A User-Centered Desktop Application for AI-Powered Geomorphologic Analysis

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1. Manuscript

1.1 Introduction

Monitoring surface dynamics of alpine landforms is essential for understanding geomorphological processes in the context of accelerating climate change. A recently published workflow by Hendrickx et al. (2025) combines two complementary open-source methods: PIPs++ (Harley et al., 2022; Zheng et al., 2023), a deep-learning-based point tracking algorithm, and GIRAFFE (Elias, 2024), a photogrammetric image-to-geometry registration tool. This hybrid approach enables the extraction of spatially distributed velocity fields from webcam time-lapse imagery at high temporal resolution. The method is robust to large displacements, illumination changes, and occlusions caused by, e.g., changing weather conditions or rock slides. The resulting image measurements are subsequently transferred into object space using GIRAFFE.
Despite this progress, a substantial gap remains between the capabilities of these tools and their usability in everyday scientific research. The proposed workflow is fragmented and requires non-trivial expertise in environment management, dependency resolution, and command-line operation. Because of the high barrier to entry, the intended user group is largely excluded from utilizing these workflows.

2. Objective

To address the usability challenges of the existing PIPs++/GIRAFFE workflow, a user-centred (installable) desktop application with graphical user interface (GUI) was conceived and implemented. The design process follows Garrett's Five-Plane Model (Garrett, 2011), covering the planes of *Strategy, Scope, Structure*, *Skeleton* and *Surface*, and is complemented by the human-centred design framework of ISO 9241-210:2010. System Requirements are specified following ISO/IEC/IEEE 29148:2018, balancing user requirements with the technical constraints of the underlying algorithms.

3. Implementation and Evaluation

The application is structured into two modules: an installer that manages software dependencies, virtual environments, and CUDA-capable hardware detection, and an execution module that provides workflow parameter configuration, file selection, and execution control through a GUI. Both modules are implemented in Python using PySide6, while the Qt Modeling Language (QML)-based user interface is developed in Qt Design Studio. The software architecture enforces a strict separation between presentation, interaction and execution logic. Long-running tasks, such as software installation and workflow execution, are handled asynchronously to maintain interface responsiveness.
The application was evaluated through two complementary approaches. Iterative user evaluations with representatives of the target group informed design decisions throughout the development process and assessed the application's usability. System tests verified compliance with functional and non-functional requirements. Together, these evaluations provided insights into both the usability of the resulting tool and the suitability of the chosen methodological framework for transferring scientific research workflows into a user-centered application.
The configuration windows for PIPs++ and GIRAFFE are shown in Figures 1 and 2, respectively.

4. Results and Discussion

The developed application operationalizes the main functionality of the existing PIPs++/GIRAFFE workflow in a desktop application for windows 10/11 operating systems. The installer requires Python 3.10 64-Bit to perform the installation. While a CUDA compatible GPU is not required for installation, without it PIPs++ is not usable in the current version of the application.

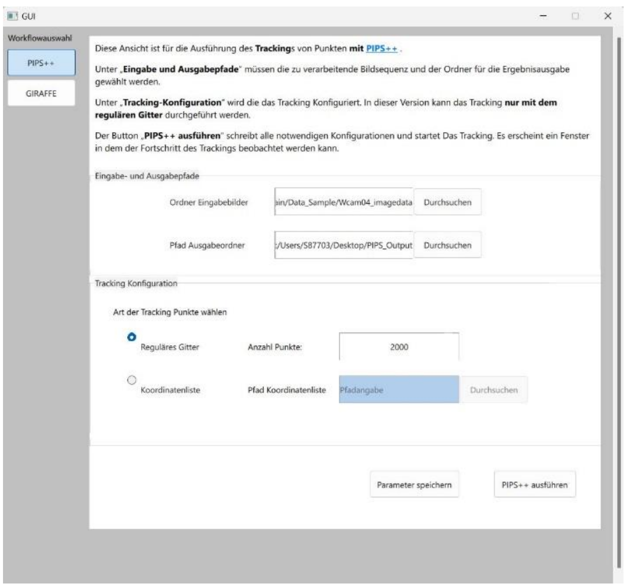

Figure 1 PIPs++ configuration view

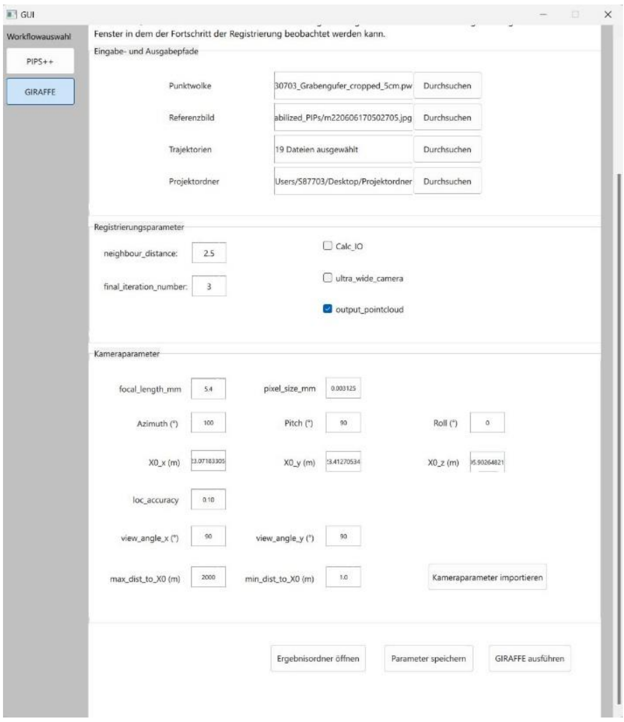

Figure 2 GIRAFFE configuration view

While the GUI significantly lowers the barrier to entry, some usability challenges remain to be addressed. The differing expectations of PIPs++ and GIRAFFE regarding file system organisation are partially mitigated by folder and file selection windows, though full alignment has not yet been achieved. Furthermore, GIRAFFE expects a specific point cloud format, which could lead to unexpected errors for unaware users. Clearer guidance here will help users avoid these errors. Due to the GPU memory demand of PIPs++, large image batch sizes or high image resolutions may exceed available memory at runtime; optimising for these cases is planned for future versions. Conflicting environment variables from other Python-based software suites can cause the application to invoke the wrong interpreter rather than the dedicated virtual environment. The issue was resolved for the installer but remains so far in the application.

The GUI was developed with a user-centred design approach, and input data validation is an area with clear potential for enhancement in future iterations. The current scope deliberately prioritised core functionality, leaving room for more robust validation down the line. One notable opportunity for improvement, highlighted directly by the user group of representatives during the application evaluation, is the ability to input coordinate lists for tracking predetermined points with PIPs++. Building on the existing regular implementation, this feature is a strong candidate for an upcoming release.
Currently the application is only available in German but this likely will be addressed in future versions

5. Conclusion

The application allows users to configure and execute the PIPs++/GIRAFFE workflow through a graphical user interface. The application is installed through its own installer which handles all environment management, dependency resolution. An internet connection is required for installation of the required Python libraries and packages. The installer and application handle all tasks that before required manual command line configuration while providing the user with log-prints of ongoing operations. This corresponds strongly with the user-centred approach and aims to provide not only a functional and useful application but also a positive user experience.
All in all, evaluations indicated a positive attitude towards the application and a strong interest among the target user group to apply the analytical capabilities of the PIPs++/GIRAFFE workflow on existing data sets.

The application will be made available open source, both as a downloadable executable for windows machines (Win 11) and as code base to be packaged and installed manually. Future additions could be data input validation, improved data structure handling and AMD-GPU support.

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