VISUALIZING MATERIAL STRESS USING COMPUTER VISION AND AUGMENTED REALITY BASED ON FEM SIMULATION MATCHING

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Augmented reality (AR) combined with physics-based computer simulations offers a powerful toolset for visualising invisible phenomena – such as internal stress or deformation – in fields like mechanical education, industrial diagnostics, and infrastructure monitoring. Motivated by this potential, this research aims to develop a hybrid vision-simulation system that overlays simulated stress distributions onto real-world photographs of a bent pipe.

The system is designed to work with pipes under static load and employs Finite Element Method (FEM) simulations as a reference. FEM has long been established as a fundamental tool for stress analysis in structural mechanics [1]. These simulations, generated using ANSYS software, show how a pipe deforms under increasing weight. Each frame of the simulation is processed to extract both the pipe's contour and key deformation metrics, including vertical displacements and spline curvature features.

To analyse a real-world scenario, an image of a loaded pipe is captured, and its shape is segmented using a deep learning-based segmentation model – the Segment Anything Model (SAM) [2]. The segmented pipe mask is then used to extract the central axis of the pipe. Using this axis, the system computes relative vertical displacements and curve geometry at several reference points along the pipe.

Once the pipe's shape is extracted from the real image, the system compares it to the preprocessed simulation metadata and selects the most similar deformation pattern. The similarity is calculated using a distance metric based on vertical displacements.

By allowing users to "see" invisible deformations in AR, this method opens the door to fast, low-cost augmented feedback in structural mechanics. It also aligns with modern approaches to virtualised maintenance and engineering diagnostics.

As part of the broader outlook, the system may be extended to work with arbitrary and constantly changing camera poses by building an environment map using photogrammetry [3]. Further improvements may also include optimising the solution for mobile devices using real-time video input.

References:

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