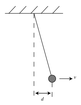

Dynamical Systems Theory Applied To Autonomics

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Introduction

Computer systems are increasing in complexity and interconnectivity. One attempt to deal with this is via Autonomic Computing, for which several implementations are available.

However, complex systems cannot always be allowed the free reign afforded to them by these autonomic systems, for example the medical industry requires strict controls and limits. This requirement for bounds, combined with a requirement for predictabiltiy within these systems requires a new paradigm for autonomic computing.

Predictability

Autonomic systems employing AI and learning techniques are not deterministic.

Operational bounds

Limits placed within the ambient space will ensure the system does not enter into disallowed states.

Autonomic Systems

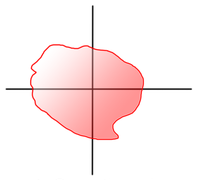

Figure 1: Operational bounds

Autonomic systems are best illutrated as shown in figure 2. They comprise of sensors reporting information, an analysis component, a decision process and an action.

The highlighted regions, **analysis** and **decision**, can be aided by dynamical systems theory.

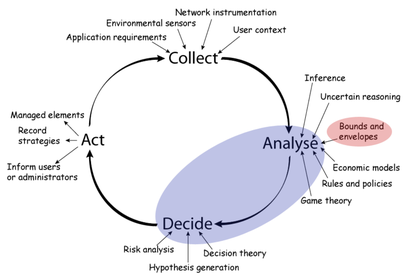

Figure 2: Autonomic Control Loop

Dynamical Systems

Dynamical Systems theory deals with complex time dependent systems. It is a mathematical formalisation of a system state within the ambient space for that system.

Ambient Space

An amient space is a multi-dimensional space, in which the system state must be located.

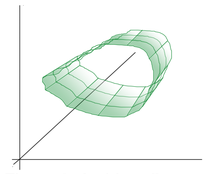

Figure 3: Ambient Space

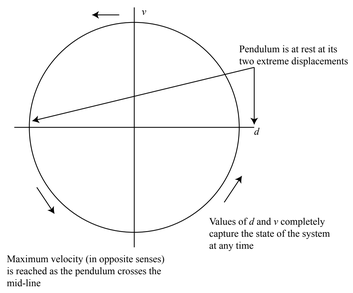

Figure 4: Ambient Space for a pendulum

Figure 4 depicts a simplified ambient space for a pendulum. Using the ambient space the pendulums speed and position can be determined.

Vector Space/Trajectories

Vector spaces can also be used to describe a dynamical system. A vector space can potentially be used to describe bounds within the system and trajectories, all within the ambient space.

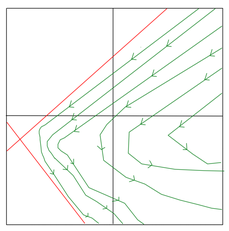

Figure 5: Trajectories

Trajectories are directional curves or surfaces within the ambient space. These should aid predictabliy within the system, and allow for sections of the ambient space to be designated as undesirable areas,.

Example

Figure 6 depicts a simple example in which a car is moving towards an obstacle. The system must stop prior to impact with the obstacle.

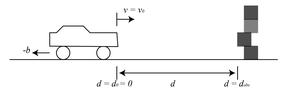

Figure 6: A Car moving towards an obsacle

Figure 7 illustrates bounds, and via the colour differences trajectories. The shaded red zone may be visualised as a slope, the top of which is the bound (e), and the bottom of which is the blue shaded zone, beginning at the bound (c).

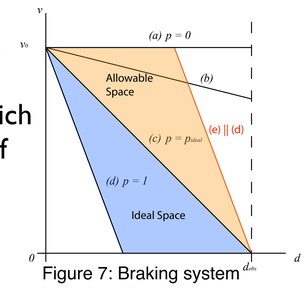

Figure 7: Braking system bounds and trajectory

Known Issues

Dynamical systems are limited to continuous systems in traditional mathematics, however this limitation should be overcome through the use of a mathematical construct known as manifolds. Manifolds allow for dis-continous and highly complex systems to be expressed and manipulated in simpler spaces. Figure 8 illustrates a simple example, the mapping of a sphere to a disc. In this example the disc is the manifold.

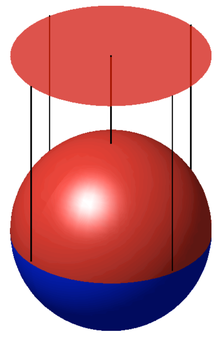

Figure 8: Sphere manifold

Conclusion

Dynamical Systems Theory may prove to be very useful in the determination of opertaional bounds and trajecories within autinomic systems. Bounds and limits may prove to be useful in all autonomic systems, not just in the envisioned uses of automotive and medical systems.