# THE DYNAMIC CONTROL OF HEAD STABILISATION IN CHEETAHS: A COMPUTER VISION AND OPTIMISATION APPROACH

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## Introduction

The cheetah, the fastest land mammal, exhibits specialised adaptations for prey tracking, including vestibular mechanisms for gaze and head stabilisation [1]. Studying these dynamics in wild, endangered animals is challenging, which motivated a non-invasive Computer Vision (CV) approach to collect 3D points of interest. Building on approaches such as AcinoSet [2], we developed a new dataset and a markerless reconstruction pipeline in MATLAB® that extracts 3D points of interest and quantifies motion dynamics. The workflow integrates computationally intensive tasks, such as model-based optimisation and rendering, which can be parallelised and scaled on High Performance Computing (HPC) systems. Beyond the case study presented here, these methods highlight the potential for applying markerless 3D reconstruction to a wide range of animal and human models, supporting research in biomechanics, conservation, and robotics.

## Methods

A unique dataset of cheetahs in a moving vehicle was collected using four GoPro Hero 12s, raised and angled towards the centre of the car's platform. The cameras recorded at 240 frames per second with a resolution of 1920×1080 pixels, and inertial measurements were recorded simultaneously from a sensor attached to the car. All recordings were time synchronised. The dataset included 2D labels for key points of the cheetah based off a skeletal model [2], by hand-labelling over 1000 video frames used in training a DeepLabCut [3,4] network. For camera calibration, we used a 10×7 checkerboard with square sizes of 40 mm and MATLAB® camera calibrator tools. The 2D key point labels from the DeepLabCut neural network were used in an error function that was optimised with MATLAB®'s `lsqnonlin`.

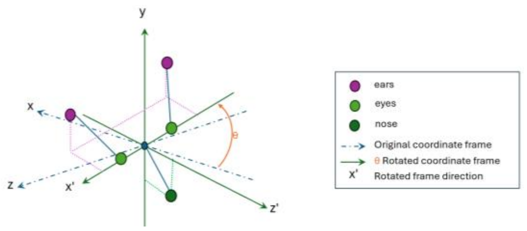


*Figure 1: 3D head model example for model-based optimisation approach*

Essentially, it minimised error between the 3D kinematic model of a cheetah adapted from [2] (Figure 1), and the 3D triangulated position of a key point to produce an optimal trajectory in a 3D reconstruction (Figure 2). This was used, alongside AcinoSet data [2], to inversely infer the cheetah's head stabilisation. Once the optimisation is computed, the optimisation can be benchmarked on different desktop systems, and on a High Performance Cluster for Parallelisation (MATLAB® Parallel Computing Toolbox).

## Results & Discussion

The cheetah stabilises its head and gaze during high-speed or agile manoeuvres, and when balancing on a perturbed platform. Results from our analysis suggest the utilisation of feedback control, while the head stabilisation relative to the torso can be accurately quantified. The prominent stability factors quantified were related to vestibular stability, namely: head vs torso vertical acceleration during passive motion, and head pitch target fixation during prey pursuit.

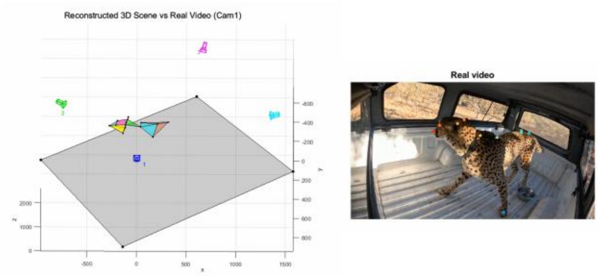


*Figure 2: 3D Reconstructed head and torso in vehicle scene*

Markerless motion capture in conjunction with optimisation methods produces remarkable 3D reconstructions with noise reduction and it was successfully used to further understand the neuromechanical motor adjustments specific to cheetah head stabilisation. This work can give insights into markerless motion capture and feedback control of observed animal behaviour in a biomechanical context. The viability of this work can confidently be extended to other animal or human models and field tests, and HPC can extend the capabilities of the methodology further.

## References

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