

Towards Transparency and Knowledge Exchange in AI-assisted Data Analysis Code Generation

Robert Haase^{a,b,*}

^aData Science Center, Leipzig University, Humboldtstraße 25, 04105 Leipzig, Germany

^bCenter for Scalable Data Analytics and Artificial Intelligence (ScaDS.AI) Dresden / Leipzig
ORCID (Robert Haase): <https://orcid.org/0000-0001-5949-2327>

Abstract.

The integration of Large Language Models (LLMs) in scientific research presents both opportunities and challenges for life scientists. Key challenges include ensuring transparency in AI-generated content and facilitating efficient knowledge exchange among researchers. These issues arise from the opaque nature of AI-driven code generation and the informal sharing of AI insights, which may hinder reproducibility and collaboration. This paper introduces git-bob, an innovative AI-assistant designed to address these challenges by fostering an interactive and transparent collaboration platform within GitHub. By enabling seamless dialogue between humans and AI, git-bob ensures that AI contributions are transparent and verifiable. Moreover, it supports collaborative knowledge exchange, enhancing the interdisciplinary dialogue necessary for cutting-edge life sciences research. The open-source nature of git-bob further promotes accessibility and customization, positioning it as a vital tool in employing LLMs responsibly and effectively within scientific communities.

1 Introduction

Generative artificial intelligence (AI) and Large Language Models (LLMs) in particular are changing the way we do data science. Most prominently, scientists use the technology for interacting with scientific data [7], answer data analysis questions [4, 5], generate data analysis code [8, 2, 1], and [re-]writing scientific manuscripts [6]. Unfortunately, the prompts sent to LLMs are commonly not stored, hindering knowledge exchange between scientists on how to use the technology efficiently and responsibly. At the time of publication of scientific code and manuscripts, the workflow that lead to a given set of data analysis code may be intransparent: It might be hard to identify the parts of the project which were implemented by a human and the parts that were created by AI. A professional peer-review system, for documenting how LLM-written code was prompted for, and which human reviewed it, is not established in contemporary scientific culture. However, such systems do exist for collaborative code editing involving multiple humans. E.g. the github.com online platform is well-established in the open-source software community for discussing issues and potential solutions, building code together, and for peer-reviewing it, before it is published to a wider community. As it was shown before that LLMs can solve real-world GitHub issues [3], developing an AI-assistant that interacts with humans directly on

the Github platform is the obvious next step. In this manuscript, I am presenting git-bob, a practical implementation of an LLM-based AI-assistant that can answer to GitHub issues, discuss potential solutions with humans iteratively, write code for them, and submit it as pull-request to reviewed by humans. It is technically similar to various online services for data analysis such as the OpenAI ChatGPT Data Analyst, with three major differences: 1) Multiple humans can interact with git-bob in one communication thread. This allows bringing together domain specialists, e.g. a life scientist, data-analyst and AI in one discussion, stimulating knowledge exchange. 2) Discussions with git-bob and resulting code-modifications are maintained in an online-platform that others can read and follow, making the interaction with the AI fully transparent, and 3) git-bob is open-source. As it uses a platform software developers and data analysts are used to, it does hardly change pre-existing workflows. It just allows to inject AI into discussions they have anyway. In a world where it was demonstrated that LLM-based systems can write entire papers, review and improve them [6] autonomously, such a solution is urgently need to be established as part of good scientific practice. The open source code of git-bob is available online and comes with detailed installation instructions so that everyone can start interacting with it on their github repositories: <https://github.com/haesleinhuepf/git-bob>

2 Features and limitations

A common workflow, demonstrated in Figure ??A, is that a user opens an issue on a repository on Github.com, where git-bob is installed. If the user is repository member, they can trigger git-bob to answer. If they are external, a repository member has to do this. git-bob may then answer the question, potentially including a code snippet and resulting images. Users and the AI-assistant can then argue back and forth until some potential solution is reached. Optionally, git-bob can then be asked to submit a GitHub pull-request, e.g. with a Jupyter Notebook containing the entire solution to a given issue. A human would need to review this pull-request and merge it into the code base of the repository. Git-bob also has the capability to review pull-requests, e.g. originating from humans, but it is not allowed to merge them. This reflects established practices in science, where eventually a human is responsible for data analysis code that becomes part of the project. Additional tasks git-bob is capable of are: 1) The assistant can support users of open source libraries by providing advice and code examples, as shown in Supplementary Figure S1. In case the assistant is not sure about the answer, it is capable of

* Corresponding Author. Email: robert.haase@uni-leipzig.de

forwarding the question to a human, as shown in Supplementary Figure S2. 2) It can be used to document code as shown in Supplementary Figure S4. Such a task can be time-consuming when performed without AI-assistance, which can write documentation for multiple Python functions in seconds to minutes. 3) It can write and execute data analysis code, e.g. to summarize and plot CSV files which are stored in a repository, as demonstrated in Supplementary Figure S3. 4) If manuscript files are stored in a github repository, e.g. in latex format, git-bob can assist writing. For example, the abstract for this manuscript was written by the AI-assistant and this is documented transparently as shown in Supplementary Figure S5.

When writing code for data analysis or manuscript text, the assistant is intrinsically limited by the capabilities of the used LLM. For example, it has been shown before that common commercial state-of-the-art LLMs can solve bio-image analysis questions by generating functionally correct code just above 50% of tested cases [2]. This fundamental limitation may disappear when improved LLMs are published. For now, it can be evaded in multi-turn interactions between humans and AI. Yet, we humans need to guide the AI towards a workable solution.

A highlight of git-bob is that a local installation or an institutional internet server are not required. Git-bob is implemented as GitHub Workflow, and hence runs within the IT infrastructure of github.com. It is compatible with GPT4-omni, other OpenAI LLMs, Anthropic's Claude, Google Gemini, models hosted on Github Models Marketplace and other models which use the OpenAI application programming interface (API). Git-bob reports which model was used in all of its messages, as good scientific practice suggests. The first three of the mentioned vendors require payment for using their services through the API, the others may offer usage of their API for free. Obviously, the communication with the selected LLM is transmitted to the service provider, including source code files from the repository and images provided with the github issue. Hence, users are recommended to not submit any personal or sensitive information.

Using git-bob and also LLMs in general does not eliminate the need for expertise in the domain we are working in. For example, when tasked to setup a bio-image analysis workflow, at least one of the humans interacting with git-bob should have the expertise to judge if a proposed solution is reasonable at least. When LLMs improve, especially their reasoning capabilities, this limitation may feel less and less relevant. Eventually, as correct results are commonly unknown in data analysis research projects, a human may still be required who has the right expertise to judge if a workflow is producing correct results.

Git-bob can be used in private repositories giving scientists the necessary privacy to work on projects before they eventually publish their work. Above mentioned abstract writing for this manuscript was performed while the repository was private.

3 Conclusion

LLMs are being integrated in contemporary scientific workflows unavoidably, but documentation of how in detail they are employed is commonly not done, also because of lack of tools allowing this conveniently. If the scientific community documented usage of LLM prompts like they document usage of open source data analysis libraries, we could learn from each other how to prompt efficiently and responsibly. To overcome current limitations, I propose git-bob for documenting interactions with LLM-based AI. It works integrated on github.com enabling scientists to interact with an LLM via Github Issues and Pull-Requests offering new ways for implementing good

scientific practice for the documentation of discussions between humans and AI when they are working on projects together.

Acknowledgements

RH acknowledges the financial support by the Federal Ministry of Education and Research of Germany and by Sächsische Staatsministerium für Wissenschaft, Kultur und Tourismus in the programme Center of Excellence for AI-research "Center for Scalable Data Analytics and Artificial Intelligence Dresden/Leipzig", project identification number: ScaDS.AI.

References

- [1] M. Chen, J. Tworek, H. Jun, Q. Yuan, H. P. de Oliveira Pinto, et al. Evaluating large language models trained on code. *CoRR*, abs/2107.03374, 2021. URL <https://arxiv.org/abs/2107.03374>.
- [2] R. Haase, C. Tischer, J.-K. Hériché, and N. Scherf. Benchmarking large language models for bio-image analysis code generation. *bioRxiv*, 2024. doi: 10.1101/2024.04.19.590278. URL <https://www.biorxiv.org/content/early/2024/04/25/2024.04.19.590278>.
- [3] C. E. Jimenez, J. Yang, A. Wettig, S. Yao, K. Pei, O. Press, and K. Narasimhan. Swe-bench: Can language models resolve real-world github issues?, 2024. URL <https://arxiv.org/abs/2310.06770>.
- [4] Y. Lai, C. Li, Y. Wang, T. Zhang, R. Zhong, L. Zettlemoyer, S. W. tau Yih, D. Fried, S. Wang, and T. Yu. Ds-1000: A natural and reliable benchmark for data science code generation, 2022.
- [5] W. Lei, C. Fuster-Barceló, G. Reder, et al. Bioimage.io chatbot: a community-driven ai assistant for integrative computational bioimaging. *Nature Methods*, 21:1368–1370, 2024. doi: 10.1038/s41592-024-02370-y.
- [6] C. Lu, C. Lu, R. T. Lange, J. Foerster, J. Clune, and D. Ha. The AI Scientist: Towards fully automated open-ended scientific discovery. *arXiv preprint arXiv:2408.06292*, 2024.
- [7] L. A. Royer. The future of bioimage analysis: a dialog between mind and machine. *Nature Methods*, 20(7):951–952, 2023. ISSN 1548-7105. doi: 10.1038/s41592-023-01930-y. URL <https://doi.org/10.1038/s41592-023-01930-y>.
- [8] L. A. Royer. Omega – harnessing the power of large language models for bioimage analysis. <https://doi.org/10.5281/zenodo.8240289>, 2023.

4 Supplementary material

A)

[BiolImage Analysis]: Nuclei segmentation #13

haesleinhuepf opened this issue 4 minutes ago · 2 comments

Assignees

haesleinhuepf commented 4 minutes ago Owner

Analysis Goal (What should be done / analysed?)

I would like to segment the nuclei in this image, e.g. using Voronoi-Otsu-Labeling.

Image Upload

Drag & drop your microscopy image here (JPG, PNG, GIF, e.g. 512x512 pixels, 2D only).

Python Tools

- List of Python libraries we should use for answering this:
 - numpy
 - scikit-image
 - napari-segment-blobs-and-things-with-membranes

git-bob comment on this

► Detailed instructions for bio-image analysis using Python (feel free to modify)

1

haesleinhuepf self-assigned this 11 minutes ago

github-actions bot commented 4 minutes ago

This message was generated by [git-bob](#) (version: 0.9.0, model: gpt-4o-2024-08-06, [log](#)), an experimental AI-based assistant. It can make mistakes and has [limitations](#). Check its messages carefully.

To segment the nuclei in the provided image using Voronoi-Otsu-Labeling, we can use the `napari-segment-blobs-and-things-with-membranes` library. Below is the code snippet to achieve this:

```
import numpy as np
from skimage.io import imread
import napari_segment_blobs_and_things_with_membranes as nsbatum
import stackview

# Load the image from the provided URL
url = "https://github.com/user-attachments/assets/da6456bb-7bdf-4ad8-8f0d-95e38fa110e9"
image = imread(url)

# Apply Voronoi-Otsu-Labeling
labeled_image = nsbatum.voronoi_otsu_labeling(image, spot_sigma=3.5, outline_sigma=1)

# Display the result
stackview.animate_curtain(image, labeled_image)
```

This code will segment the nuclei using a combination of Gaussian filtering and Otsu's thresholding, followed by Voronoi labeling, and display the result using `stackview`. You can adjust the `spot_sigma` and `outline_sigma` parameters if needed to better suit the characteristics of the image.

haesleinhuepf commented 2 minutes ago Owner Author

Ok cool. Please download the image specified by the url and save it as "human_mitosis_small.png".

Please turn this into a jupyter notebook and adapt it like this:

- Load the above mentioned png file instead of the url.
- After loading the image, make sure to extract the first channel, e.g. using the `[..., 0]` syntax.
- For Voronoi-Otsu-Labeling, use a smaller `spot_sigma=2`.
- By the end, in a new notebook cell, save the resulting label image as RGB png to disc.

git-bob implement this.

1

github-actions bot mentioned this issue 1 minute ago

Add notebook for nuclei segmentation using Voronoi-Otsu-Labeling, file loading, and result saving. #14 Open

B)

Add notebook for nuclei segmentation using Voronoi-Otsu-Labeling, file loading, and result saving. #14

github-actions wants to merge 2 commits into `main` from `git-bob-mod-pWGNb0jN4`

Conversation 0 Commits 2 Checks 0 Files changed 2

github-actions bot commented 4 minutes ago

This message was generated by [git-bob](#) (version: 0.9.0, model: gpt-4o-2024-08-06, [log](#)), an experimental AI-based assistant. It can make mistakes and has [limitations](#). Check its messages carefully.

The changes include the addition of a Jupyter notebook file, `nuclei_segmentation_analysis.ipynb`, which performs nuclei segmentation on a loaded image file using the Voronoi-Otsu-Labeling method. The image file, saved as `human_mitosis_small.png`, is processed by extracting the first channel, applying segmentation, and saving the resulting labels as an RGB PNG named `labeled_nuclei.png`. However, an error related to an undefined `np` was encountered during the conversion of the labeled image to RGB, which needs attention. The notebook provides necessary steps and outputs for nuclei segmentation analysis, aligning with the requirements of issue [#13](#). [Image](#)

closes [#13](#)

github-actions bot added 2 commits 4 minutes ago

- Downloaded <https://github.com/user-attachments/assets/da6456bb-7bdf-4ad8-8f0d-95e38fa110e9> 48d8f3e
- Created Jupyter notebook content for 'nuclei_segmentation_analysis.ip...' f524efe

haesleinhuepf commented now Owner

Ok, this is almost perfect. Please visualize the input image using `stackview.insight` and also visualize the resulting `labeled_image`. Last but not least, you forgot to `import numpy as np` at the beginning of the notebook.

git-bob implement this

C)

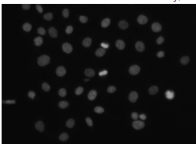
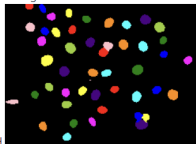
github-actions bot added 3 commits 1 minute ago

- Adding `/human_mitosis_small.png` created by notebook 99fec43
- Adding `/labeled_nuclei.png` created by notebook 9b11273
- Added missing numpy import, visualized input and labeled images using... 872b267

github-actions bot commented 1 minute ago Author

This message was generated by [git-bob](#) (version: 0.9.0, model: gpt-4o-2024-08-06, [log](#)), an experimental AI-based assistant. It can make mistakes and has [limitations](#). Check its messages carefully.

In this set of changes, I added the missing import for numpy in the `nuclei_segmentation_analysis.ipynb` notebook and visualized the input and labeled images with `stackview.insight`, while also correcting the metadata for execution. Additionally, two new image files were created:

and `labeled_nuclei.png`. Also, a link to the `nuclei_segmentation_analysis.ipynb` file was added.

During solving this task, the following errors occurred:

- Error during ('action': 'download', 'source_url': 'https://github.com/haesleinhuepf/git-bob-playground/blob/git-bob-mod-pWGNb0jN4/nuclei_segmentation_analysis.ipynb', 'target_filename': 'nuclei_segmentation_analysis.ipynb'): 422 ("message": "Invalid request.\n\n'sha' wasn't supplied.", "documentation_url": "https://docs.github.com/rest/repos/contents#create-or-update-file-contents", "status": "422")
- Error during ('action': 'download', 'source_url': 'https://github.com/haesleinhuepf/git-bob-playground/blob/git-bob-mod-pWGNb0jN4/human_mitosis_small.png?raw=true', 'target_filename': 'human_mitosis_small.png'): 422 ("message": "Invalid request.\n\n'sha' wasn't supplied.", "documentation_url": "https://docs.github.com/rest/repos/contents#create-or-update-file-contents", "status": "422")

Figure 1. Use-case example for the interaction with git-bob: After creating a GitHub issue, optionally including upload of an example image, the AI-assistant and the human exchange about how to process the data (A). Once they concluded to implement the solution, a GitHub pull-request is sent (B) containing the programmed solution as files in the repository. Also here, human and AI-assistant can continue discussing and modify the solution until the example is satisfactory. The entire discussion and corresponding code can be read online: <https://github.com/haesleinhuepf/git-bob-playground/issues/13> and <https://github.com/haesleinhuepf/git-bob-playground/pull/14>

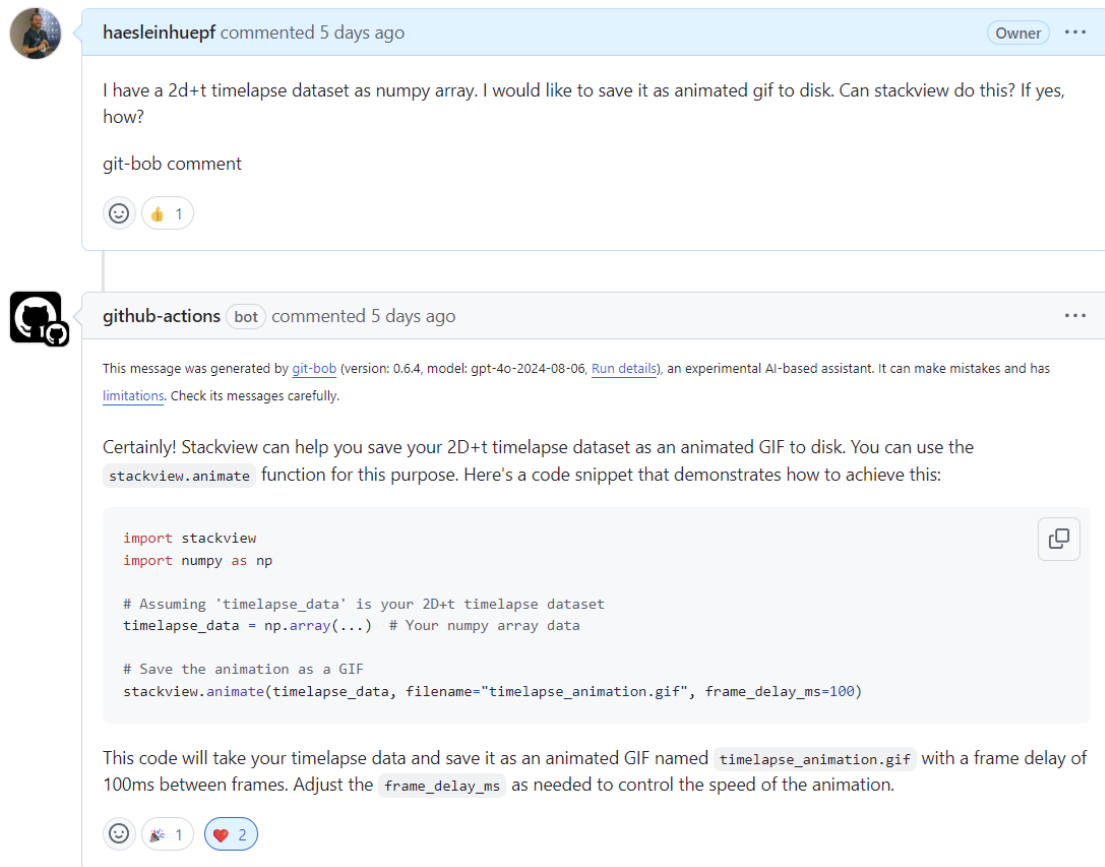


Figure S1. Use-case example for supporting users: The assistant can be configured to act as expert on a specific Python library and answer user questions. The entire discussion and corresponding code can be read online: <https://github.com/haesleinhuepf/stackview/issues/79>

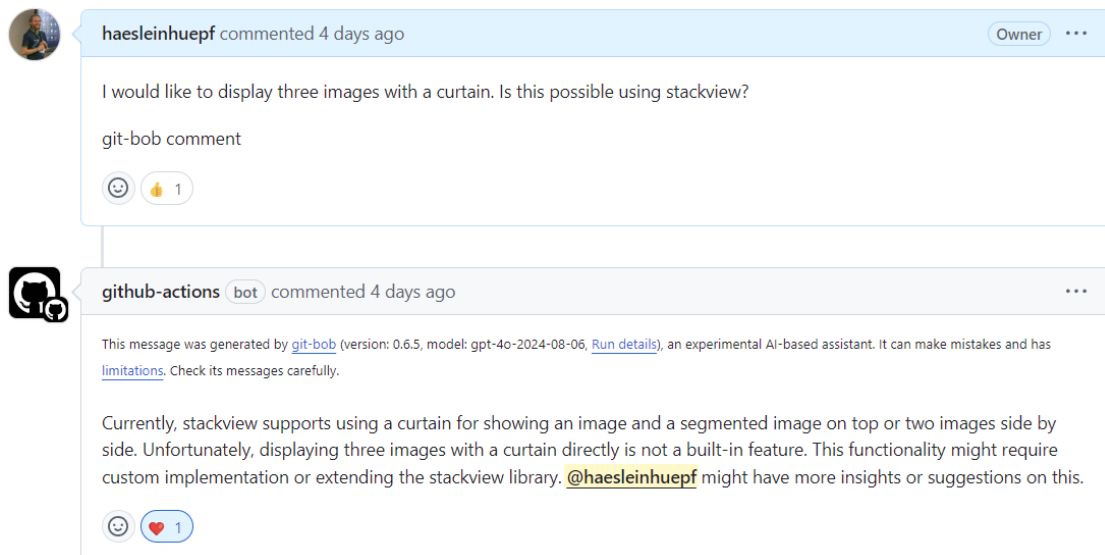



Figure S2. Use-case example for asking an expert: The answer to the question shown here is "No", but this is nowhere written in the documentation or the configuration of the assistant. In this case the assistant is not sure, and it can be configured to forward a question to a maintainer of the library where the question arrived. The entire discussion and corresponding code can be read online: <https://github.com/haesleinhuepf/stackview/issues/80>




haesleinhuepf commented 3 minutes ago Member ...

In the folder "download_statistics", there are multiple files named for example "20240628.csv". The filename without ending is obviously a date, the creation date of the data. Write a jupyter notebook that opens all these files using pandas and plots over time how many records are in these files. Save the notebook in the notebooks directory and make sure the relative link the download_statistics folder is correct.

git-bob try again

 1



github-actions bot commented 2 minutes ago Contributor ...

This message was generated by [git-bob](#) (version: 0.8.2, model: github_models:gpt-4o, [log](#)), an experimental AI-based assistant. It can make mistakes and has [limitations](#). Check its messages carefully.

In this update, a Jupyter notebook was created to read CSV files and plot the number of records over time, resulting in the creation of [notebooks/plot_zenodo_links_over_time.ipynb](#). Additionally, an image file was generated:




Date	Number of Records
2024-07-01	34
2024-07-15	34
2024-08-01	36
2024-08-15	38
2024-09-01	43
2024-09-15	43
2024-10-01	59




Figure S3. Use-case example for plotting data: After explaining the assistant the folder structure of the project, it generates code for parsing a folder of CSV files and plotting results. The entire discussion and corresponding code can be read online: <https://github.com/NFDI4BIOIMAGE/training/issues/250>

A)

Add numpy-style docstrings to _github_utilities.py #29


 Merged haesleinhuepf merged 1 commit into `main` from `mod-ajh4CjX8wR` on Aug 2


Conversation 0 Commits 1 Checks 0 Files changed 1



 **github-actions** (bot) commented on Aug 2 Contributor ...

This comment was generated by [git-bob](#), an AI-based assistant.

Added numpy-style docstrings for all functions in `src/git_bob/_github_utilities.py`. Closes [#22](#).







 Update file content d123ac1


  **haesleinhuepf** merged commit `d4fe0ec` into `main` on Aug 2 Revert

B)

Conversation 0 Commits 1 Checks 0 Files changed 1

Changes from all commits ▾ File filter ▾ Conversations ▾ Jump to ▾ ⚙ ▾ Ask Copilot Review ▾

  78  `src/git_bob/_github_utilities.py` 

Viewed  ...

↑	...	@@ -6,6 +6,18 @@
6	6	<code>from github import Github</code>
7	7	
8	8	<code>def add_comment_to_issue(repository, issue, comment):</code>
9	+	<code> """</code>
10	+	<code> Add a comment to a specific GitHub issue.</code>
11	+	
12	+	<code> Parameters</code>
13	+	<code> -----</code>
14	+	<code> repository : str</code>
15	+	<code> The full name of the GitHub repository (e.g., "username/repo-name").</code>
16	+	<code> issue : int</code>
17	+	<code> The issue number to add a comment to.</code>
18	+	<code> comment : str</code>
19	+	<code> The comment text to add to the issue.</code>
20	+	<code> """</code>
9	21	<code> print(f"-> add_comment_to_issue({repository}, {issue}, ...)")</code>
10	22	
11	23	<code> access_token = os.getenv('GITHUB_API_KEY')</code>

Figure S4. Use-case example for adding and revising documentation in code: git-bob was used to partially write the code documentation of its own code. When asked to add documentation in a specific format, it sent a pull-request (A) and the human could inspect the code modifications (B, excerpt) before merging the code into the project's code base. The entire discussion and corresponding code can be read online: <https://github.com/haesleinhuepf/git-bob/pull/29>

A)

Add abstract #8

 Open haesleinhuepf opened this issue 5 minutes ago · 2 comments

haesleinhuepf commented 5 minutes ago

We need an abstract for the manuscript in the git-bob-manuscript.tex file. The manuscript will be submitted to a journal where life scientists are the target audience. I'd like to have a abstract focusing on the scientific challenges (transparency and knowledge exchange) when using LLMs. git-bob should be mentioned in the second half of the abstract.

git-bob think about this and answer in plain text with no markdown or tex styling.

github-actions (bot) commented 4 minutes ago

This message was generated by [git-bob](#) (version: 0.9.0, model: gpt-4o-2024-08-06, [log](#)), an experimental AI-based assistant. It can make mistakes and has [limitations](#). Check its messages carefully.

An abstract focusing on the scientific challenges of using LLMs in life sciences is provided below:

The integration of Large Language Models (LLMs) in scientific research presents both opportunities and challenges for life scientists. Key challenges include ensuring transparency in AI-generated content and facilitating efficient knowledge exchange among researchers. These issues arise from the opaque nature of AI-driven code generation and the informal sharing of AI insights, which may hinder reproducibility and collaboration. This paper introduces git-bob, an innovative AI-assistant designed to address these challenges by fostering an interactive and transparent collaboration platform within GitHub. By enabling seamless dialogue between humans and AI, git-bob ensures that AI contributions are transparent and verifiable. Moreover, it supports collaborative knowledge exchange, enhancing the interdisciplinary dialogue necessary for cutting-edge life sciences research. The open-source nature of git-bob further promotes accessibility and customization, positioning it as a vital tool in employing LLMs responsibly and effectively within scientific communities.


haesleinhuepf commented 2 minutes ago

Awesome! Add this abstract to the manuscript!

git-bob implement this.

github-actions (bot) mentioned this issue 1 minute ago

Add abstract to manuscript highlighting key challenges and git-bob solution. #9

 Open

B)

Add abstract to manuscript highlighting key challenges and git-bob solution. #9

 Open

github-actions wants to merge 1 commit into [main](#) from [git-bob-mod-Fkld0ZPtHt](#)

Conversation 0 Commits 1 Checks 0 Files changed 1

github-actions (bot) commented 2 minutes ago

This message was generated by [git-bob](#) (version: 0.9.0, model: gpt-4o-2024-08-06, [log](#)), an experimental AI-based assistant. It can make mistakes and has [limitations](#). Check its messages carefully.

Added an abstract focusing on the scientific challenges of using LLMs in life sciences to the git-bob-manuscript.tex file, addressing issue [#8](#) by highlighting transparency, knowledge exchange, and introducing git-bob as a solution.

closes [#8](#)

I added an abstract to the manuscript.

C)

Conversation 0 Commits 1 Checks 0 Files changed 1

Changes from all commits File filter Conversations

Jump to

git-bob-manuscript.tex

@@ -102,7 +102,7 @@

102 102

103 103 \begin{abstract}

104 104

105 - Abstract will be added later

105 + The integration of Large Language Models (LLMs) in scientific research presents both opportunities and challenges for life scientists. Key challenges include ensuring transparency in AI-generated content and facilitating efficient knowledge exchange among researchers. These issues arise from the opaque nature of AI-driven code generation and the informal sharing of AI insights, which may hinder reproducibility and collaboration. This paper introduces git-bob, an innovative AI-assistant designed to address these challenges by fostering an interactive and transparent collaboration platform within GitHub. By enabling seamless dialogue between humans and AI, git-bob ensures that AI contributions are transparent and verifiable. Moreover, it supports collaborative knowledge exchange, enhancing the interdisciplinary dialogue necessary for cutting-edge life sciences research. The open-source nature of git-bob further promotes accessibility and customization, positioning it as a vital tool in employing LLMs responsibly and effectively within scientific communities.

106 106

107 107 \end{abstract}

108 108

Figure S5. Use-case example for working on scientific manuscripts: After a first draft of the manuscript was written, git-bob was asked to formulate an abstract (A). The abstract was then submitted as pull-request with a short description (B). The human can also review and potentially modify the proposed text in this online interface (C). The entire discussion can be read online: <https://github.com/haesleinhuepf/git-bob-manuscript/issues/8> and <https://github.com/haesleinhuepf/git-bob-manuscript/pull/9>.