Orbital Research Inc.

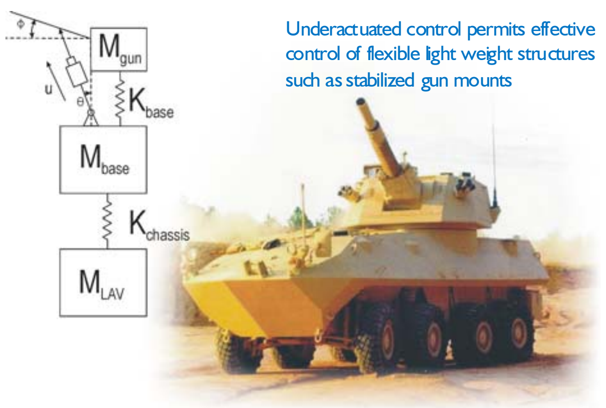
ADVANCED CONTROLS GROUP

State-of-the-art control innovations enabling tomorrow's products

Orbital Research's Advanced Controls Group creates custom control solutions for our customers by leveraging our portfolio of proprietary control algorithms with our extensive experience in state of the art control design. We offer a complete range of control solutions that combines our expertise in modern control techniques, advanced nonlinear control approaches, nontraditional methods and artificial intelligence with our expertise in automation, GNC, and autonomous vehicle control. We are dedicated to helping our customers achieve their goals and develop a competitive advantage for their products by providing unmatched control design capabilities and outstanding engineering solutions.

Technology

Orbital Research's Advanced Controls group has a wealth of expertise and design capabilities across the entire range of control system design philosophies – from highly advanced nonlinear design techniques to nontraditional methods such as artificial neural networks. The Advanced Control Group's strength lies in creating innovative solutions to difficult control engineering problems by combining the different techniques in novel ways. Though each of these techniques can be used in a stand-alone fashion, more powerful and intelligent control systems can be produced when they are designed to operate in concert. These hybrid controllers are capable of effectively controlling systems that are intractable to any single approach and provides a level of flexibility and robustness that cannot be achieved in any other way.



Underactuated control permits effective control of flexible light weight structures such as stabilized gun mounts

Modern/Advanced Control

In addition to extensive knowledge of modern state space control design techniques such as optimal and robust control, we possess proprietary, cutting edge nonlinear control algorithms that provide a level of performance, stability and robustness unrivaled by any commercially available control algorithm. These proprietary algorithms include computationally efficient adaptive control algorithms that can be implemented in real time for highly dynamic systems and nonlinear control algorithms that can be readily applied to large numbers of real world systems.

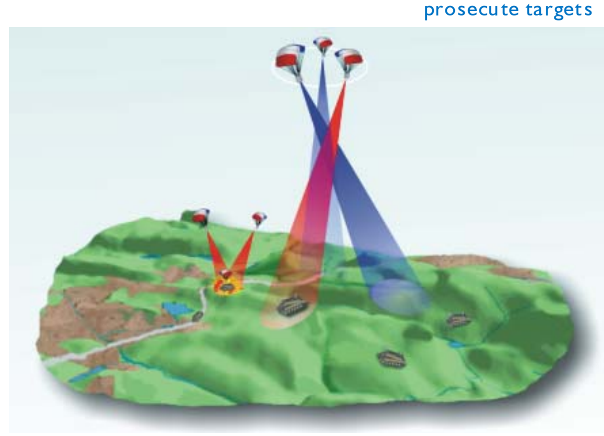
For systems whose characteristics evolve smoothly over their operating range (i.e., changing fuel levels or component wear), we have several linear adaptive control algorithms including Self Tuning Regulators (STR), Model Reference Adaptive Systems (MRAS) and a computationally efficient Generalized Predictive Control (GPC). We have developed and demonstrated control systems for suppression of aircraft wing flutter, missile tracking telescopes and distributed flow effectors.

For more difficult challenges such as the design of fault tolerant control systems for aircraft, we have a family of nonsmooth control algorithms based upon the principle of feedback domination and Lyapunov stability. These algorithms are not only capable of accommodating systems whose dynamics change in a nonsmooth fashion but can also control unstable nonlinear systems that are otherwise uncontrollable with any other existing control techniques. These nonlinear controllers have characteristics that make them particularly useful for controlling underactuated nonlinear systems such as gun stabilizers on light-weight, flexible gun mount.

Nontraditional Control

Many systems are not readily controllable by standard control approaches. For example, cooperative control of a group of autonomous vehicles lacks the inherent input/output nature assumed by traditional control design approaches. Often, all that can be specified a priori is some desired outcome, not the specific actions of each member of the group. In other cases like

Swarm intelligence enables sensor fuzed submunitions to collaboratively prosecute targets



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distributed control of nonlinear systems, theory is not sufficiently advanced to be useful. In these cases we possess a portfolio of biologically inspired algorithms and artificial intelligence techniques that permit the development of effective, robust and flexible control systems.

One type of biologically inspired algorithm, known as a Swarm intelligence-based algorithm, a type of biologically inspired algorithm derived from the observed behaviors of social animals such as ants. This type of algorithm has been proven to be very effective in the design of cooperative control algorithms for large groups of unmanned vehicles. In these instances, optimization is not feasible in real time and there is a clear need for the development of decentralized strategies that will enable the vehicles to coordinate effectively. By observing the myriad of ways in which colonies of insects use simple, reactionary behaviors to emerge complex group actions such as the creation of temperature regulated nests or birds flocking, we have extracted simple principles and behaviors which allow the development of group coordination algorithms for applications such as UAV swarm control, cargo handling, data packet routing, data mining and multi-sensor fusion.

Algorithm development suite enables rapid formulation of control systems for complex systems including human-in-the-loop (HIL) systems

We have developed several biologically inspired Artificial Neural

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

Network (ANN) reflex control systems. The architectures of these systems is based upon the actual neural architecture of a cockroach's escape reflex. The cockroach possesses an incredibly robust escape reflex that has been perfected over millions of years through evolution and can, among other things, successfully evade multiple predators simultaneously and take environmental considerations such as obstacles into account, nearly instantaneously. By mimicking this neural architecture we have developed Autonomous Threat Response (ATR) and collision avoidance systems, targeting algorithms and sensor data fusion algorithms. We have also developed and applied ANNs to numerous other systems.

Products and Solutions

Orbital Research's Advanced Control Group offers a full range of control algorithms and control system design services. In addition to our portfolio of control algorithms, we have a suite of proprietary design and analysis tools for the development and customization of control algorithms for specific applications. This suite includes a distributed simulation environment, Hybrid Integrated Virtual Environment (HIVE), which permits the rapid development of high fidelity numerical models and facilitates the interaction between multiple systems including human in the loop (HIL) systems. HIVE interacts with our Advanced Control Toolbox (ACT), which allows the rapid formulation of control laws and algorithms as well as their refinement through optimizing searches such as Genetic Algorithms (GA). One of the strengths of HIVE is the ability to use a common system from development through deployment.

Control Solutions

The following table provides the features, benefits and descriptions for Orbital Research's portfolio of control solutions.

Algorithm	Advantages	Benefits	Technology Description	Technology Readiness Level
ORICA: *Generalized Predictive Control (**GPC**)*	• Computationally efficient • Robust • Accommodates system lags • Adaptive	• Real Time adaption • Extends operating range	Adaptive controller based upon a linear predictive model	TRL-5
Nonsmooth Adaptive Control: *Feedback Domination*	• Globally Asymptotically Regulating (GAR) • Uses nonlinear dynamics • Controls system with uncontrollable, unstable linearizations	• Real time adaption • Global operating range • Controls underactuated systems • Fault tolerant	Nonlinear adaptive controller based upon principle of Feedback Domination and Lyapunov Stability	TRL-2
BioAvert: *Autonomous Threat Response (**ATR**)*	• Computationally efficient • Robust • Context dependent • Unpredictable	• Fast response time • Fault tolerant • Accommodates multiple threats • Hard to target	Neural network threat avoidance reflex based upon the escape response of a cockroach	TRL-4
BioTarget: *Endgame Enhancement*	• Computationally efficient • Robust • Context dependent • Unpredictable	• Fast response time • Fault tolerant • Accommodates multiple threats • Hard to target	Neural network targeting reflex based upon the escape response of a cockroach	TRL-4
Optimal Path Planner: *Dynamic Replanning (**DR**)*	• Computationally efficient • Optimal • Embeds vehicle dynamics	• Fast response time • Energy efficient • Accurate	Optimal path planning based on geometric simplification for determining planar trajectories	TRL-3
MAPPER: *Dynamic Replanning (**DR**)*	• Extensible to multiple D.O.F. • Rapid near optimal • Embeds vehicle dynamics • Embeds constraints • Unpredictable	• Fast response time • Accommodates nonlinear attitude planning • Hard to target	Optimal path/attitude planning based upon Genetic Algorithm search	TRL-3
Swarm Algorithms *Multi-Vehicle Cooperation (**MVC**)*	• Computationally efficient • Robust • Distributed • Emerges behavior • Inherently parallel • Redundant	• Fast time response • Fault tolerant • No single point of failure • Can achieve complex goals • Low Cost (economies of scale)	A collection of swarm intelligence-based algorithms for group coordination	TRL-5

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