Constant Space Complexity Environment Representation for Vision-based Navigation

**Visualization:**

Left: Perception and tracking in the image plane output multiple objects

Right: The potential field collapses these objects to a fixed-size representation

**Algorithm & Complexity:**

In Algorithm 1, all non-trivial operations are iterations over the width of the image plane. The operations on Lines 5 & 7 depend on the user defined parameters, but these are also bounded by image width. In Algorithm 2, Line 4 is a call to Algorithm 1, and Line 11 is assumed to be implemented with an $O(C)$ proportional law. Thus, the algorithm as a whole has constant complexity in space and time, with respect to the camera image space.

Algorithm 1

Given an image-space potential field $F$, compute the set of steering and acceleration commands that satisfy $\tau \leq T_s$, and $\tau > 0.5 \times \tau$, where $T_s > 0$ is some desired time headway, $w_k$ and $w_a$ are kernel widths for computing steering angle and acceleration maps, and $\tau > 0$ is a buffer.

1. procedure SafeControls($F, T_s, \tau, w_k, w_a, t$)
2. Let $I_t$ be the list of image column indices
3. Let $M_t$ map $i \in I_t$ to steering angles
4. Let $h$ be the height (row count) of $F$
5. Let $M_t = \{ (\tau, \xi) \in M_t : \tau \geq T_s \}$
6. Let $W$ be a centered $w_k \times h$ window in $F$
7. Let $(x, \tau_{min})$ be the min. $\tau$ over $W$
8. Let $L \leftarrow \emptyset$ be a container for safe accelerations
9. do
10. if $M_t = \emptyset$ then
11. $M_t \leftarrow 0$, $L \leftarrow [-1, -1]$
12. else if $\tau_{min} > T_s$ then
13. $L \leftarrow [-1, 1]$
14. else
15. if $f(\tau, x) = 0$ then
16. $L \leftarrow [-1, -1]$
17. else
18. $L \leftarrow [-1, 0]$
19. end if
20. end if
21. return $M_t, L$
22. end procedure

Algorithm 2

For a desired pixel location $(x_d, y_d)$ and setpoint speed $\dot{x}_s$, compute the Selective Determinism control that safely guides the agent $A$ toward $(x_d, y_d).$ See Algorithm 1 for descriptions of the other parameters.

1. procedure ControlSafe($x_d, y_d$, $F, T_s, \tau, t, w_k, w_a, t$)
2. Let $\theta_1, \theta_2$ be the steering angle and speed of $A$
3. Let $\theta_3$ be the steering angle corresponding to $t$
4. Let $M_t, L \leftarrow SafeControls(F, T_s, \tau, w_k, w_a, t)$
5. Let $\dot{\theta} \leftarrow \emptyset$ contain the new steering angle
6. for $\theta \in M_t$ do
7. if $|\dot{\theta} - \theta| < |\theta_0 - \theta|$ then
8. $\dot{\theta} \leftarrow \theta$
9. end if
10. end for
11. Let $\tau \in L$ be chosen proportionally to $L_d - \dot{x}_s$
12. return $\theta$, $\dot{\theta}$
13. end procedure

**Video:**

A visualization of ISP fields can be seen online by scanning the QR code or visiting the link below the QR code.

https://youtu.be/yHoR3ZpX1KE

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