Human Modeling for Micromobility Safety

Shinya Abe[1], Jobin John[1], Johan Iraeus[1], Mats Svensson[1]

[1]Chalmers University of Technology, Dep. of Mechanics and Maritime Sciences

email: shinya.abe@chalmers.se, jobin.john@chalmers.se, johan.iraeus@chalmers.se, mats.svensson@chalmers.se

CHALMERS UNIVERSITY OF TECHNOLOGY

UNIVERSITY OF GOTHENBURG

Problem and Purpose

Micromobility vehicles, for example, **e-scooter**, have been recently gaining a larger share among urban transport modes, fast becoming an alternative that is efficient, sustainable, and accessible. However, this growth in users has also led to increasing casualties[1] in recent years. Micromobility users—classified as vulnerable road users (VRUs)—commonly sustain injuries to the head (including the face) as well as the upper and lower extremities[2] (Fig 1). Micromobility brings new challenges to safety, mainly arising from new types of crashes configurations (for instance, face impact on ground).

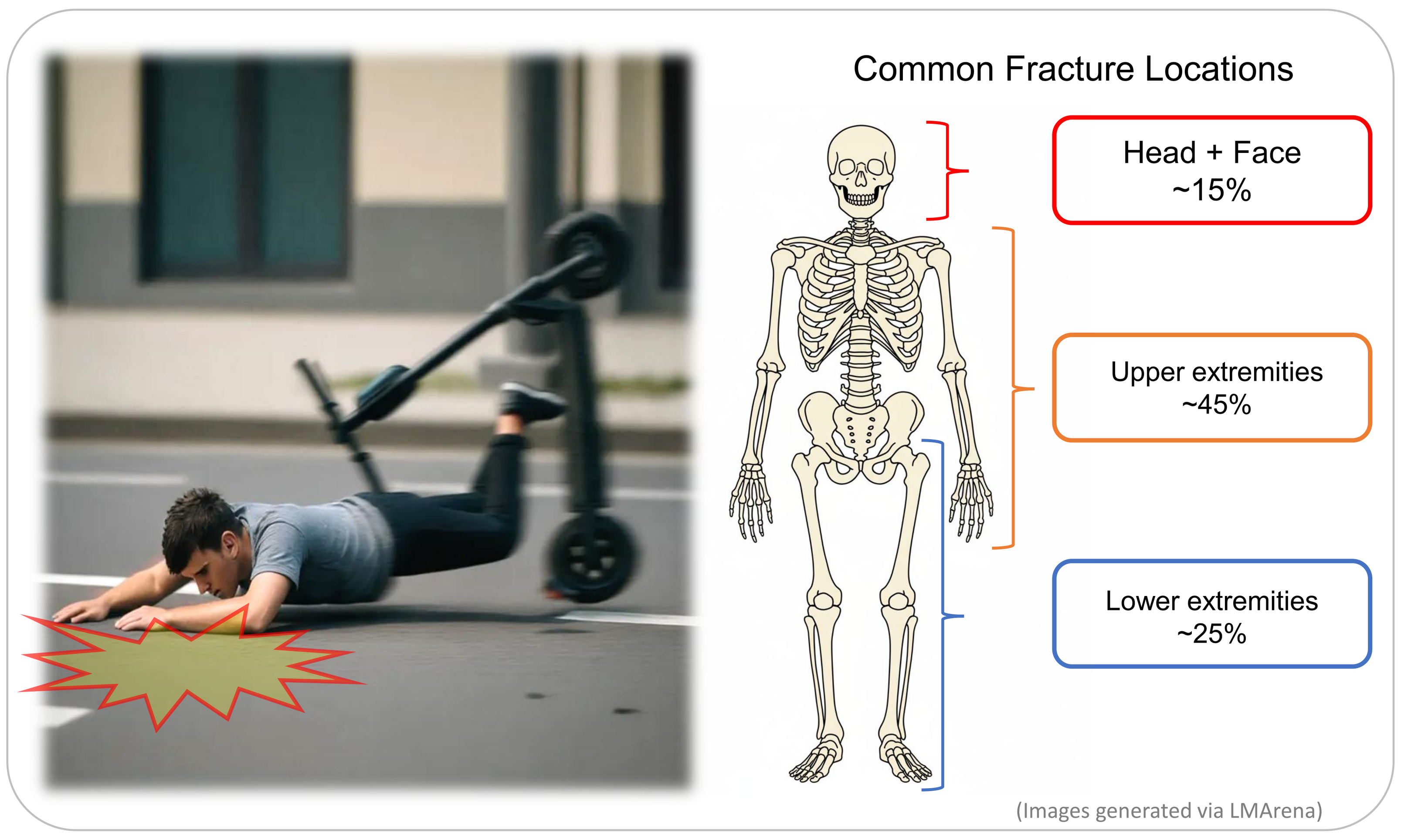

Figure 1: E-scooter crash and common fracture locations

The aim of this project is to develop simulation tools for studying micromobility injuries and creating countermeasures to prevent future injuries.
This project involves two parts:

1) **Updating and validating human body finite element (FE) models (HBMs)** —particularly the upper extremities and face—so that injuries from micromobility crashes can be predicted accurately

2) **Developing a workflow to reconstruct real-world micromobility crashes**

Realization 1. Updating HBMs

The open-source VIVA+ HBMs[3], co-developed by Chalmers, Graz University of Technology (TU Graz), and University of Ljubljana, have currently been updated and validated to accurately predict injuries from micromobility crashes. While this HBM is already validated for predicting injuries in selected body regions for occupants and pedestrians, it still needs to be adapted specifically for micromobility crashes. In particular, this will focus on adding prediction capabilities of upper extremity and facial skeletal injuries. The bones in these HBM regions will be validated to predict fracture response and the joints will be updated for biofidelic injury responses.

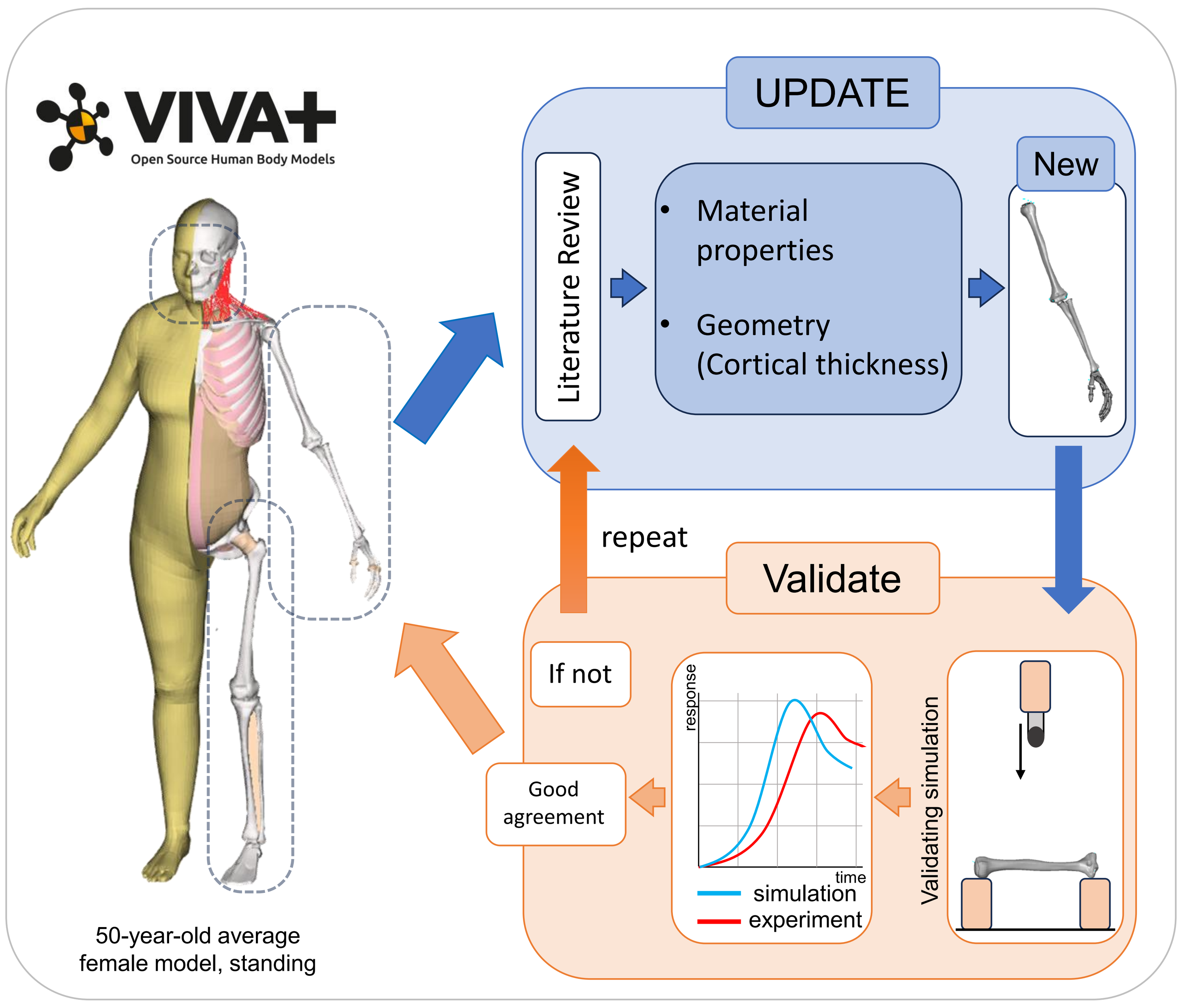

Figure 2: Update and validation of the VIVA+ human body model (HBM)

Realization 2. Crash Reconstruction Workflow

Micromobility crashes are characterized by greater variability as the users are not constrained inside a vehicle. In addition, the distinct design of micromobility vehicles and their interaction with existing road infrastructure lead to a variety of impact postures and impact velocity vectors. Therefore, the HBMs developed in the previous step (Realization 1) will be integrated into a semi-automated workflow to simulate real-world micromobility crashes. This will involve the sequential steps illustrated in Fig 2. These steps will utilize a series of tools (for e.g. KinePose, PIPER).

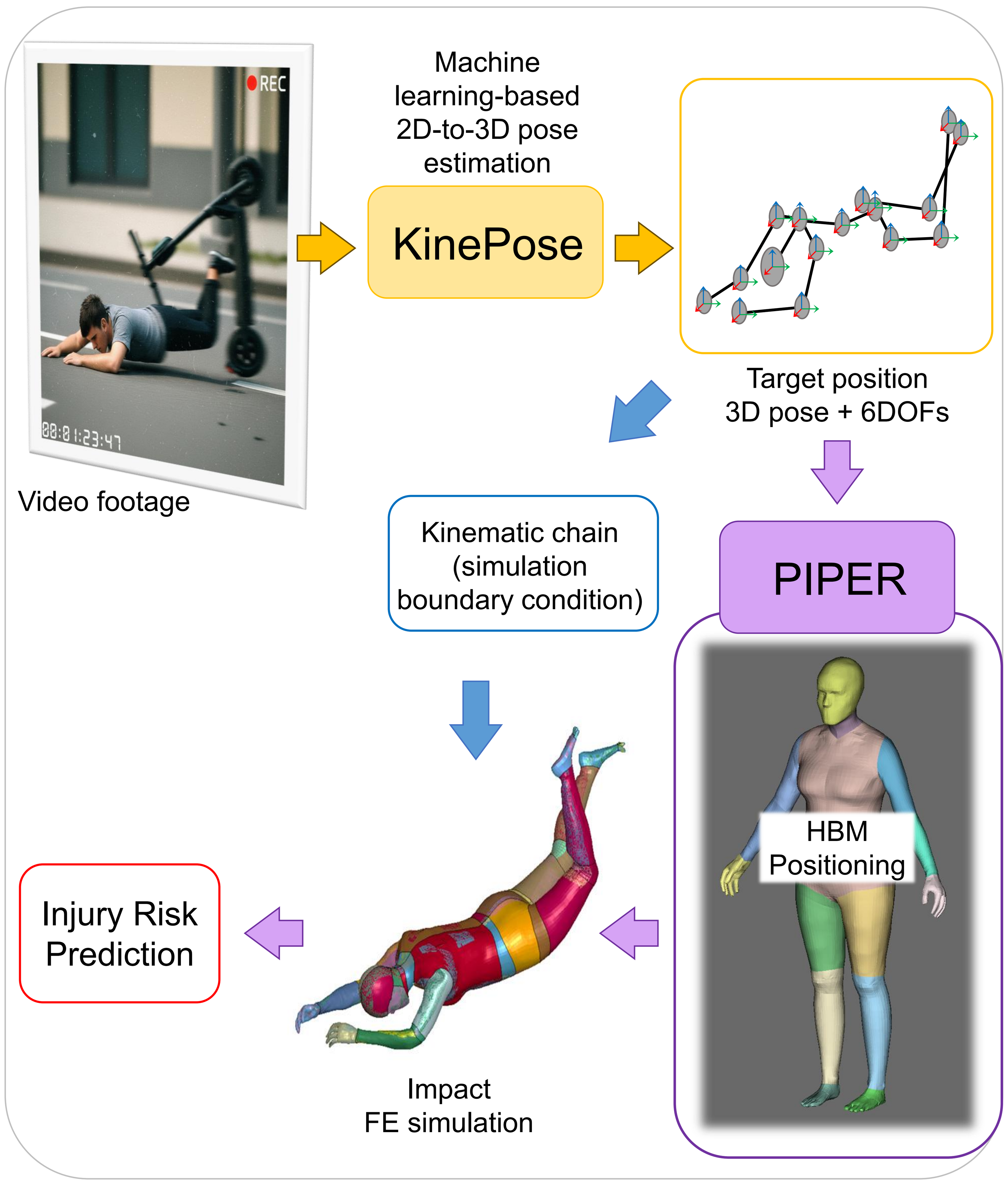

Figure 3: Workflow for reconstruction of real-world micromobility crashes

Results

The workflow for positioning the VIVA+ HBM using PIPER has been developed and was presented as an open-source tool at the VIVA+ 2025 User Meeting. A comprehensive literature review on e-scooter crash injuries guided the decision to focus updates of the VIVA+ HBM on the upper extremities and face. Updating and validating these components is currently underway.

The project outcomes will advance understanding of injury mechanisms and support the design of protective devices and safer micromobility infrastructure. **The updated HBMs and workflow will be openly available** through VIVA+ HBM and the OpenVT virtual testing platform. The reconstruction workflow also has potential applications beyond micromobility, such as **predicting occupant pre-crash posture and behavior** or **analyzing pre-crash postures in sports**.

Unlike many existing VRU HBMs—often limited to average male models—this project will provide both average female and male models, to ensure ***inclusive* safety assessment**. The project also includes collaboration with researchers from TU Graz (Vehicle Safety Institute) and the developer of KinePose, whose tools and resources will be integrated and further developed.

References

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