Inverted pendulum visual servo control with dynamic computation offloading

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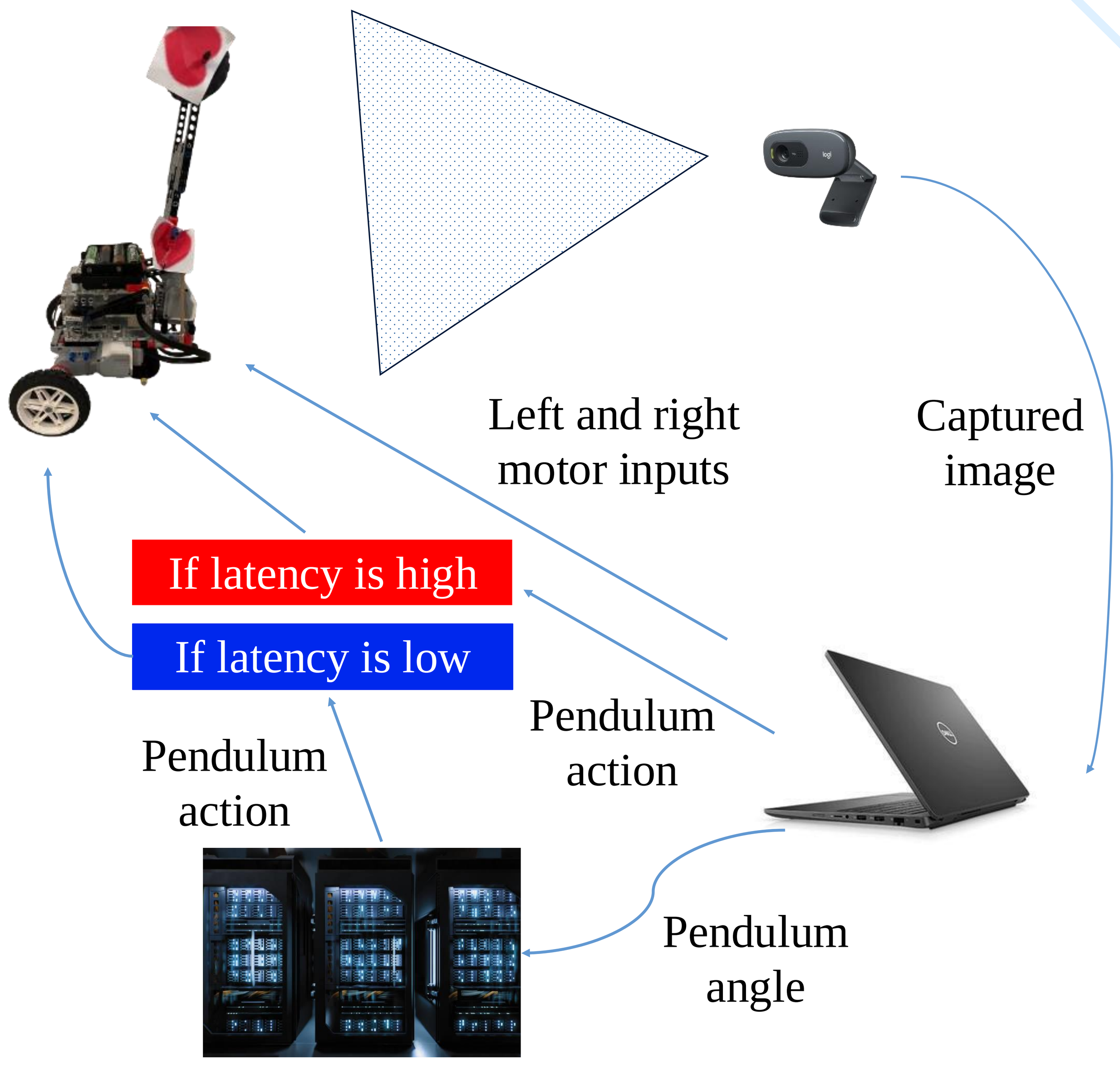
Objective

- Showcase a real-time edge computing application with stringent latency requirements

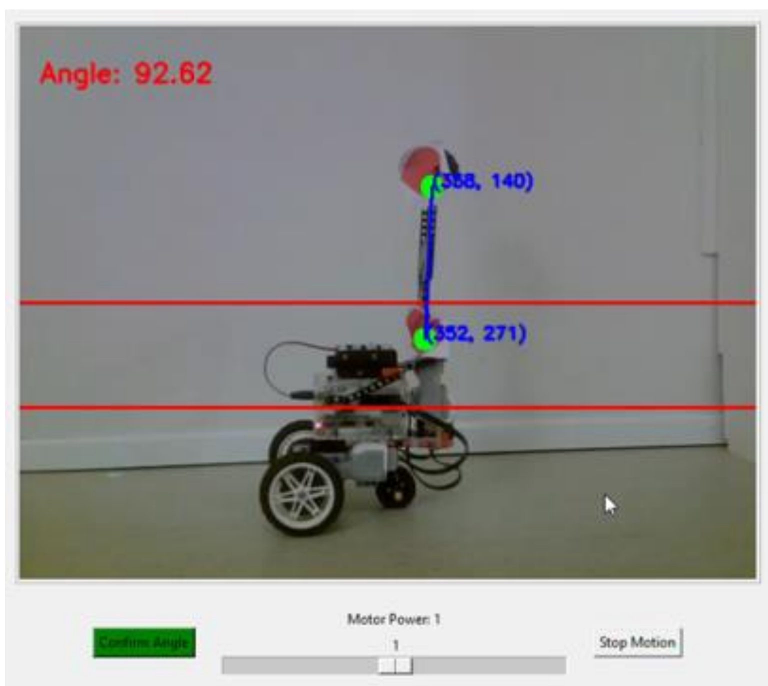
System components

- Compact, battery-powered rover with an inverted pendulum
- Camera for angle estimation
- Communication latency monitor
- Offloading orchestrator to choose controller



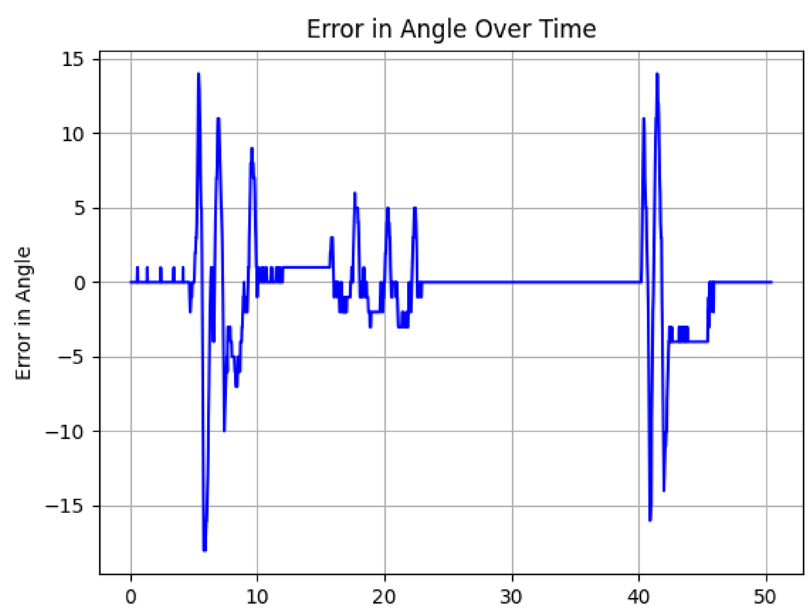
Computer vision for angle estimation

To improve detection accuracy of the pendulum's tip and bottom, we designate a specific region within the video frames where the bottom of the pendulum should be located (indicated in the figure by the area between two red lines). The tip of the pendulum should be above that area. For detecting the tip and the bottom, the detector applies template matching, which finds the location of the template image in each captured frame.



Confirmation of the Reference Angle

The demo allows setting the reference angle of the pendulum from the user UI. The visual servo then keeps the chosen angle.



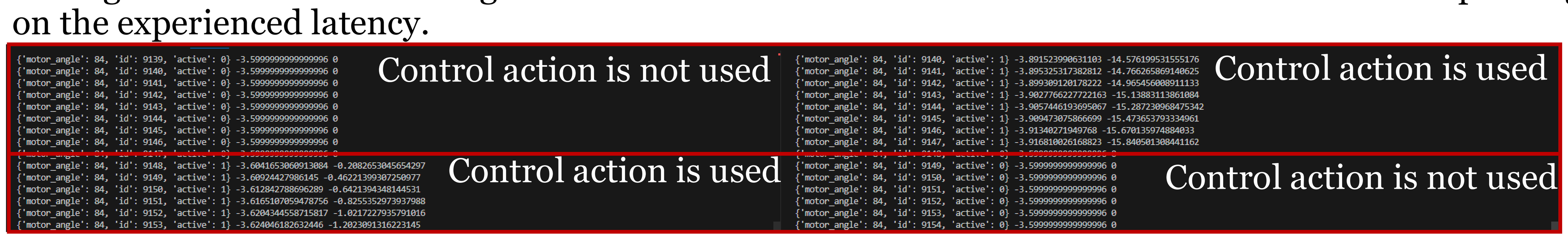
Latency Aware Online Controller

After the visual servo estimates the instantaneous angle of the pendulum, it computes the error compared to the reference. The computed error is sent to the edge server, which allows the edge server to compute the control action. At the same time, the user computer estimates the latency to the edge server.

If the latency to the edge server is below a threshold, then the rover listens to control actions sent by the containerized controller application hosted on the edge server.

Otherwise, the rover listens to control actions computed on the user computer. We do not perform onboard computations on the rover to save energy, which allows the demo to run longer even if offloading is not possible due to poor network conditions.

The figure below shows the logs of the controller as it selects between the two controllers depending on the experienced latency.



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For more interesting research

[J1] F. Tütüncüoğlu, S. Jošilo and G. Dán, "Online Learning for Rate-Adaptive Task Offloading Under Latency Constraints in Serverless Edge Computing," in *IEEE/ACM Transactions on Networking*, vol. 31, no. 2, pp. 695-709, April 2023

[J2] F. Tütüncüoğlu and G. Dán, "Optimal Service Caching and Pricing in Edge Computing: A Bayesian Gaussian Process Bandit Approach," in *IEEE Transactions on Mobile Computing*, vol. 23, no. 1, pp. 705-718, Jan. 2024

[J3] F. Tütüncüoğlu and G. Dán, "Joint Resource Management and Pricing for Task Offloading in Serverless Edge Computing," in *IEEE Transactions on Mobile Computing*

[C1] F. Tütüncüoğlu and G. Dán, "Optimal Pricing for Service Caching and Task Offloading in Edge Computing," *2022 in Proc. of Wireless On-Demand Network Systems and Services Conference (WONS)*, Oppdal, Norway, 2022, pp. 1-8

[C2] Feridun Tütüncüoglu, György Dán,``Sample-efficient Learning for Edge Resource Allocation and Pricing with BNN Approximators," *in Proc. of IEEE INFOCOM Workshop on Intelligent Cloud Computing and Networking, May 2024.*