

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

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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 in-transparent 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 reproducible. 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.

Data Analysis, Bio-image Analysis, LLM, Code Generation
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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 (1), answer data analysis questions (2, 3), generate data analysis code (4–6), and [re-]write scientific manuscripts (7). Unfortunately, the prompts sent to LLMs are commonly not conserved, and thus, at the time of publication, it might be hard to differentiate human-made and AI-generated parts of the scientific work. A professional peer-review system, for documenting how LLM-generated 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 online platform github.com is well-established in the open-source software community for discussing issues and potential solutions, building code together, and for peer-reviewing contents. As it was shown before that LLMs can solve real-world GitHub issues (8), developing an AI-assistant that interacts with humans directly within the Github platform is the obvious next step. I am presenting *git-bob*, a functional proof-of-concept implementation of an LLM-based AI-assistant that can respond to GitHub issues, discuss potential solutions with humans itera-

tively, write code for them, and submit it as pull-request to be reviewed by humans. It is technically similar to various online services for data analysis such as the OpenAI ChatGPT Data Analyst or Github Copilot Workflows, with three major differences: 1) Multiple humans can interact with *git-bob* in one communication thread. This allows bringing together domain specialists, such as life scientists, data-analysts and the AI-assistant in one discussion, stimulating knowledge exchange on how to interact properly with the AI-assistant. 2) Discussions with *git-bob* and resulting code-modifications are conserved in an online-platform that others can read and follow, making the interaction with the AI-assistant fully transparent, and 3) *git-bob* is open-source. Other developers can read its built-in system prompts and modify them to their needs. *Git-bob*'s source code is available online: <https://github.com/haesleinhuepf/git-bob>.

Features and limitations

A common workflow involving *git-bob* is demonstrated in Figure 1: a user opens an issue, a kind of discussion thread, on a repository on github.com, where *git-bob* is installed. A repository member can then trigger *git-bob* to answer by writing a command such as “*git-bob* comment on this”. If externals try so, an automatic response will inform them that only repository members are allowed to trigger *git-bob* because running *git-bob* may cause costs for repository owners. Once triggered, *git-bob* will use an LLM to respond to the question, potentially including a code snippet and resulting plots or images. Users and the AI-assistant can then discuss back and forth until some potential solution is reached. Optionally, *git-bob* can then be asked to implement the solution and send a GitHub pull-request, another kind of discussion thread, but accompanied by file modifications to the repository, e.g. including a Jupyter Notebook containing the previously discussed code 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 originating from humans, but it is not allowed to merge them. This reflects established practices in science, where eventually a scientist 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 forwarding the question to a human (Supplementary Figure S2). 2) It can be used to document code (Supplementary Figure S4). Such a task can be time-consuming when performed without AI-assistance, which can generate documentation for multiple Python functions in seconds to minutes. 3) it can analyse data in the repository directly, e.g. summarize and plot data in CSV files (Supplementary Figure S3). 4) If manuscript files are stored in a github repository, e.g. in latex format, git-bob can assist in 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. A highlight of git-bob is that a local installation is not required. Git-bob is implemented as GitHub workflow, which can be installed by uploading a configuration file to a repository and setting access rights. It is compatible and was tested with the commercial models OpenAI's GPT4-omni, Anthropic's Claude, Google Gemini and freely available models hosted on Github Models Marketplace. Git-bob reports which model was used in all of its messages, as good scientific practice suggests. 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. When writing data analysis code, git-bob is intrinsically limited by the capabilities of the used LLM. For example, it has been shown that state-of-the-art (SOTA) LLMs can solve bio-image analysis questions by generating functionally correct code just above 50% of tested cases (5). This fundamental limitation may disappear when improved LLMs are published. For now, it can be evaded by the humans guiding the AI-assistant in multi-turn interactions towards a workable solution. Further technical limitations arise from prompt-length limitations of the underlying LLMs. When modifying or generating a file, these files must be below specified limits, e.g. GPT4-omni has 128k tokens input and 16k output tokens as limit (1 token \approx approx. 3/4 words). Also when processing data, limitations of the GitHub IT infrastructure have to be considered: Git-bob executed in public repositories runs on virtual machines with 4 CPU cores, 16 GB of RAM and 14 GB of SSD storage. In private repositories, only 2 CPU cores and 7 GB RAM are available (9). More capable systems are available on a paid basis.

Conclusion

LLMs are being integrated in scientific workflows unavoidably, but commonly it is not documented how they were employed, also because of lack of tools conserving this information conveniently. If the scientific community documented how the prompted LLMs like they document how data analysis software was used, we could learn from each other how to prompt efficiently and responsibly. To overcome current limitations, I propose git-bob, a functional, LLM-based proof-of-concept AI-assistant embedded in the GitHub platform. It enables scientists to interact with an LLM via Github Issues and Pull-Requests offering new ways for implementing

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

ACKNOWLEDGEMENTS

I would like to thank Elena Katharina Nicolay (UFZ Leipzig) for testing git-bob in its early days and for providing constructive feedback on the manuscript. I am also glad that I could use the bioRxiv manuscript template by Ricardo Henriques, which is licensed CC-BY 4.0. I acknowledge 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. I also acknowledge financial support from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under the National Research Data Infrastructure – NFDI 46/1 – 501864659 - NFDI4BioImage.

References

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A)
[BioImage Analysis]: Nuclei segmentation #13
 haesleinhuepf opened this issue 4 minutes ago · 2 comments

Assignees

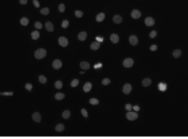
haesleinhuepf commented 4 minutes ago Owner

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)

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 nsbatm
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 = nsbatm.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, 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.

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-pWGb0Ylr4

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.ipynb' 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)

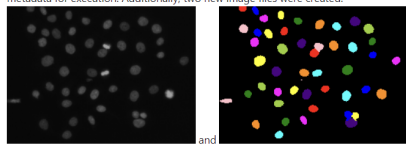
github-actions bot added 3 commits 1 minute ago

- Adding /human_mitosis_small.png created by notebook 99fec43
- Adding /labeled_nuclei.png created by notebook 9e11273
- 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:



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-pWGb0Ylr4/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-pWGb0Ylr4/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"]

Fig. 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 (C). The discussion also contains error messages observed while the AI-assistant was executing code or creating files, allowing to modify prompts or improve git-bob itself. Words triggering git-bob are underlined in magenta. 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>

Supplementary material

haesleinhuepf commented 5 days ago Owner ...

I have a 2d+t timelapse dataset as numpy array. I would like to save it as animated gif to disk. Can stackview do this? If yes, how?

git-bob comment

👍 1

github-actions bot commented 5 days ago ...

This message was generated by git-bob (version: 0.6.4, model: gpt-4o-2024-08-06, [Run details](#)), an experimental AI-based assistant. It can make mistakes and has [limitations](#). Check its messages carefully.

Certainly! Stackview can help you save your 2D+t timelapse dataset as an animated GIF to disk. You can use the `stackview.animate` function for this purpose. Here's a code snippet that demonstrates how to achieve this:

```
import stackview
import numpy as np

# Assuming 'timelapse_data' is your 2D+t timelapse dataset
timelapse_data = np.array(...) # Your numpy array data

# Save the animation as a GIF
stackview.animate(timelapse_data, filename="timelapse_animation.gif", frame_delay_ms=100)
```

This code will take your timelapse data and save it as an animated GIF named `timelapse_animation.gif` with a frame delay of 100ms between frames. Adjust the `frame_delay_ms` as needed to control the speed of the animation.

👍 1 ❤️ 2

Fig. 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. Words triggering git-bob are underlined in magenta. The entire discussion and corresponding code can be read online: <https://github.com/haesleinhuepf/stackview/issues/79>

haesleinhuepf commented 4 days ago Owner ...

I would like to display three images with a curtain. Is this possible using stackview?

git-bob comment

👍 1

github-actions bot commented 4 days ago ...

This message was generated by git-bob (version: 0.6.5, model: gpt-4o-2024-08-06, [Run details](#)), an experimental AI-based assistant. It can make mistakes and has [limitations](#). Check its messages carefully.

Currently, stackview supports using a curtain for showing an image and a segmented image on top or two images side by side. Unfortunately, displaying three images with a curtain directly is not a built-in feature. This functionality might require custom implementation or extending the stackview library. [@haesleinhuepf](#) might have more insights or suggestions on this.

👍 1 ❤️ 1

Fig. 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. Words triggering git-bob are underlined in magenta. 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



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:

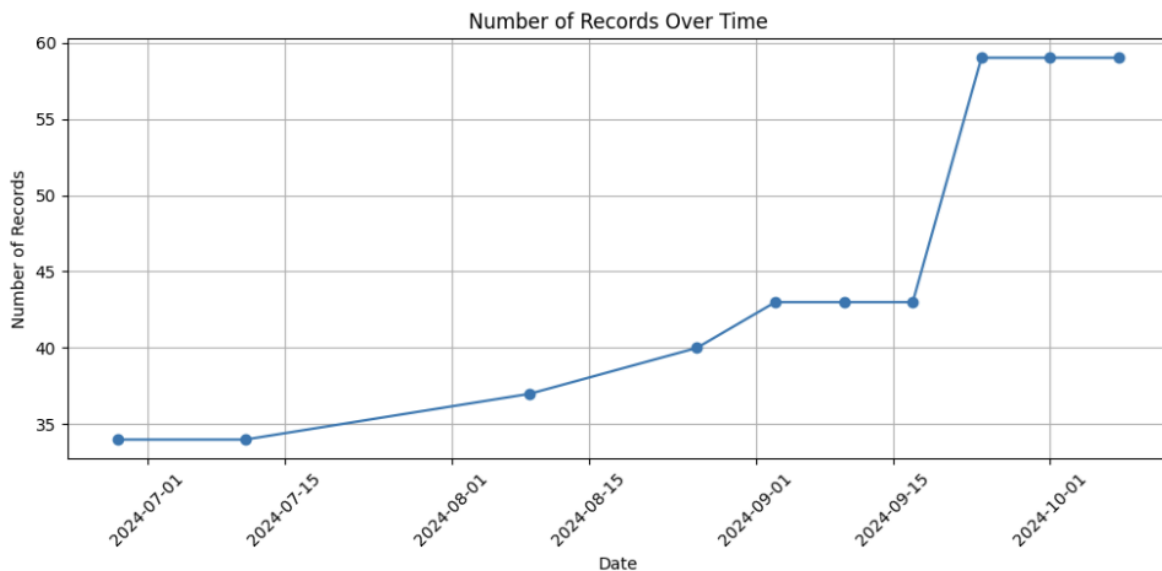


Fig. S3. Use-case example for plotting data: after explaining the folder structure of the project, it generates code for parsing a folder of CSV files and plotting results. Words triggering git-bob are underlined in magenta. The entire discussion and corresponding code can be read online: <https://github.com/NFDI4BIOIMAGE/training/issues/250>

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 dafef0ec 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

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

Fig. 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 Author

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-F1Wd0ZPHW

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. 8b4a46a

C)

Conversation 0 Commits 1 Checks 0 Files changed 1

Changes from all commits File filter Conversations Ask Copilot Review

```

git-bob-manuscript.tex
@@ -102,7 +102,7 @@
102 102
103 103 \begin{abstract}
104 104
105 105 - Abstract will be added later
105 105 + 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

```

Fig. 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). Words triggering git-bob are underlined in magenta. 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>.