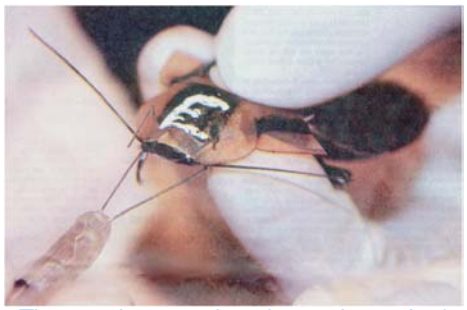
Orbital Research Inc.

Neural Networks For Control And Signal Processing

Biologically inspired neural circuits for autonomy and sensor fusion

Animals must integrate large amounts of sensor information to orient movement towards goals and away from threats, often in milliseconds, to survive. Nature, through evolution and natural selection, has optimized this behavior. In particular, insects initiate actions reflexively in situations where no time for detailed information processing or planned decision making is possible. Orbital Research, Inc. has developed a neural circuit based upon over twenty years of research by biologists on the escape response of the American cockroach that provides a key tool for achieving this capability.

Biological Inspiration



The neural circuit is based upon the work of biologists studying the American Cockroach.

Although "Biologically Inspired" approaches are becoming increasingly popular in engineering, few research groups have succeeded in tightly integrating biological principles into controller design. Tight integration of biological principles requires an approach involving close feedback between research in biology and engineering. Key steps for making this tightly integrated approach are:

- Identification of behavioral capabilities of biological organisms directly relevant to the task of interest
- Identification of biological species that are suited for studying these capabilities
- Drawing upon biological studies and experimental evidence to understand how natural systems accomplish desired tasks
- Abstract and implement those capabilities that are needed for a particular engineering task.

By working closely with biologists under this paradigm, ORI has developed several reflex control algorithms that incorporate many of the advantages seen in biological organisms, including:

Sensor Integration: In nature, animals are capable of integrating large amounts of sensory information from multiple sensors and sensor types so action decisions may be made rapidly. Autonomous vehicles with this capability react to current flight conditions and mission scenarios in real-time.

Context Dependent Behavior: Animal's reactions are continuously updated based upon physiological state and environment. Enabling this ability in autonomous vehicles increases their efficiency and adaptability.

Multi Constraint Incorporation: Many autorouters only address higher-level path planning behavior where the vehicular dynamics and constraints (such as varying flight envelopes) are not considered. Autonomous vehicles with this biological solution are capable of mission optimization within a host of varying conditions.

Instantaneous Path Generation and Tracking Reactions: Few control methodologies are capable of extremely rapid reactions. Nature has addressed this need through the development of locally controlled reflexes as in the American Cockroach whose neural organization is mimicked for autonomous vehicle control. Thus, autonomous vehicles with this biologically inspired algorithm are capable of processing, planning around, and reacting to changes or threats in real-time

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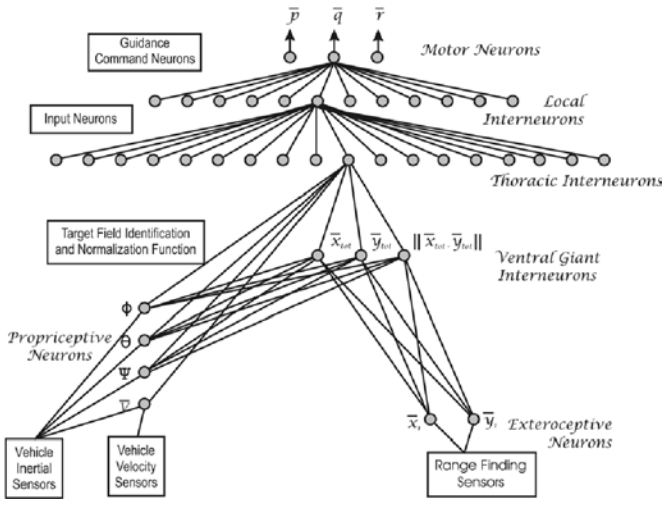
Evolved Pattern Response: The response of biological organisms is the result of the incorporation of millions of generations of natural selection. This permits robust instantaneous reactions to every situation by combining and tuning pre-developed reflexes. Thus, autonomous vehicles can rapidly reconfigure operational scenarios to accomplish the overall mission goal.



Implementation of cockroach escape reflex4es as an obstacle avoidance system for autonomous vehicles, the cockroach's neural architecture is labeled with italics and the obstacle avoidance system's analogs are shown in the blocks

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Rev: RMK 2-2-2004

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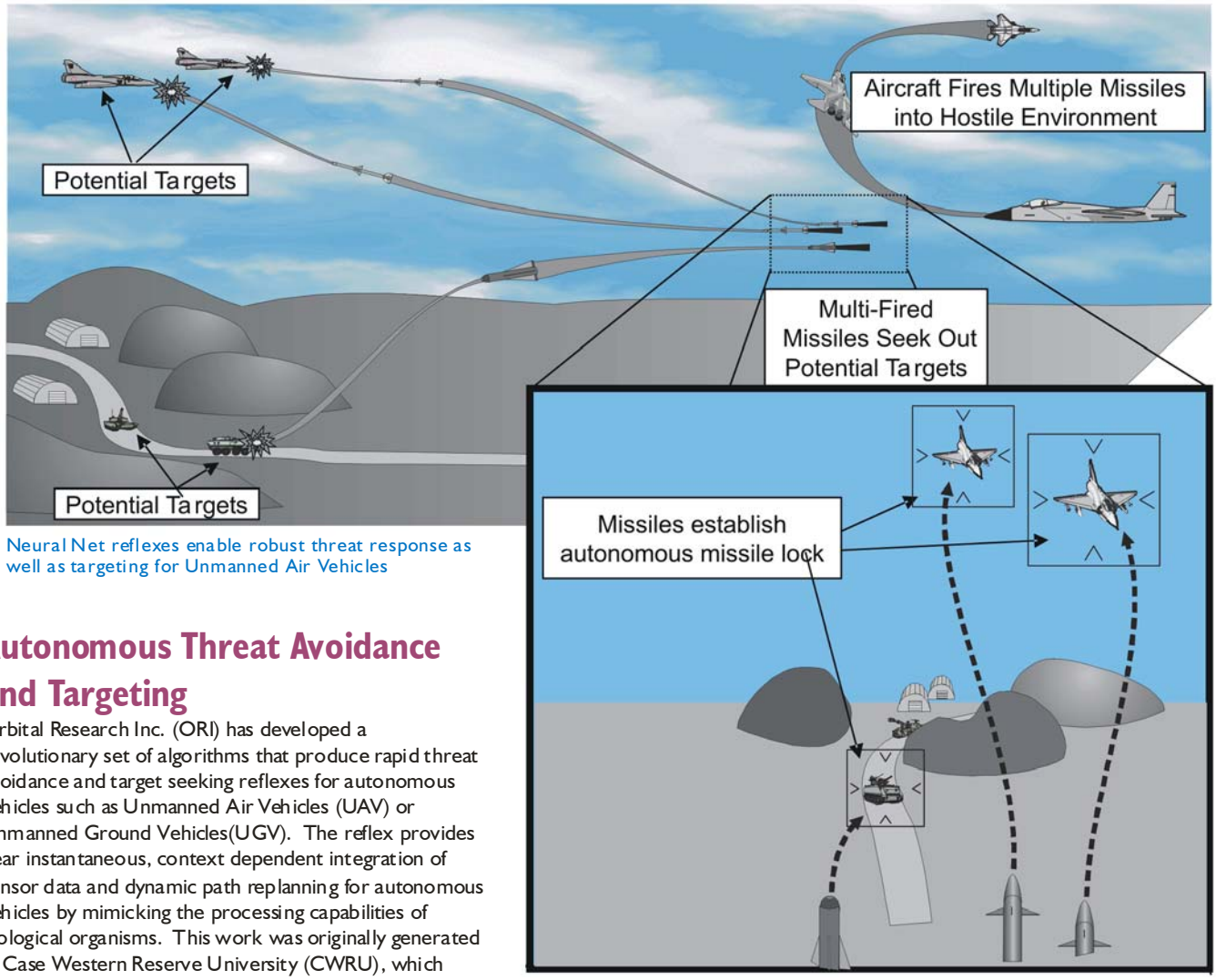

Neural Net reflexes enable robust threat response as well as targeting for Unmanned Air Vehicles

Autonomous Threat Avoidance and Targeting

Orbital Research Inc. (ORI) has developed a revolutionary set of algorithms that produce rapid threat avoidance and target seeking reflexes for autonomous vehicles such as Unmanned Air Vehicles (UAV) or Unmanned Ground Vehicles(UGV). The reflex provides near instantaneous, context dependent integration of sensor data and dynamic path replanning for autonomous vehicles by mimicking the processing capabilities of biological organisms. This work was originally generated at Case Western Reserve University (CWRU), which invested 20 years into studying the biological and evolutionary development of biological organisms. Orbital Research has transitioned the first implementation of this technology to autonomous vehicles for target seeking (BioSeek) and threat/obstacle avoidance (BioAVERT). In both simulation and demonstration flights using an unmanned air vehicle, ORI has proven the efficacy of these artificial reflexes:

Target seeking reflex shown reacting to a detected virtual target during flight testing.

Sensor Fusion for Next Generation Navigation

Researchers at ORI are currently developing integrative architectures for sensor fusion that take advantage of the sensor fusive capabilities and context dependent behavior of the cockroach escape response. The unique ability to combine contextual awareness with sensor fusion offers tremendous potential for the development of systems that incorporate information from diverse sources to produce coherent and accurate data. One implementation currently under development is an Ultra Tightly Coupled GPS/INS system that integrates GPS signal information with the raw data from Inertial Measurement Units (IMU) to simultaneously provide robust and accurate position data and track the GPS signal. It is believed that this system will provide increased precision and accuracy while proving more robust to sensor misalignment, GPS signal drop out and GPS signal jamming or spoofing. In addition, this technology has application to many in the other sensor fusion problems such as those occuring in the use of radar, sonar, and phase and focal plane arrays of sensors.

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