Attractor dynamics approach to behavior generation: vehicle motion

Gregor Schöner, INI, RUB
Basic ideas of attractor dynamics approach

- behavioral variables
- time courses from dynamical system: attractors
- tracking attractors
- bifurcations for flexibility
Behavioral variables: example

Vehicle moving in 2D: heading direction

Robot

Heading direction

Fixed (but irrelevant) world axis
Behavioral variables: example

Constraints: obstacle avoidance and target acquisition

- Obstacle: $\Delta \psi$
- Robot
- Target: $\Psi_{\text{tar}}$
- Arbitrary, but fixed reference axis

$Y_{\text{tar}}$ and $Y_{\text{obs}}$
Behavioral variables

- describe desired motor behavior
- “enactable”
- express constraints as values/value ranges
- appropriate level of invariance
Behavioral dynamics

- generate behavior by generating time courses of behavioral variables
- generate time course of behavioral variables from attractor solutions of a (designed) dynamical system
- that dynamical system is constructed from contributions expressing behavioral constraints
Behavioral dynamics: example

behavioral constraint: target acquisition
Behavioral dynamics: example

- behavioral constraint: obstacle avoidance
Behavioral dynamics

Each contribution is a “force-let” with:
- specified value
- strength
- range

\[
\frac{d\phi}{dt} \sim \text{strength}
\]

\[
\psi_{\text{tar}} \quad \text{specified value}
\]

\[
\text{range}
\]

\[
\phi
\]
Behavioral dynamics

- multiple constraints: superpose “force-lets”
- fusion

Vehicle

Target 1

Target 2

\[ \frac{d\phi}{dt} \]

Fused attractor

Individual attractors
Behavioral dynamics

- Decision making

Vehicle

Target 1

Target 2

\[ \frac{d\phi}{dt} \]

Repellor = Attractor boundary

Individual attractors = Resultant attractors => bistable
Bifurcations switch between fusion and decision making.
Behavioral dynamics

- an example closer to “real life”: bifurcations in obstacle avoidance and target acquisition
- constraints not in conflict
Behavioral dynamics

- Constraints in conflict

Diagram showing obstacles and a target with a graph of \( d\phi/dt \) over \( \phi \).
transition from “constraints not in conflict” to “constraints in conflict” is a bifurcation
Behavioral dynamics

- Such design of decision making is only possible because system “sits” in attractor.

- This reduces the difficult design of the full flow (ensemble of all transient solutions) of non-linear dynamical systems to the easier design of attractors (bifurcation theory).
But how may complex behavior be generated while “sitting” in an attractor?

Answer: force-lets depend on sensory information and sensory information changes as the behavior unfolds.
vehicle

heading direction

obstacle

target

d\phi/dt

F

dF/dt

\phi
Visual information is obtained from two video cameras, one containing sufficient information to specify the action to be taken. Previous work within the dynamic approach (Schöner et al. 1988) has dealt primarily with cases in which such specification was possible, at least, in principle.

The closed-loop nature of the methods makes it highly desirable to work with real robots. We developed and refined the techniques reported here during several hundred hours of experimental work with the robot system shown in Fig. 1.

In both cases, the behavior emerges from the stable states of the dynamics at the fixed point. The strength expresses the maximal real part of the eigenvalues specified value. (ii) The strength of the contribution of one sensor or (undesired behaviors) of the behavioral dynamics at the fixed point are used to characterize the direction where the vehicle must return. This dynamics fuses continuously available dead-reckoning information with fluctuating sensory information obtained from correlating memorized images with current views. The visual information permits the motion planning dynamics. The driving speed is adjusted and the right cameras, together with information about the robot position, heading direction or velocity. Examples of such variables are sampled images using a fast correlational algorithm (Little, Shapiro 1992). For our purposes, however, this is not a major problem addressed here is reconciling stability to obtain an estimate of the minimal time-to-contact and decision-making. For homing a dynamical system manages this property of the dynamics suppresses oscillations of the goal location, are fed into a dynamical system that controls the forward and rotation velocities of the robot. The hysteresis of the dynamics, which manages the turning rate of the robot, reduces the effect of fluctuations of time-to-contact estimates. Hysteresis of the dynamics, which manages the so as to allow for a temporal averaging of time-to-contact estimates. For obstacle avoidance the resulting problem of ambiguous time-to-contact by a dynamical system which fuses dead-reckoning and visual information is not available (because a memorized scene is not or only incompletely in view either because of the curvature of the environment or because the scene is not visible due to obstacles). To provide visual input for behavior generation to handle two elementary problems necessary, in principle.

We briefly present the main concepts of the dynamic approach to the design of autonomous systems in the form of experimental work with the robot system shown in Fig. 1. The robot is heading towards the home base while avoiding an obstacle. After it reaches the home base it starts a new excursion. The various configurations the robot runs through are indicated by symbols: 1. (a) Flow is estimated for two purposes: for obstacle avoidance (the robot is heading. The home base was established at position 5 in the visual field; and for homing to obtain estimates of course, to transform values of these variables into appropriate actions of the robot. Examples of such variables are be expressible as points or simple sets in the space defined by the source of sensory information determines which focal points. These conditions lead us to compute optic flow on coarsely sampled images using a fast correlational algorithm (Little, Shapiro 1992). For our purposes, however, this is not a major problem addressed here is reconciling stability to obtain an estimate of the minimal time-to-contact and decision-making. For homing a dynamical system manages this property of the dynamics suppresses oscillations of the goal location, are fed into a dynamical system that controls the forward and rotation velocities of the robot. The hysteresis of the dynamics, which manages the turning rate of the robot, reduces the effect of fluctuations of time-to-contact estimates. Hysteresis of the dynamics, which manages the so as to allow for a temporal averaging of time-to-contact estimates. For obstacle avoidance the resulting problem of ambiguous time-to-contact by a dynamical system which fuses dead-reckoning and visual information is not available (because a memorized scene is not or only incompletely in view either because of the curvature of the environment or because the scene is not visible due to obstacles). To provide visual input for behavior generation to handle two elementary problems necessary, in principle.

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[Schöner, Dose, Engels, 1995]
... this is a “symbolic” approach

- in the sense that we talk about “obstacles” and “targets” as objects, that have identity, preserved over time...

- making demands on perceptual systems...

- in the implementation we see that these demands can be relaxed...

- so next we’ll look at how a “sub-symbolic” attractor dynamics approach may work