Visual Servoing for Mobile Ground Navigation

Jeffrey Kane Johnson, Maeve Automation

contact@maeveautomation.org

ABSTRACT

This vision-based control framework attempts to mitigate several shortcomings of current approaches to mobile navigation, including the requirement for detailed 3D maps. The framework defines potential fields in image space and uses a subsumption process to combine hard, physical constraints with soft, guidance constraints while guaranteeing that hard constraint information is preserved. In addition, this representation can be defined with constant size, which can enable strong run-time guarantees to be made for visual servoing based control.

MAIN POINTS

1. Many navigation systems require detailed 3D maps, but these can be difficult or expensive to create and maintain or unavailable
2. Agents often encounter large and varying numbers of entities in a scene, which can be problematic for approaches whose complexities are sensitive to entity counts
3. Many robotic systems may be subject to rigorous verification and validation procedures that are difficult to perform with current approaches.

To help address these issues, this paper expands on previous work [7] to present a subsumption control framework built around Image Space Potential (ISP) fields. Under this framework, sensor data is transformed directly into a potential field defined in an image plane where an Image-Based Visual Servoing (IBVS) routine computes control commands to guide the agent toward its goal. The use of image space can help mitigate the three problems cited above.

DEMONSTRATIONS

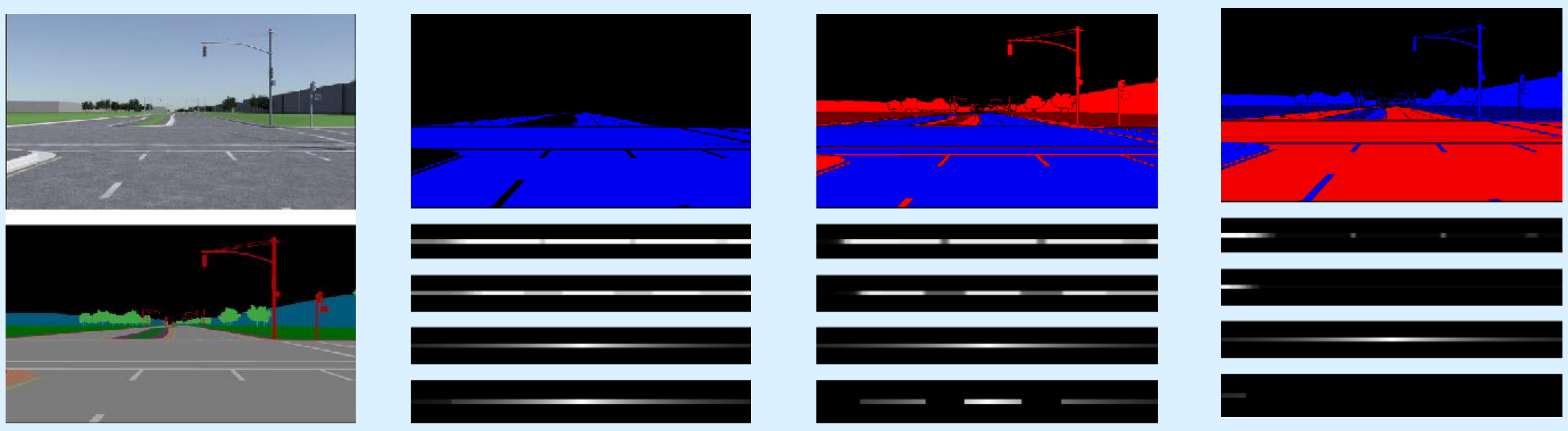
1. The first shows how soft constraint values guide navigation, and is performed with publicly available data sets [26]. Figure 3 shows the effect that modifying the user-defined soft constraint values has on the set of controls. The soft constraint values are color-coded in the figure across the top, and the control space output is shown varying with colors along the bottom.

2. In the second, perception input comes from the fiducial tracking system ar_track_alvar [29]. The sequence of detections in image space can be used to calculate estimates of τ for each detection. Figure 4 describes the experiment and shows the mobile test platform as it navigates the slalom (link to video in caption).

CONCLUSIONS

Image Space Potential (ISP) fields are a visual servoing-based subsumption control architecture for mobile navigation. ISP fields are constant space complexity with respect to the image, which is crucial for ensuring scalability and running time of algorithms. Under reasonable assumptions, the formulation of the control architecture can also ensure collision-free navigation. An implementation of the framework described in this paper is publicly available [30] under the MIT open source license [31].

1



(a) Top: The raw camera image input. This image passes through a perception routine that can produce a segmentation. Bottom: The segmentation output of perception.

(b) Road pixels have positive bias (blue), all others have neutral (black). The final horizon (bottom) essentially mirrors the guidance horizon (second from bottom).

(c) Road pixels have positive bias (blue), while lane markers have negative (red). The final horizon (bottom) strongly avoids forward motion that aligns with lane boundaries.

(d) Road pixels have negative bias (red), while lane markers have positive (blue). The final horizon (bottom) strongly avoids virtually all forward motion save for a faint patch at the far left.

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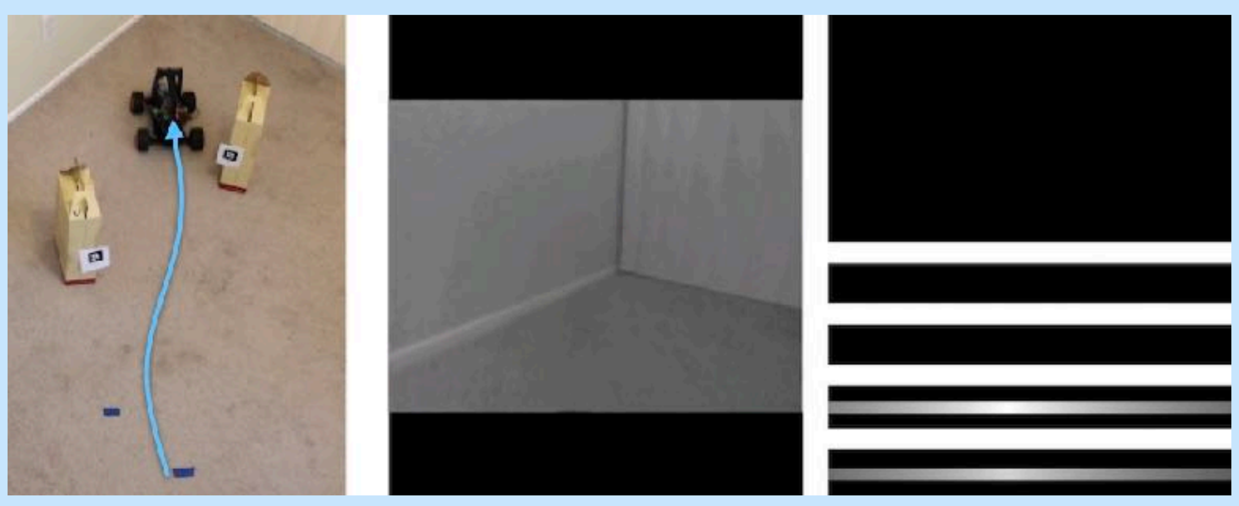
(a) Initial approach of the agent to the obstacles. The bias brings the vehicle towards the near obstacle. At this point the agent is stationary, so the ISP field (top right) is empty.

(b) Once the agent begins moving forward, the near obstacle induces an increasing negative potential region in the ISP field (top right). As the potential drops, the controls that steer the agent toward the obstacle are made unavailable (bottom right).

(c) As a result of avoiding the first obstacle, the agent approaches the second obstacle, which induces a different portion of the control set to become unavailable (bottom right).



(d) Once the agent moves past the obstacles, the ISP field becomes empty again, and the bias value guides control unperturbed.

References

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