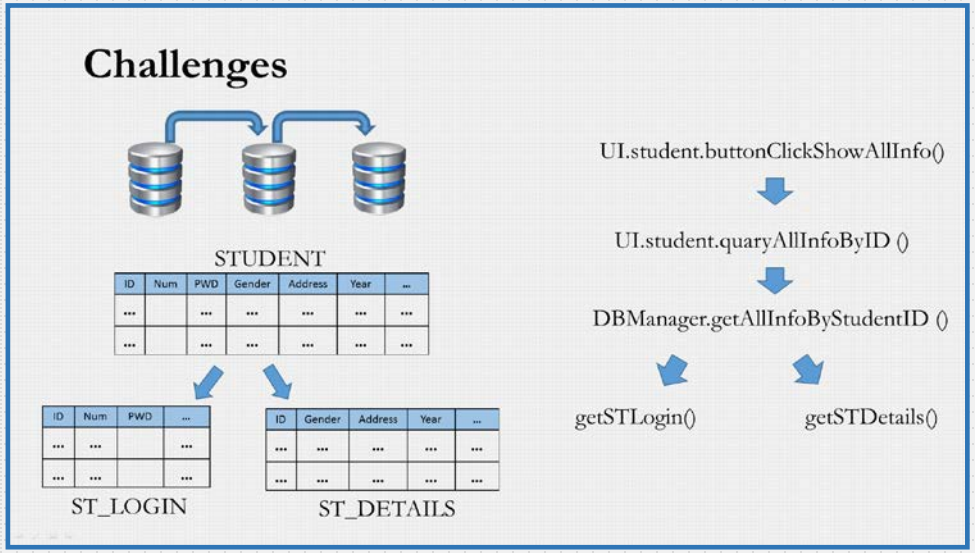
(ii) Developers do not update comments when changes are done to database-related methods

Automation

(iii) Tracing schema constraints through call-chains in the call graph is not an easy task in most of the cases

Calling context

Summary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ST_LOGIN
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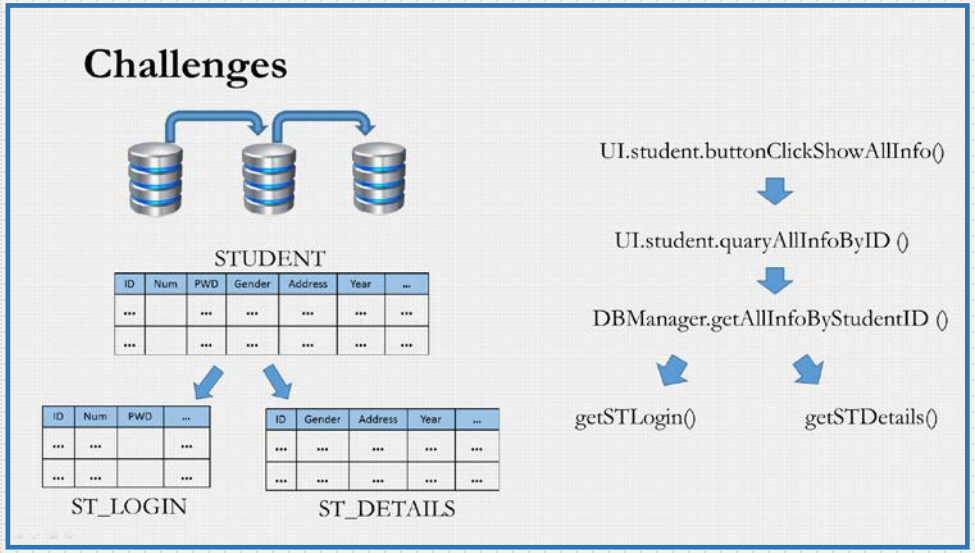
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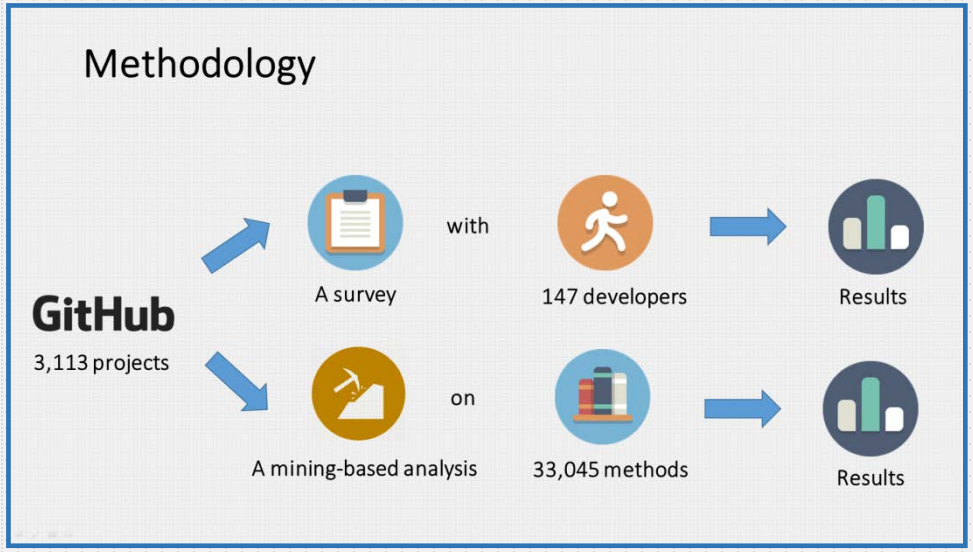
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...		...	...	...	...	...
...		...	...	...	...	...

ID	Num	PWD	...
...	...		...
...	...		...

ST_LOGIN

ID	Gender	Address	Year	...
...	...	...	...	...
...	...	...	...	...

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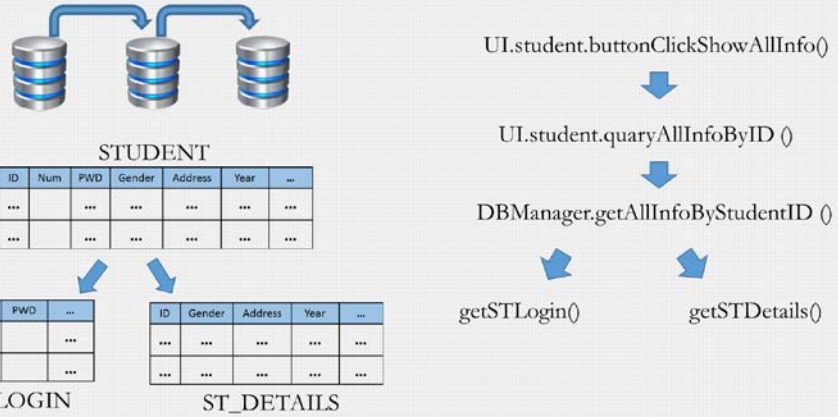

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