CROKAGE: Effective Solution Recommendation for Programming Tasks by Leveraging Crowd Knowledge

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Abstract. *Developers often search for relevant code examples on the web for their programming tasks. Unfortunately, they face three major problems. First, they frequently need to read and analyse multiple results from the search engines to obtain a satisfactory solution. Second, the search is impaired due to a lexical gap between the query (task description) and the information in the solution (e.g., code example). Third, the retrieved solution may not be comprehensible, i.e., the code segment might miss a succinct explanation. To address these three problems, we propose CROKAGE (Crowd Knowledge Answer Generator), a tool that takes the description of a programming task (the query) as input and delivers a comprehensible solution for the task. Our solutions contain not only relevant code examples but also their succinct explanations written by human developers. We evaluate and compare our approach against ten baselines, including the state-of-art. We show that CROKAGE outperforms the ten baselines in suggesting relevant solutions for 902 programming tasks (i.e., queries) of three popular programming languages: Java, Python and PHP. Furthermore, we use 24 programming tasks (queries) to evaluate our solutions with 29 developers and confirm that CROKAGE outperforms the state-of-art tool in terms of relevance of the suggested code examples, benefit of the code explanations and the overall solution quality (code + explanation).*

Resumo. *Os desenvolvedores frequentemente pesquisam exemplos de código relevantes na web para suas tarefas de programação. Não obstante, eles enfrentam três problemas principais. Primeiro, eles geralmente precisam ler e analisar vários resultados dos mecanismos de pesquisa para obter uma solução satisfatória. Em segundo lugar, a pesquisa é prejudicada devido a uma lacuna léxica entre a consulta (descrição da tarefa) e as informações na solução (p.ex., exemplo de código). Por último, a solução pode não ser compreensível, ou seja, o segmento de código pode não ser acompanhado de uma explicação sucinta. Para resolver esses três problemas, propomos o CROKAGE (Crowd Knowledge Answer Generator), uma ferramenta que recebe a descrição de uma tarefa de programação (a consulta) como entrada e fornece uma solução compreensível para a tarefa. As soluções contêm não apenas exemplos de código relevantes, mas também suas explicações sucintas escritas por desenvolvedores humanos. Avaliamos e comparamos a abordagem com dez baselines, incluindo o estado-da-arte. Mostramos que CROKAGE supera todos baselines ao sugerir soluções relevantes para 902 tarefas de programação (ou seja, consultas) de três linguagens de programação populares: Java, Python e PHP. Além disso, usamos*

24 tarefas de programação (consultas) para avaliar nossas soluções com 29 desenvolvedores e confirmar que CROKAGE supera a ferramenta estado-da-arte em termos de relevância dos exemplos de código sugeridos, utilidade das explicações do código e qualidade geral da solução (código + explicação).

1. Overview of CROKAGE

We have proposed an approach namely CROKAGE (**Cro**wd **K**nowledge **A**nswer **Ge**nerator) that takes a task description in natural language (the query) as input and then returns relevant, comprehensible programming solutions containing both code examples and succinct explanations [da Silva et al. 2020]. In particular, we address the limitations of the two earlier approaches [Xu et al. 2017, Huang et al. 2018]. First, unlike AnswerBot [Xu et al. 2017] (i.e., provides only answer summary texts), we deliver both relevant code segments and their corresponding explanations. Second, while BIKER [Huang et al. 2018] returns only generic explanations extracted from the official Java API documentation, we provide succinct code explanations written by human developers. We extract code and explanations from Stack Overflow answers. They contain a wide range of development topics and APIs, and serve as a large repository of source code examples (code snippets + explanations).

The main contributions of CROKAGE includes: 1) a novel approach that suggests programming solutions containing both code snippets and explanations for programming tasks (i.e., queries) written in natural language texts by harnessing the crowd knowledge from Stack Overflow; 2) an empirical evaluation of CROKAGE on the suggestion of relevant code examples for programming tasks and a comparison with the state-of-art study [Huang et al. 2018]. Our approach outperforms ten baselines, including the state-of-art, in retrieving relevant and comprehensible programming solutions 3) a manually curated benchmark dataset composed of 11K answers (6,558 Java + 201 PHP + 4,691 Python) for 1,805 (115 Java + 10 PHP + 1,680 Python) programming tasks. The dataset was constructed by two professional developers spending 94 man hours; 4) a replication package[1] containing CROKAGE's prototype, detailed results of our user study and our used dataset for replication or third party reuse; 5) the implementation of the CROKAGE tool[2] to support developers with their programming tasks, which can be invoked by a web browser or by any REST (Representational State Transfer) service; 6) an usage analysis of the tool during five months after its release regarding 15,865 queries and 784 user ratings.

References

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[1] https://github.com/muldon/crokage-emse-replication-package

[2] http://isel.ufu.br:9000/