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Autonomous Systems and Robotics: 2000-2004

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October 2004

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OCTOBER 2004

20040088120

Automated fault-management in a simulated spaceflight micro-world

Lorenz, Bernd, Author; Di Nocera, Francesco, Author; Rottger, Stefan, Author; Parasuraman, Raja, Author; Aviation, space, and environmental medicine; Sep 2002; ISSN 0095-6562; Volume 73, Issue 9, 886-97; In English; Copyright; Avail: Other Sources

BACKGROUND: As human spaceflight missions extend in duration and distance from Earth, a self-sufficient crew will bear far greater onboard responsibility and authority for mission success. This will increase the need for automated fault management (FM). Human factors issues in the use of such systems include maintenance of cognitive skill, situational awareness (SA), trust in automation, and workload. This study examine the human performance consequences of operator use of intelligent FM support in interaction with an autonomous, space-related, atmospheric control system. METHODS: An expert system representing a model-base reasoning agent supported operators at a low level of automation (LOA) by a computerized fault finding guide, at a medium LOA by an automated diagnosis and recovery advisory, and at a high LOA by automate diagnosis and recovery implementation, subject to operator approval or veto. Ten percent of the experimental trials involved complete failure of FM support. RESULTS: Benefits of automation were reflected in more accurate diagnoses, shorter fault identification time, and reduced subjective operator workload. Unexpectedly, fault identification times deteriorated more at the medium than at the high LOA during automation failure. Analyses of information sampling behavior showed that offloading operators from recovery implementation during reliable automation enabled operators at high LOA to engage in fault assessment activities CONCLUSIONS: The potential threat to SA imposed by high-level automation, in which decision advisories are automatically generated, need not inevitably be counteracted by choosing a lower LOA. Instead, freeing operator cognitive resources by automatic implementation of recover plans at a higher LOA can promote better fault comprehension, so long as the automation interface is designed to support efficient information sampling.

NLM

Artificial Intelligence; Automatic Control; Life Support Systems; Management Systems; Space Flight

20040087729

Robonaut: a robot designed to work with humans in space

Bluethmann, William, Author; Ambrose, Robert, Author; Diftler, Myron, Author; Askew, Scott, Author; Huber, Eric, Author; Goza, Michael, Author; Rehnmark, Fredrik, Author; Lovchik, Chris, Author; Magruder, Darby, Author; Autonomous robots; Mar-May 2003; ISSN 0929-5593; Volume 14, Issue 2-3, 179-97; In English; Copyright; Avail: Other Sources

The Robotics Technology Branch at the NASA Johnson Space Center is developing robotic systems to assist astronauts in space. One such system, Robonaut, is a humanoid robot with the dexterity approaching that of a suited astronaut. Robonaut currently has two dexterous arms and hands, a three degree-of-freedom articulating waist, and a two degree-of-freedom neck used as a camera and sensor platform. In contrast to other space manipulator systems, Robonaut is designed to work within existing corridors and use the same tools as space walking astronauts. Robonaut is envisioned as working with astronauts, both autonomously and by teleoperation, performing a variety of tasks including, routine maintenance, setting up and breaking down worksites, assisting crew members while outside of spacecraft, and serving in a rapid response capacity.

NLM

Astronauts; Extravehicular Activity; Man Machine Systems; Robotics; Robots; Spacecrews

20040086904 NASA Ames Research Center, Moffett Field, CA, USA

Planning and Execution: The Spirit of Opportunity for Robust Autonomous Systems

Muscettola, Nicola; [2004]; In English; No Copyright; Avail: Other Sources; Abstract Only

One of the most exciting endeavors pursued by human kind is the search for life in the Solar System and the Universe

at large. NASA is leading this effort by designing, deploying and operating robotic systems that will reach planets, planet moons, asteroids and comets searching for water, organic building blocks and signs of past or present microbial life. None of these missions will be achievable without substantial advances in.the design, implementation and validation of autonomous control agents. These agents must be capable of robustly controlling a robotic explorer in a hostile environment with very limited or no communication with Earth. The talk focuses on work pursued at the NASA Ames Research center ranging from basic research on algorithm to deployed mission support systems. We will start by discussing how planning and scheduling technology derived from the Remote Agent experiment is being used daily in the operations of the Spirit and Opportunity rovers. Planning and scheduling is also used as the fundamental paradigm at the core of our research in real-time autonomous agents. In particular, we will describe our efforts in the Intelligent Distributed Execution Architecture (IDEA), a multi-agent real-time architecture that exploits artificial intelligence planning as the core reasoning engine of an autonomous agent. We will also describe how the issue of plan robustness at execution can be addressed by novel constraint propagation algorithms capable of giving the tightest exact bounds on resource consumption or all possible executions of a flexible plan.
Author
Mars Roving Vehicles; Autonomy; Solar System; Artificial Intelligence; Planning; Scheduling

20040086877 NASA Langley Research Center, Hampton, VA, USA
Predictive Multiple Model Switching Control with the Self-Organizing Map
Motter, Mark A.; [2000]; In English; No Copyright; Avail: CASI; A02, Hardcopy

A predictive, multiple model control strategy is developed by extension of self-organizing map (SOM) local dynamic modeling of nonlinear autonomous systems to a control framework. Multiple SOMs collectively model the global response of a nonautonomous system to a finite set of representative prototype controls. Each SOM provides a codebook representation of the dynamics corresponding to a prototype control. Different dynamic regimes are organized into topological neighborhoods where the adjacent entries in the codebook represent the global minimization of a similarity metric. The SOM is additionally employed to identify the local dynamical regime, and consequently implements a switching scheme that selects the best available model for the applied control. SOM based linear models are used to predict the response to a larger family of control sequences which are clustered on the representative prototypes. The control sequence which corresponds to the prediction that best satisfies the requirements on the system output is applied as the external driving signal.
Author
Nonlinear Systems; Automatic Control; Control Systems Design; Self Organizing Systems; Sequential Control; Dynamic Models

20040086148 Michigan Univ., Ann Arbor, MI
Development of a Formal Theory of Agent-Based Computing for System Evaluation and System-Design Guidance
Pollack, Martha E.; Jun. 2004; In English; Original contains color illustrations
Contract(s)/Grant(s): F30602-00-2-0621; DARPA ORDER-K550; Proj-TASK
Report No.(s): AD-A424483; AFRL-IF-RS-TR-2004-129; No Copyright; Avail: CASI; A06, Hardcopy

This report summarizes the research done on the DARPA-sponsored project on the Development of a Formal Theory 0 Agent-Based Computing for System Evaluation and System- Design Guidance, as part of the TASK program. The work was performed between September 2000 and September 2003, at the Artificial Intelligence Laboratory in the Department of Electrical Engineering and Computer Science at the University of Michigan. During the course of the project, significant advances have been made in the area of commitment strategies for autonomous agents, to enable such agents to manage sets of plans with rich temporal constraints in dynamic, uncertain environments. Specifically, we developed a set of computationally efficient techniques for both determining the consistency of sets of actions in order to decide whether or not newly introduced actions are compatible with existing commitments, and for merging new% commitments into sets of existing ones. We also developed strategies for modifying a set of commitments in response to a new, incompatible action. Finally, we applied these computational techniques to various applications of interest to the TASK effort, including e- commerce, a briefing agent', and autonomous unmanned vehicles.
DTIC
Artificial Intelligence; Computers; Systems Analysis; Systems Engineering

20040082505 Vanderbilt Univ., Nashville, TN, USA
Robot Behavior Acquisition Superposition and Composting of Behaviors Learned through Teleoperation
Peters, Richard Alan, II; July 07, 2004; In English; Original contains black and white illustrations
Contract(s)/Grant(s): NAG9-1515; No Copyright; Avail: CASI; A03, Hardcopy

Superposition of a small set of behaviors, learned via teleoperation, can lead to robust completion of a simple articulated reach-and-grasp task. Results support the hypothesis that a set of learned behaviors can be combined to generate new behaviors of a similar type. This supports the hypothesis that a robot can learn to interact purposefully with its environment through a developmental acquisition of sensory-motor coordination. Teleoperation bootstraps the process by enabling the robot to observe its own sensory responses to actions that lead to specific outcomes. A reach-and-grasp task, learned by an articulated robot through a small number of teleoperated trials, can be performed autonomously with success in the face of significant variations in the environment and perturbations of the goal. Superpositioning was performed using the Verbs and Adverbs algorithm that was developed originally for the graphical animation of articulated characters. Work was performed on Robonaut at NASA-JSC.

Author

Teleoperators; Robots; Artificial Intelligence; Autonomy; Superposition (Mathematics)

20040081158 NASA Goddard Space Flight Center, Greenbelt, MD, USA

Approach for Autonomous Control of Unmanned Aerial Vehicle Using Intelligent Agents for Knowledge Creation

Dufrene, Warren R., Jr.; 2004; In English, 24-28 Oct. 2004, Salt Lake City, UT, USA; No Copyright; Avail: Other Sources; Abstract Only

This paper describes the development of a planned approach for Autonomous operation of an Unmanned Aerial Vehicle (UAV). A Hybrid approach will seek to provide Knowledge Generation thru the application of Artificial Intelligence (AI) and Intelligent Agents (IA) for UAV control. The application of many different types of AI techniques for flight will be explored during this research effort. The research concentration will be directed to the application of different AI methods within the UAV arena. By evaluating AI approaches, which will include Expert Systems, Neural Networks, Intelligent Agents, Fuzzy Logic, and Complex Adaptive Systems, a new insight may be gained into the benefits of AI techniques applied to achieving true autonomous operation of these systems thus providing new intellectual merit to this research field. The major area of discussion will be limited to the UAV. The systems of interest include small aircraft, insects, and miniature aircraft. Although flight systems will be explored, the benefits should apply to many Unmanned Vehicles such as: Rovers, Ocean Explorers, Robots, and autonomous operation systems. The flight system will be broken down into control agents that will represent the intelligent agent approach used in AI. After the completion of a successful approach, a framework of applying a Security Overseer will be added in an attempt to address errors, emergencies, failures, damage, or over dynamic environment. The chosen control problem was the landing phase of UAV operation. The initial results from simulation in FlightGear are presented.

Author

Artificial Intelligence; Automatic Control; Pilotless Aircraft; Approach Control; Control Systems Design

20040081136 NASA Ames Research Center, Moffett Field, CA, USA

Explanation Constraint Programming for Model-based Diagnosis of Engineered Systems

Narasimhan, Sriram; Brownston, Lee; Burrows, Daniel; 2004; In English, 6-13 Mar. 2003, Big Sky, MT, USA; Original contains black and white illustrations

Report No.(s): IEEE-AC-Paper 1139; No Copyright; Avail: CASI; A02, Hardcopy

We can expect to see an increase in the deployment of unmanned air and land vehicles for autonomous exploration of space. In order to maintain autonomous control of such systems, it is essential to track the current state of the system. When the system includes safety-critical components, failures or faults in the system must be diagnosed as quickly as possible, and their effects compensated for so that control and safety are maintained under a variety of fault conditions. The Livingstone fault diagnosis and recovery kernel and its temporal extension L2 are examples of model-based reasoning engines for health management. Livingstone has been shown to be effective, it is in demand, and it is being further developed. It was part of the successful Remote Agent demonstration on Deep Space One in 1999. It has been and is being utilized by several projects involving groups from various NASA centers, including the In Situ Propellant Production (ISPP) simulation at Kennedy Space Center, the X-34 and X-37 experimental reusable launch vehicle missions, Techsat-21, and advanced life support projects. Model-based and consistency-based diagnostic systems like Livingstone work only with discrete and finite domain models. When quantitative and continuous behaviors are involved, these are abstracted to discrete form using some mapping. This mapping from the quantitative domain to the qualitative domain is sometimes very involved and requires the design of highly sophisticated and complex monitors. We propose a diagnostic methodology that deals directly with quantitative models and behaviors, thereby mitigating the need for these sophisticated mappings. Our work brings together ideas from model-based diagnosis systems like Livingstone and concurrent constraint programming concepts. The system uses explanations derived from the propagation of quantitative constraints to generate conflicts. Fast conflict generation algorithms are used to generate

and maintain multiple candidates whose consistency can be tracked across multiple time steps.
Author
Automatic Control; Algorithms; Error Analysis; Computer Programs

20040079373 NASA Goddard Space Flight Center, Greenbelt, MD, USA
Asteroid Exploration with Autonomic Systems
Truszkowski, Walt; Rash, James; Rouff, Christopher; Hinchey, Mike; [2004]; In English, 24-27 May 2004, Brno, Czech Republic; No Copyright; Avail: CASI; A02, Hardcopy

NASA is studying advanced technologies for a future robotic exploration mission to the asteroid belt. The prospective ANTS (Autonomous Nano Technology Swarm) mission comprises autonomous agents including worker agents (small spacecra3) designed to cooperate in asteroid exploration under the overall authoriq of at least one ruler agent (a larger spacecraft) whose goal is to cause science data to be returned to Earth. The ANTS team (ruler plus workers and messenger agents), but not necessarily any individual on the team, will exhibit behaviors that qualify it as an autonomic system, where an autonomic system is defined as a system that self-reconfigures, self-optimizes, self-heals, and self-protects. Autonomic system concepts lead naturally to realistic, scalable architectures rich in capabilities and behaviors. In-depth consideration of a major mission like ANTS in terms of autonomic systems brings new insights into alternative definitions of autonomic behavior. This paper gives an overview of the ANTS mission and discusses the autonomic properties of the mission.
Author
Asteroid Belts; Autonomy; Nanotechnology; Space Missions; Artificial Intelligence; Spacecraft Instruments

20040077084 NASA Ames Research Center, Moffett Field, CA, USA
Verification and Validation of Autonomous Systems
Pecheur, Charles; Research and Technology 1999; December 2000, 135; In English; No Copyright; Avail: CASI; A01, Hardcopy

Ames researchers, in collaboration with Carnegie Mellon University (CMU), are developing technologies for rigorously verifying requirements for software models used in autonomous controllers for space devices. These models describe the different components and failure modes of a complex device such as a spacecraft. They are used by the Livingstone fault recovery system to detect, diagnose, and recover from failures by comparing the observed condition of the spacecraft with the one predicted by the model.
Derived from text
Failure Modes; Technology Assessment; Computer Programs; Proving

20040074295 NASA, Washington, DC, USA
The Lunar L1 Gateway Concept: Supporting Future Major Space Science Facilities
Thronson, H.; Geffre, J.; Prusha, S.; Caroff, L.; Weisbin, C., et al.; New Concepts for Far-Infrared and Submillimeter Space Astronomy; April 2004, 259-263; In English; No Copyright; Avail: CASI; A01, Hardcopy

We report here on a series of ongoing studies to evaluate alternative architectures for future space science facilities and how robots, humans, and autonomous systems might be optimally used to support them. This presentation outlines one scenario -- a ‘Gateway’ at the Earth-Moon L1 point for supporting multiple options beyond Low Earth Orbit -- plus our process for evaluating human/robotic activities to construct telescopes.
Derived from text
Evaluation; Architecture (Computers); Support Systems

20040068278 NASA Ames Research Center, Moffett Field, CA, USA
Identifying Model-Based Reconfiguration Goals through Functional Deficiencies
Benazera, Emmanuel; Trave-Massuyes, Louise; [2004]; In English, 23-25 Jun. 2004, Carcassonne, France
Report No.(s): Rept-1; No Copyright; Avail: CASI; A02, Hardcopy

Model-based diagnosis is now advanced to the point autonomous systems face some uncertain and faulty situations with success. The next step toward more autonomy is to have the system recovering itself after faults occur, a process known as model-based reconfiguration. After faults occur, given a prediction of the nominal behavior of the system and the result of the diagnosis operation, this paper details how to automatically determine the functional deficiencies of the system. These deficiencies are characterized in the case of uncertain state estimates. A methodology is then presented to determine the

reconfiguration goals based on the deficiencies. Finally, a recovery process interleaves planning and model predictive control to restore the functionalities in prioritized order.
Author
Failure Analysis; System Failures; Automatic Control; Fault Detection

20040062101 NASA Goddard Space Flight Center, Greenbelt, MD, USA
From Present Surveying to Future Prospecting of the Asteroid Belt
Clark, P. E.; Curtis, S. A.; Rilee, M.; Cheung, C.; Lunar and Planetary Science XXXV: Asteroids, Meteors, Comets; 2004; In English
Contract(s)/Grant(s): NAS5-99189; ITMI-0299189EER; Copyright; Avail: CASI; A01, Hardcopy; Available from CASI on CD-ROM only as part of the entire parent document

We have applied a future mission architecture, the Autonomous Nano-Technology Swarm (ANTS), to a proposed mission for in situ survey, or prospecting, of the asteroid belt, the Prospecting Asteroid Mission (PAM) as part of a NASA 2003 Revolutionary Aerospace Concept (RASC) study. ANTS architecture builds on and advances recent trends in robotics, artificial intelligence, and materials processing to minimize costs and maximize effectiveness of space operations. PAM and other applications have been proposed for the survey of inaccessible, high surface area populations of great interest from the standpoint of resources and/or solar system origin. The ANTS architecture is inspired by the success of social insect colonies, a success based on the division of labor within the colonies in two key ways: 1) within their specialties, individual specialists generally outperform generalists, and 2) with sufficiently efficient social interaction and coordination, the group of specialists generally outperforms the group of generalists. Thus systems designed as ANTS are built from potentially very large numbers of highly autonomous, yet socially interactive, elements. The architecture is self-similar in that elements and sub-elements of the system may also be recursively structured as ANTS on scales ranging from microscopic to interplanetary distances. Here, we analyze requirements for the mission application at the low gravity target end of the spectrum, the Prospecting Asteroid Mission (PAM), and for specialized autonomous operations which would support this mission. ANTS as applied to PAM involves the activities of hundreds of individual specialist 'sciencecraft'. Most of them, called Workers, carry and operate eight to nine different scientific instruments, as listed in the table, including spectrometers, ranging and radio science devices, and imagers. The remaining specialists, Messenger/Rulers, provide communication and coordination functions among specialists operating autonomously as individuals, team members, and subswarms.
Author (revised)
Artificial Intelligence; Architecture (Computers); Nanotechnology; Spacecraft Control

20040059204 Office of Naval Research, Arlington, VA
Distributed Machine Intelligence for Automated Survivability
Drew, Katherine F.; Scheidt, David; Mar. 2004; In English; Original contains color illustrations
Report No.(s): AD-A422118; No Copyright; Avail: CASI; A02, Hardcopy

Future Naval platforms face new dynamic operational scenarios that demand more flexible performance. At the same time, reduced manning and lower total ownership costs are now major design and acquisition objectives. Improved warfighting capability can be achieved by reducing vulnerability to damage and failure events. Rapid system recovery from unanticipated damage using current doctrine and practice conflicts with today's reduced manning objectives. Decentralized ship system architectures and agent-based technologies promise to enable the Navy to improve rapid system recovery and assist in meeting these affordability challenges. Decentralization of systems and resources improves both ship survivability and fight through capability. This is accomplished through rapid sensing and response and dynamic reconfiguration, which results in improved continuity of service of ship systems. Embedded intelligence at the component level insures rapid, effective autonomous reaction and response to local fault conditions. Agent-based technologies are utilized to provide autonomous cooperation between sensors and actuators, in which elements reason and react locally while achieving global objectives through agent-to-agent communications. While intelligent decision making is performed locally by autonomous agents, the sailor will direct these agents through comprehensive supervisory control with improved on-demand situational awareness. When fielded, these systems will provide increased situational awareness, increased fight through capability, and improved damage control. This paper describes Navy Science and Technology projects currently underway in academia, industry, and Navy laboratories to achieve these goals. (14 figures, 16 refs.)
DTIC
Artificial Intelligence; Failure; Manpower; System Failures

20040059179 Space and Naval Warfare Systems Command, San Diego, CA
Autonomy and Intelligence - A Question of Definitions
Blackburn, Michael R.; May 2002; In English
Report No.(s): AD-A422063; No Copyright; Avail: CASI; A01, Hardcopy

It is tempting to call a mechanism that works by itself autonomous. The common dictionary definition of autonomy supports this temptation. According to Webster's Ninth New College Dictionary, autonomy is 'the quality or state of being self-governing'. But governance implies more than simple perpetual motion. Does the earth's rotation around the sun constitute an autonomous trajectory? Probably we would not commonly think so. What if an asteroid suddenly appeared in the earth's path? What would the earth do about it? Would the earth modify its trajectory and avoid the impending collision? Not likely. A collision would confirm for us that the earth was not autonomous. Now take a laboratory robot equipped with a SONAR array. The output of the SONAR array could be used to steer the robot away from looming obstacles, thus avoiding many potential collisions, Would we then say that the robot was autonomous? Many robotics developers, based on the titles and texts of their documents, do indeed say that obstacle avoidance is an autonomous behavior. Those very same robots, however, usually have an on-off switch. When that switch is in the off position, the robot cannot avoid a looming object and a serious and destructive collision is likely to occur. The on state of the robot could also be compromised by depletion of the robot's energy reserve, again making it vulnerable to environmental calamities. Something similar could happen to us when we are asleep or are otherwise not paying particular attention. Should we say then that autonomy is a state-dependent attribute?
DTIC
Autonomy; Intelligence

20040055653 Michigan Univ., Ann Arbor, MI
Multilevel Coordination Mechanisms for Real-Time Autonomous Agents
Durfee, Edmund H.; Feb. 2004; In English; Original contains color illustrations
Contract(s)/Grant(s): F30602-98-2-0142; DARPA ORDER-J356; Proj-AGEN
Report No.(s): AD-A421748; AFRL-IF-RS-TR-2004-33; No Copyright; Avail: CASI; A05, Hardcopy

This report summarizes the research and development efforts performed in the DARPA-sponsored project in Multilevel Coordination Mechanisms for Real-Time Autonomous Agents, as part of the DARPA Control of Agent Based Systems (CoABS) program. The work was performed from May of 1998 to April of 2003. During the course of the project, significant advances have been made in the area of plan-based control and coordination of semi-autonomous agents. Specifically, techniques for modeling and coordinating agents based on hierarchical representations of their plans have been shown to be efficient and effective in enabling multiple agents, each with its own sophisticated plans and objectives, to predict and resolve unintended conflicts between their operations, as well as to anticipate and exploit opportunities for cooperation. The basic research results have been implemented into a Multilevel Coordination Agent (MCA) that operates on the CoABS Grid. The MCA has been demonstrated as part of the Coalition Agents Experiment (CoAX), culminating in the October 2002 demonstration at the Naval Warfare Development Center in Newport, RI.
DTIC
Adaptation; Autonomy; Coordination; Real Time Operation

20040055652 Honeywell Technology Center, Minneapolis, MN
MASA-CIRCA: Multi-Agent Self-Adaptive Control for Mission-Critical Systems
Musliner, David J.; Goldman, Robert P.; Pelican, Michael J.; Drebsbach, Kurt D.; Feb. 2004; In English; Original contains color illustrations
Contract(s)/Grant(s): F30602-00-C-0017; DARPA ORDER-J124; Proj-J124
Report No.(s): AD-A421747; AFRL-IF-RS-TR-2004-32; No Copyright; Avail: CASI; A04, Hardcopy

The goal of this contract effort was to begin extending the Cooperative Intelligent Real-Time Control Architecture (CIRCA) with abilities to automatically monitor its own performance and adapt in real-time, forming Multi- Agent Self Adaptive (MASA) CIRCA. CIRCA is a coarse-grained architecture designed to control autonomous systems which require both intelligent, deliberative planning activity and highly reliable, hard real-time reaction to safety threats. The MASA-CIRCA project extended this architecture with the ability to reason accurately about its own real-time behavior, and adapt that behavior in response to performance feedback. Major issues investigated during this project include formally verifying real-time control plans, dynamically decomposing long-term plans into sub goals, and building real- time control plans using probabilistic information to reason about most-likely states first. We provided digital video demonstrations of these features, with

MASA-CIRCA operating in a combat oriented multi-aircraft flight simulation domain.
DTIC
Adaptive Control; Self Adaptive Control Systems

20040043677 NASA Ames Research Center, Moffett Field, CA, USA
Simulation-Based Verification of Autonomous Controllers via Livingstone PathFinder
Lindsey, A. E.; Pecheur, Charles; [2004]; In English, [2004]; No Copyright; Avail: CASI; A03, Hardcopy

AI software is often used as a means for providing greater autonomy to automated systems, capable of coping with harsh and unpredictable environments. Due in part to the enormous space of possible situations that they aim to addrs, autonomous systems pose a serious challenge to traditional test-based verification approaches. Efficient verification approaches need to be perfected before these systems can reliably control critical applications. This publication describes Livingstone PathFinder (LPF), a verification tool for autonomous control software. LPF applies state space exploration algorithms to an instrumented testbed, consisting of the controller embedded in a simulated operating environment. Although LPF has focused on NASA s Livingstone model-based diagnosis system applications, the architecture is modular and adaptable to other systems. This article presents different facets of LPF and experimental results from applying the software to a Livingstone model of the main propulsion feed subsystem for a prototype space vehicle.
Author
Autonomy; Controllers; Architecture (Computers); Simulation; Automatic Control; Algorithms; Proving

20040035804 Nova Southeastern Univ., Fort Lauderdale, FL, USA
Application of Artificial Intelligence Techniques in Uninhabitated Aerial Vehicle Flight
Dufrene, Warren R., Jr.; [2003]; In English, 12-16 Oct. 2003, Indianapolis, IN, USA; Original contains black and white illustrations; Copyright; Avail: CASI; A02, Hardcopy

This paper describes the development of an application of Artificial Intelligence (AI) for Unmanned Aerial Vehicle (UAV) control. The project was done as part of the requirements for a class in AI at NOVA southeastern University and a beginning project at NASA Wallops Flight Facility for a resilient, robust, and intelligent UAV flight control system. A method is outlined which allows a base level application for applying an Artificial Intelligence method, Fuzzy Logic, to aspects of Control Logic for UAV flight. One element of UAV flight, automated altitude hold, has been implemented and preliminary results displayed.
Author
Artificial Intelligence; Control Systems Design; Pilotless Aircraft; Autonomy

20040031515 Vanderbilt Univ., Nashville, TN, USA
Robot Acquisition of Active Maps Through Teleoperation and Vector Space Analysis
Peters, Richard Alan, II; October 14, 2003; In English
Contract(s)/Grant(s): NAG9-1428
Report No.(s): Rept-4-22-420-3504; No Copyright; Avail: CASI; A03, Hardcopy

The work performed under this contract was in the area of intelligent robotics. The problem being studied was the acquisition of intelligent behaviors by a robot. The method was to acquire action maps that describe tasks as sequences of reflexive behaviors. Action maps (a.k.a. topological maps) are graphs whose nodes represent sensorimotor states and whose edges represent the motor actions that cause the robot to proceed from one state to the next. The maps were acquired by the robot after being teleoperated or otherwise guided by a person through a task several times. During a guided task, the robot records all its sensorimotor signals. The signals from several task trials are partitioned into episodes of static behavior. The corresponding episodes from each trial are averaged to produce a task description as a sequence of characteristic episodes. The sensorimotor states that indicate episode boundaries become the nodes, and the static behaviors, the edges. It was demonstrated that if compound maps are constructed from a set of tasks then the robot can perform new tasks in which it was never explicitly trained.
Author
Robotics; Teleoperators; Vector Spaces; Artificial Intelligence; Topology

20040029214

The expanding venue and persistence of planetary mobile robotic exploration - New technology concepts for Mars and beyond

Schenker, Paul S.; Elfes, Alberto; Hall, Jeffrey L.; Huntsberger, Terry L.; Jones, Jack A.; Wilcox, Brian H.; Zimmerman, Wayne F.; Proceedings of SPIE - The International Society for Optical Engineering; 2003; ISSN 0277-786X; Volume 5267, p. 43-59; In English; Intelligent Robots and Computer Vision XXI: Algorithms, Techniques, and Active Vision, Oct. 28-29, 2003, Providence, RI, USA; Copyright; Avail: Other Sources

The domain and technology of mobile robotic space exploration are fast moving from brief visits to benign Mars surface regions to more challenging terrain and sustained exploration. Further, the overall venue and concept of space robotic exploration are expanding - ‘from flatland to 3D’ - from the surface, to sub-surface and aerial theatres on disparate large and small planetary bodies, including Mars, Venus, Titan, Europa, and small asteroids. These new space robotic system developments are being facilitated by concurrent, synergistic advances in software and hardware technologies for robotic mobility, particularly as regard on-board system autonomy and novel thermo-mechanical design. We outline these directions of emerging mobile science mission interest and technology enablement, including illustrative work at JPL on terrain-adaptive and multi-robot cooperative rover systems, aerobotic mobility, and subsurface ice explorers.

EI

Aerospace Sciences; Artificial Intelligence; Computer Programs; Mobility; Robots

20030112640 Naval Postgraduate School, Monterey, CA

Interoperability, Data Control and Battlespace Visualization using XML, XSLT and X3D

Neushul, James D.; Sep. 2003; In English; Original contains color illustrations

Report No.(s): AD-A418222; No Copyright; Avail: CASI; A09, Hardcopy

This work represents the realization of Network-Centric goals of interoperability, information management, systems integration and cohesive battlespace visualization using networked computer technology. The application of structured data methodologies using the Extensible Markup Language (XML) allows organizations and systems to exchange and process battlespace information cooperatively. The practical application of this technology is demonstrated. Governance of information systems using structured data and the rejection of proprietary, application specific solutions is a leadership responsibility that is defined as Data Control. XML is presented as a leadership control measure that can be used to achieve Network-Centricity on the battlefield. The fundamental principles of XML application development are presented in the context of warfighting. Exemplars address a cross-section of battlespace applications. The visualization of the physical battlefield is demonstrated with network delivered 3D terrain views. Geodesy and position reporting is addressed using an XML defined data structure to enforce interoperability. An XML expression of the Battlespace Generic Hub is applied to joint and multilateral interoperability and information exchange. An approach to the effective employment of multiple different, but cooperative, autonomous systems in the battlespace uses XML to define parameters that determine artificial intelligence multi agent behavior and environmental factors. This thesis combines a critical analysis of the priorities of Network-Centricity and interoperability with practical and functional exemplars that demonstrate the efficacy of extensible architectures. The pragmatic approach is directed at the warfighter, and leadership challenges are identified.

DTIC

Document Markup Languages; Information Management; Interoperability; Scientific Visualization; Systems Integration

20030112585 Erica Inc, Charlottesville VA

Machine Detection of Operationally Significant Cognitive Events for C4ISR

Lankford, Christopher P.; Jun. 22, 2003; In English; Original contains color illustrations

Contract(s)/Grant(s): DAAH01-03-RO58

Report No.(s): AD-A418055; TR-ECROOO2Z; No Copyright; Avail: CASI; A03, Hardcopy

A machine capable of detecting cognitively significant events in its user could prevent potential disaster by signaling to commanders that a soldier is under high stress. This project seeks to establish that these cognitive events can be captured in an autonomous fashion through the use of an eye-tracking system. The experiment in this study requires subjects to find a particular person hidden in a sequence of complex images that contain crowded scenes of different people performing different activities. Project tasks included creating the test stimulus, running test subjects, and analyzing the captured data. This analysis indicates that a pupil dilation increase during a period of prolonged fixation occurs when the test subject finds the target person in the stimulus. Additional testing is necessary to validate this finding in a more realistic setting, but this study represents a

preliminary step in developing a machine capable of autonomously detecting cognitive events.
DTIC
Autonomy; Man Machine Systems

20030111362 NASA Goddard Space Flight Center, Greenbelt, MD, USA
Exploring with PAM: Prospecting ANTS Missions for Solar System Surveys
Clark, P. E.; Rilee, M. L.; Curtis, S. A.; Lunar and Planetary Science XXXIV; 2003; In English; Copyright; Avail: CASI; A01, Hardcopy; Available from CASI on CD-ROM only as part of the entire parent document

ANTS (Autonomous Nano-Technology Swarm), a large (1000 member) swarm of nano to picoclass (10 to 1 kg) totally autonomous spacecraft, are being developed as a NASA advanced mission concept. ANTS, based on a hierarchical insect social order, use an evolvable, self-similar, hierarchical neural system in which individual spacecraft represent the highest level nodes. ANTS uses swarm intelligence attained through collective, cooperative interactions of the nodes at all levels of the system. At the highest levels this can take the form of cooperative, collective behavior among the individual spacecraft in a very large constellation. The ANTS neural architecture is designed for totally autonomous operation of complex systems including spacecraft constellations. The ANTS (Autonomous Nano Technology Swarm) concept has a number of possible applications. A version of ANTS designed for surveying and determining the resource potential of the asteroid belt, called PAM (Prospecting ANTS Mission), is examined here.
Derived from text
Autonomy; Nanotechnology; NASA Space Programs; Space Missions; Solar System

20030108279 George Mason Univ., Fairfax, VA
Topics in Evolutionary Computation
Grefenstette, John J.; Jun. 13, 2003; In English
Contract(s)/Grant(s): N00173-00-1-G013; Proj-02-C176-02
Report No.(s): AD-A417080; No Copyright; Avail: CASI; A03, Hardcopy

Autonomous robotic systems are expected to play a significant role in a wide range of areas including surveillance, deep space and undersea exploration and construction, urban search and recovery, mining, and hazardous waste cleanup. Systems that need to operate for extended periods of time out of range of human control should be adaptable to changing or unexpected conditions. This work examines some possible designs for such adaptive autonomous robotics systems, focusing on the adaptation to component failures in autonomous mobile robots. Adaptation is defined as the ability to continue to perform a task, perhaps at a degraded level, despite the loss of some of the robots original sensor and effector capabilities. The project addresses the problem of adaptation through an approach called Continuous Embedded Learning. Simulation and experimental results are reported.
DTIC
Autonomy; Robotics; Artificial Intelligence; Machine Learning

20030107270 NASA Ames Research Center, Moffett Field, CA, USA
Time-Extended Payoffs for Collectives of Autonomous Agents
Tumer, Kagan; Agogino, Adrian K.; May 02, 2002; In English; Copyright; Avail: CASI; A03, Hardcopy

A collective is a set of self-interested agents which try to maximize their own utilities, along with a a well-defined, time-extended world utility function which rates the performance of the entire system. In this paper, we use theory of collectives to design time-extended payoff utilities for agents that are both aligned with the world utility, and are 'learnable', i.e., the agents can readily see how their behavior affects their utility. We show that in systems where each agent aims to optimize such payoff functions, coordination arises as a byproduct of the agents selfishly pursuing their own goals. A game theoretic analysis shows that such payoff functions have the net effect of aligning the Nash equilibrium, Pareto optimal solution and world utility optimum, thus eliminating undesirable behavior such as agents working at cross-purposes. We then apply collective-based payoff functions to the token collection in a gridworld problem where agents need to optimize the aggregate value of tokens collected across an episode of finite duration (i.e., an abstracted version of rovers on Mars collecting scientifically interesting rock samples, subject to power limitations). We show that, regardless of the initial token distribution, reinforcement learning agents using collective-based payoff functions significantly outperform both natural extensions of single agent algorithms and global reinforcement learning solutions based on 'team games'
Author
Autonomy; Algorithms; Distributed Parameter Systems; Artificial Intelligence

20030105757 Draper (Charles Stark) Lab., Inc., Cambridge, MA, USA

The Earth Phenomena Observing System: Intelligent Autonomy for Satellite Operations

Ricard, Michael; Abramson, Mark; Carter, David; Kolitz, Stephan; Intelligent Systems for Aeronautics; June 2003, 3-1 - 3-12; In English; Original contains color illustrations

Contract(s)/Grant(s): NAS3-00163; Copyright; Avail: CASI; C01, CD-ROM; A03, Hardcopy; Available on CD-ROM as part of the entire parent document

Earth monitoring systems of the future may include large numbers of inexpensive small satellites, tasked in a coordinated fashion to observe both long term and transient targets. For best performance, a tool which helps operators optimally assign targets to satellites will be required. We present the design of algorithms developed for real-time optimized autonomous planning of large numbers of small single-sensor Earth observation satellites. The algorithms will reduce requirements on the human operators of such a system of satellites, ensure good utilization of system resources, and provide the capability to dynamically respond to temporal terrestrial phenomena. Our initial real-time system model consists of approximately 100 satellites and large number of points of interest on Earth (e.g., hurricanes, volcanoes, and forest fires) with the objective to maximize the total science value of observations over time. Several options for calculating the science value of observations include the following: 1) total observation time, 2) number of observations, and the 3) quality (a function of e.g., sensor type, range, slant angle) of the observations. An integrated approach using integer programming, optimization and astrodynamics is used to calculate optimized observation and sensor tasking plans.

Author

Artificial Satellites; Earth Observations (From Space); Satellite Control; Artificial Intelligence; Autonomous Navigation

20030105749 Dassault Aviation, Saint-Cloud, France

A Multi-Agent Approach for Complex System Design

Degirmenciyan-Cartault, Irene; Intelligent Systems for Aeronautics; June 2003, 5-1 - 5-13; In English; Copyright; Avail: CASI; A03, Hardcopy; Available from CASI on CD-ROM only as part of the entire parent document

Multi-agent systems that arose from research in Distributed Artificial Intelligence are now considered as a new paradigm to design and model complex systems. The design of complex systems seems to be more intuitive with cognitive agents because the designer works at a high level of abstraction where the agent is an important granularity entity with aspects of calculation, reasoning and control which make it quasi autonomous. After a brief overview of the required notions to understand the multi-agent systems' domain, we describe the JACK agent-oriented environment on top of which we are developing the SCALA environment that provides a multiagent-based methodology and tool for the design of complex systems. In SCALA, the global behaviour (i.e. its goal) of the system is modelled through a functional approach based on the definition of a graph of dependencies between the basic behaviours (i.e. tasks to accomplish to achieve a goal). The definition of this graph provides the necessary knowledge to manage cooperation between the agents and to plan reactively their activities when new events occur and when they have to reorganize themselves.

Author

Artificial Intelligence; Autonomy; Complex Systems; Systems Engineering; Distributed Processing

20030070529

Biologically inspired robots as artificial inspectors

FROM; Proceedings of SPIE - The International Society for Optical Engineering; 2002; ISSN 0277-786X; Volume 4702, p. 41-48; In English; Smart Nondestructive Evaluation for Health Monitoring of Structural and Biological Systems, Mar. 18-19, 2002, San Diego, CA, USA; Copyright; Avail: Other Sources

Imagine an inspector conducting an NDE on an aircraft where you notice something is different about him - he is not real but rather he is a robot. Your first reaction would probably be to say 'it's unbelievable but he looks real' just as you would react to an artificial flower that is a good imitation. This science fiction scenario could become a reality at the trend in the development of biologically inspired technologies, and terms like artificial intelligence, artificial muscles, artificial vision and numerous others are increasingly becoming common engineering tools. For many years, the trend has been to automate processes in order to increase the efficiency of performing redundant tasks where various systems have been developed to deal with specific production line requirements. Realizing that some parts are too complex or delicate to handle in small quantities with a simple automatic system, robotic mechanisms were developed. Aircraft inspection has benefited from this evolving technology where manipulators and crawlers are developed for rapid and reliable inspection. Advancement in robotics towards making them autonomous and possibly look like human, can potentially address the need to inspect structures that are beyond the capability of today's technology with configuration that are not predetermined. The operation of these robots may take place at harsh or hazardous environments that are too dangerous for human presence. Making such robots is becoming

increasingly feasible and in this paper the state of the art will be reviewed.
EI
Artificial Intelligence; Computer Vision; Nondestructive Tests; Robots

20030068519 Research Inst. for Advanced Computer Science, Moffett Field, CA, USA
[Activities of Research Institute for Advanced Computer Science]
Gross, Anthony R., Technical Monitor; Leiner, Barry M.; December 2001; In English; Original contains black and white illustrations
Contract(s)/Grant(s): NCC2-1006
Report No.(s): RIACS-TR-AR-01; Copyright; Avail: CASI; A08, Hardcopy

The Research Institute for Advanced Computer Science (RIACS) carries out basic research and technology development in computer science, in support of the National Aeronautics and Space Administrations missions. RIACS is located at the NASA Ames Research Center, Moffett Field, California. RIACS research focuses on the three cornerstones of IT research necessary to meet the future challenges of NASA missions: 1. Automated Reasoning for Autonomous Systems Techniques are being developed enabling spacecraft that will be self-guiding and self-correcting to the extent that they will require little or no human intervention. Such craft will be equipped to independently solve problems as they arise, and fulfill their missions with minimum direction from Earth. 2. Human-Centered Computing Many NASA missions require synergy between humans and computers, with sophisticated computational aids amplifying human cognitive and perceptual abilities. 3. High Performance Computing and Networking Advances in the performance of computing and networking continue to have major impact on a variety of NASA endeavors, ranging from modeling and simulation to analysis of large scientific datasets to collaborative engineering, planning and execution. In addition, RIACS collaborates with NASA scientists to apply IT research to a variety of NASA application domains. RIACS also engages in other activities, such as workshops, seminars, visiting scientist programs and student summer programs, designed to encourage and facilitate collaboration between the university and NASA IT research communities.
Derived from text
Automatic Control; Networks; Human-Computer Interface

20030068144 NASA Glenn Research Center, Cleveland, OH, USA
Envisioning a 21st Century, National, Spacecraft Servicing and Protection Infrastructure and Demand Potential: A Logical Development of the Earth Orbit Economy
Horsham, Gary A.; July 2003; In English; Original contains color and black and white illustrations
Contract(s)/Grant(s): WBS-22-251-30-12
Report No.(s): NASA/TM-2003-212462; NAS 1.15:212462; E-14000; No Copyright; Avail: CASI; A05, Hardcopy

The modern world is extremely dependent on thin strings of several hundred civil, military, and commercial spacecraft/satellites currently stationed in space. They provide a steady stream of commerce, defense, and knowledge data. This dependency will in all likelihood increase significantly during this century. A major disruption of any kind in these essential systems and networks could be socially, economically, and politically catastrophic, on a global scale. The development of a space-based, robotic services economy could be useful in mitigating this growing risk, from an efficiency and security standpoint. This paper attempts to suggest what makes sense to invest in next for the logical, economic development of Earth orbit i.e., after ISS completion. It expands on the results of an advanced market research and analysis study that sampled the opinions of several satellite industry executives and presents these results within a broad policy context. The concept of a spacecraft carrier that serves as the nucleus of a national, space-based or on-orbit, robotic services infrastructure is introduced as the next logical step for USA leadership in space. This is viewed as a reasonable and appropriate followon to the development of ELVs and satellites in the 1950s and 1960s, the Space Shuttle/PRLV in the 1970s and 1980s, and the International Space Station (ISS) in the 1980s, 1990s and 2000s. Large-scale experience in LEO-to-GEO spacecraft/satellite servicing and protection by robotic means is assumed to be an indispensable prerequisite or stepping-stone toward the development and preservation of the large scientific exploration facilities that are envisioned by NASA for operation beyond GEO. A balanced, return on national investment (RONI) strategy for space, focused on the provision of enhanced national/homeland security for increased protection, national economic/industrial expansion for increased revenue, and national scientific exploration for increased knowledge is recommended as the next strong, irrepressible goal toward realizing and achieving the official NASA vision and mission.
Author
Robotics; Spacecraft Maintenance; Orbital Servicing

20030066325 NASA Ames Research Center, Moffett Field, CA, USA

Automated Reasoning CICT Program/Intelligent Systems Project ATAC-PRT Review

Morris, Robert; Smith, Ben; May 20, 2003; In English; Original contains black and white illustrations; No Copyright; Avail: CASI; A03, Hardcopy

An overview is presented of the Automated Reasoning CICT Program/Intelligent Systems project. Automated reasoning technology will help NASA missions by increasing the amount of science achieved, ensuring safety of spacecraft and surface explorers, and by enabling more robust mission operations.

CASI

Decision Support Systems; Knowledge Bases (Artificial Intelligence); Automatic Control; Computer Programs

20030064114 Research Inst. for Advanced Computer Science, Moffett Field, CA, USA

Research Institute for Advanced Computer Science

Gross, Anthony R., Technical Monitor; Leiner, Barry M.; [2000]; In English; Original contains black and white illustrations Contract(s)/Grant(s): NCC2-1006; No Copyright; Avail: CASI; A05, Hardcopy

The Research Institute for Advanced Computer Science (RIACS) carries out basic research and technology development in computer science, in support of the National Aeronautics and Space Administration's missions. RIACS is located at the NASA Ames Research Center. It currently operates under a multiple year grant/cooperative agreement that began on October 1, 1997 and is up for renewal in the year 2002. Ames has been designated NASA's Center of Excellence in Information Technology. In this capacity, Ames is charged with the responsibility to build an Information Technology Research Program that is preeminent within NASA. RIACS serves as a bridge between NASA Ames and the academic community, and RIACS scientists and visitors work in close collaboration with NASA scientists. RIACS has the additional goal of broadening the base of researchers in these areas of importance to the nation's space and aeronautics enterprises. RIACS research focuses on the three cornerstones of information technology research necessary to meet the future challenges of NASA missions: (1) Automated Reasoning for Autonomous Systems. Techniques are being developed enabling spacecraft that will be self-guiding and self-correcting to the extent that they will require little or no human intervention. Such craft will be equipped to independently solve problems as they arise, and fulfill their missions with minimum direction from Earth; (2) Human-Centered Computing. Many NASA missions require synergy between humans and computers, with sophisticated computational aids amplifying human cognitive and perceptual abilities; (3) High Performance Computing and Networking. Advances in the performance of computing and networking continue to have major impact on a variety of NASA endeavors, ranging from modeling and simulation to data analysis of large datasets to collaborative engineering, planning and execution. In addition, RIACS collaborates with NASA scientists to apply information technology research to a variety of NASA application domains. RIACS also engages in other activities, such as workshops, seminars, and visiting scientist programs, designed to encourage and facilitate collaboration between the university and NASA information technology research communities.

Derived from text

Artificial Intelligence; Machine Learning; Human-Computer Interface; Supercomputers; Information Systems; Computer Networks; Systems Engineering; Software Engineering

20030064070 Vanderbilt Univ., Nashville, TN, USA

Sensory Motor Coordination in Robonaut

Peters, Richard Alan, II; National Aeronautics and Space Administration (NASA)/American Society of Engineering Education (ASEE) Summer Faculty Fellowship Program - 2000; March 2003, 31-1 - 13-12; In English; Original contains black and white illustrations

Contract(s)/Grant(s): NAG9-867; No Copyright; Avail: CASI; A03, Hardcopy

As a participant of the year 2000 NASA Summer Faculty Fellowship Program, I worked with the engineers of the Dexterous Robotics Laboratory at NASA Johnson Space Center on the Robonaut project. The Robonaut is an articulated torso with two dexterous arms, left and right five-fingered hands, and a head with cameras mounted on an articulated neck. This advanced space robot, now driven only teleoperatively using VR gloves, sensors and helmets, is to be upgraded to a thinking system that can find, interact with and assist humans autonomously, allowing the Crew to work with Robonaut as a (junior) member of their team. Thus, the work performed this summer was toward the goal of enabling Robonaut to operate autonomously as an intelligent assistant to astronauts. Our underlying hypothesis is that a robot can develop intelligence if it learns a set of basic behaviors (i.e., reflexes - actions tightly coupled to sensing) and through experience learns how to sequence these to solve problems or to accomplish higher-level tasks. We describe our approach to the automatic acquisition of basic behaviors as learning sensory-motor coordination (SMC). Although research in the ontogenesis of animals development from the time of conception) supports the approach of learning SMC as the foundation for intelligent,

autonomous behavior, we do not know whether it will prove viable for the development of autonomy in robots. The first step in testing the hypothesis is to determine if SMC can be learned by the robot. To do this, we have taken advantage of Robonaut's teleoperated control system. When a person teleoperates Robonaut, the person's own SMC causes the robot to act purposefully. If the sensory signals that the robot detects during teleoperation are recorded over several repetitions of the same task, it should be possible through signal analysis to identify the sensory-motor couplings that accompany purposeful motion. In this report, reasons for suspecting SMC as the basis for intelligent behavior will be reviewed. A robot control system for autonomous behavior that uses learned SMC will be proposed. Techniques for the extraction of salient parameters from sensory and motor data will be discussed. Experiments with Robonaut will be discussed and preliminary data presented.
Author
Sensorimotor Performance; Robots; Telerobotics; Artificial Intelligence

20030063968 QSS Group, Inc., Moffett Field, CA, USA
Simulation-Based Verification of Livingstone Applications
Lindsey, Anthony E.; Pecheur, Charles; May 07, 2003; In English, 2003; No Copyright; Avail: CASI; A01, Hardcopy

AI software is viewed as a means to give greater autonomy to automated systems, capable of coping with harsh and unpredictable environments in deep space missions. Autonomous systems pose a serious challenge to traditional test-based verification approaches, because of the enormous space of possible situations that they aim to address. Before these systems are put in control of critical applications, appropriate new verification approaches need to be developed. This article describes Livingstone PathFinder (LPF), a verification tool for autonomous diagnosis applications based on NASA's Livingstone model-based diagnosis system. LPF applies state space exploration algorithms to an instrumented testbed, consisting of the Livingstone diagnosis system embedded in a simulated operating environment. The article describes different facets of LPF and reports some experimental results from applying LPF to a Livingstone model of the main propulsion feed subsystem of the X-34 space vehicle. This paper describes Livingstone PathFinder (LPF), a verification tool for autonomous diagnosis applications based on NASA's Livingstone model-based diagnosis system. LPF applies state space exploration algorithms to an instrumented testbed, consisting of the Livingstone diagnosis system embedded in a simulated operating environment. Section 2 provides an overview of Livingstone; Section 3 describes the LPF architecture; Section 4 discusses its applicability; Section 5 reviews some experimental results; Section 6 compares LPF to related verification approaches; Section 7 draws conclusions and discusses some perspectives.
Author
Computerized Simulation; Program Verification (Computers); Automatic Control; Architecture (Computers); Applications Programs (Computers); Software Engineering

20030063947 Research Inst. for Advanced Computer Science, Moffett Field, CA, USA
Design and Control of Large Collections of Learning Agents
Agogino, Adrian; April 2001; In English; Original contains color illustrations
Contract(s)/Grant(s): NCC2-1006
Report No.(s): RIACS-TR-1.07; No Copyright; Avail: CASI; A03, Hardcopy

The intelligent control of multiple autonomous agents is an important yet difficult task. Previous methods used to address this problem have proved to be either too brittle, too hard to use, or not scalable to large systems. The 'Collective Intelligence' project at NASA/Ames provides an elegant, machine-learning approach to address these problems. This approach mathematically defines some essential properties that a reward system should have to promote coordinated behavior among reinforcement learners. This work has focused on creating additional key properties and algorithms within the mathematics of the Collective Intelligence framework. One of the additions will allow agents to learn more quickly, in a more coordinated manner. The other will let agents learn with less knowledge of their environment. These additions will allow the framework to be applied more easily, to a much larger domain of multi-agent problems.
Author
Artificial Intelligence; Machine Learning; Optimization; Mathematical Logic

20030059525 Swedish Defence Research Establishment, Stockholm, Sweden
Differential Geometric Aspects of Optimal Control
Vooren, C. N.; Jan. 2002; In English
Report No.(s): PB2003-104348; FOI-R-0521-SE; No Copyright; Avail: CASI; A03, Hardcopy

This master thesis has been done within the Optimization of Missile Performance Project at the department of

Autonomous Systems at FOI. Increasing demands on missiles call for more sophisticated control methods. In this contest optimization and differential geometry are of great interest. The theory of optimal control has an underlying differential geometric structure which is explored in the present thesis.
NTIS
Autonomy; Differential Geometry; Optimal Control; Calculus of Variations

20030025360 NASA Ames Research Center, Moffett Field, CA, USA
The Intelligent Data Understanding Element of NASA's Intelligent Systems Program
Coughlan, Joseph C.; Tilton, James C.; Rood, Richard, Technical Monitor; [2002]; In English; European Union Satellite Centre (EUSC), 4-7 Dec. 2002, Rome, Italy; No Copyright; Avail: Other Sources; Abstract Only

Within the NASA Intelligent Systems Program, the Intelligent Data Understanding (IDU) element develops techniques for transforming data into scientific understanding. Automating such tools is critical for space science, space-based earth science, and planetary exploration with onboard scientific data analysis. Intelligent data understanding (IDU) is about extracting meaning from large, diverse science and engineering databases, via autonomous techniques that transform very large datasets into understanding. The earth science community in particular needs new tools for analyzing multi-formatted and geographically distributed datasets and for identifying cause-effect relationships in the complex data. Research within the IDU program element seeks to automate data analysis tasks so that humans can focus on creative hypothesis generation and knowledge synthesis. It may also enable NASA space missions in which autonomous agents must generate knowledge and take actions, and missions where limited bandwidth permits transmission of only the most interesting scientific observations, summaries, and conclusions. Twenty-seven research projects are-currently funded.
Author
NASA Space Programs; Artificial Intelligence; Autonomy; Data Bases

20030019034 Cornell Univ., Ithaca, NY USA
Compute-Intensive Methods and Hybrid Approaches for Combinatorial Problems
Gomes, Carla; Nov. 2002; In English
Contract(s)/Grant(s): F30602-99-1-0005; AF Proj. 2304
Report No.(s): AD-A409686; AFRL-IF-RS-TR-2002-299; No Copyright; Avail: CASI; A04, Hardcopy

Our research program focuses on techniques that lie at the intersection of Artificial Intelligence and Operations Research. In particular, we study computational methods for large-scale combinatorial optimization. Our research combines formal analysis and design of optimization techniques with the study of applications such as planning and scheduling, autonomous distributed agents and combinatorial auctions. Central themes of our work are (1) the integration of concepts from mathematical programming with constraint programming, (2) the study of the impact of structure on problem hardness, and (3) the use of randomization techniques to improve the performance of exact (complete) search methods. This report highlights some of our research projects and accomplishments.
DTIC
Combinatorial Analysis; Mathematical Programming

20030018262 Massachusetts Inst. of Tech., Cambridge, MA USA
Agent Based Software for the Autonomous Control of Formation Flying Spacecraft
How, Jonathan P.; Campbell, Mark; Dennehy, Neil, Technical Monitor; [2003]; In English
Contract(s)/Grant(s): NAG5-10440
Report No.(s): MIT-OSP-6891850; No Copyright; Avail: CASI; A03, Hardcopy

Distributed satellite systems is an enabling technology for many future NASA/DoD earth and space science missions, such as MMS, MAXIM, Leonardo, and LISA [1, 2, 3]. While formation flying offers significant science benefits, to reduce the operating costs for these missions it will be essential that these multiple vehicles effectively act as a single spacecraft by performing coordinated observations. Autonomous guidance, navigation, and control as part of a coordinated fleet-autonomy is a key technology that will help accomplish this complex goal. This is no small task, as most current space missions require significant input from the ground for even relatively simple decisions such as thruster burns. Work for the NMP DS1 mission focused on the development of the New Millennium Remote Agent (NMRA) architecture for autonomous spacecraft control systems. NMRA integrates traditional real-time monitoring and control with components for constraint-based planning, robust multi-threaded execution, and model-based diagnosis and reconfiguration. The complexity of using an autonomous approach for space flight software was evident when most of its capabilities were stripped off prior to launch (although more capability

was uplinked subsequently, and the resulting demonstration was very successful).
Derived from text
Formation Flying; Autonomous Navigation; Automatic Control; Applications Programs (Computers); Spacecraft Control; Flight Control; Guidance (Motion)

20030016190 National Inst. of Standards and Technology, Gaithersburg, MD USA
Measuring the Performance and Intelligence of Systems: Proceedings of the 2002 PerMIS Workshop
Messina, E. R.; Meystel, A. M.; Sep. 2002; In English, 1315 Aug. 2002, Gaithersburg, MD, USA
Report No.(s): PB2003-102175; NUST/SP-990; No Copyright; Avail: CASI; A21, Hardcopy

Contents include the following: Performance Metrics; Performance of Multiple Agents; Performance of Mobility Systems; Performance of Planning Systems; General Discussion Panel 1; Uncertainty of Representation I; Performance of Robots in Hazardous Domains; Modeling Intelligence; Modeling of Mind; Measuring Intelligence; Grouping: A Core Procedure of Intelligence; Uncertainty in Representation II; Towards Universal Planning/Control Systems.
NTIS
Conferences; Artificial Intelligence

20030014750 NASA Ames Research Center, Moffett Field, CA USA
Advances in Robotic, Human, and Autonomous Systems for Missions of Space Exploration
Gross, Anthony R.; Briggs, Geoffrey A.; Glass, Brian J.; Pedersen, Liam; Kortenkamp, David M.; Wettergreen, David S.; Nourbakhsh, I.; Clancy, Daniel J.; Zornetzer, Steven, Technical Monitor; [2002]; In English; 53rd International Astronautical Congress, 10-19 Oct. 2002, Houston, TX, USA; Copyright; Avail: CASI; A01, Hardcopy; Distribution as joint owner in the copyright

Space exploration missions are evolving toward more complex architectures involving more capable robotic systems, new levels of human and robotic interaction, and increasingly autonomous systems. How this evolving mix of advanced capabilities will be utilized in the design of new missions is a subject of much current interest. Cost and risk constraints also play a key role in the development of new missions, resulting in a complex interplay of a broad range of factors in the mission development and planning of new missions. This paper will discuss how human, robotic, and autonomous systems could be used in advanced space exploration missions. In particular, a recently completed survey of the state of the art and the potential future of robotic systems, as well as new experiments utilizing human and robotic approaches will be described. Finally, there will be a discussion of how best to utilize these various approaches for meeting space exploration goals.
Author
Space Missions; Autonomy; Robotics; Man Machine Systems; Mission Planning; Space Exploration

20030011313 Air Force Research Lab., Hanscom AFB, MA USA
A Feasible Approach for Implementing Greater Levels of Satellite Autonomy
Lindsay, Steve; Zetocha, Paul; Jan. 2002; In English
Contract(s)/Grant(s): AF Proj. 8809
Report No.(s): AD-A408679; No Copyright; Avail: CASI; A02, Hardcopy

In this paper, we propose a means for achieving increasingly autonomous satellite operations. We begin with a brief discussion of the current state-of-the-art in satellite ground operations and flight software, as well as the real and perceived technical and political obstacles to increasing the levels of autonomy on today's satellites. We then present a list of system requirements that address these hindrances and include the artificial intelligence (AI) technologies with the potential to satisfy these requirements. We conclude with a discussion of how the space industry can use this information to incorporate increased autonomy. From past experience we know that autonomy will not just 'happen,' and we know that the expensive course of manually intensive operations simply cannot continue. Our goal is to present the aerospace industry with an analysis that will begin moving us in the direction of autonomous operations.
DTIC
Artificial Intelligence; Ground Operational Support System; Aerospace Industry; Autonomy; Flight Control

20030001140 Research Inst. for Advanced Computer Science, Moffett Field, CA USA
RIACS FY2002 Annual Report
Leiner, Barry M.; Gross, Anthony R., Technical Monitor; November 2002; In English
Contract(s)/Grant(s): NCC2-1006
Report No.(s): RIACS-TR-AR-02; No Copyright; Avail: CASI; A10, Hardcopy

The Research Institute for Advanced Computer Science (RIACS) carries out basic research and technology development in computer science, in support of the National Aeronautics and Space Administration's missions. Operated by the Universities Space Research Association (a non-profit university consortium), RIACS is located at the NASA Ames Research Center, Moffett Field, California. It currently operates under a multiple year grant/cooperative agreement that began on October 1, 1997 and is up for renewal in September 2003. Ames has been designated NASA's Center of Excellence in Information Technology. In this capacity, Ames is charged with the responsibility to build an Information Technology (IT) Research Program that is preeminent within NASA. RIACS serves as a bridge between NASA Ames and the academic community, and RIACS scientists and visitors work in close collaboration with NASA scientists. RIACS has the additional goal of broadening the base of researchers in these areas of importance to the nation's space and aeronautics enterprises. RIACS research focuses on the three cornerstones of IT research necessary to meet the future challenges of NASA missions: 1) Automated Reasoning for Autonomous Systems; 2) Human-Centered Computing; and 3) High Performance Computing and Networking. In addition, RIACS collaborates with NASA scientists to apply IT research to a variety of NASA application domains including aerospace technology, earth science, life sciences, and astrobiology. RIACS also engages in other activities, such as workshops, seminars, visiting scientist programs and student summer programs, designed to encourage and facilitate collaboration between the university and NASA IT research communities.

Derived from text

Information Systems; NASA Programs; Aeronautical Engineering; Research and Development; Computer Techniques; Reports

20020094387 Honeywell Technology Center, Minneapolis, MN USA

SA-CIRCA: Self-Adaptive Control for Mission-Critical Systems

Musliner, David J.; Goldman, Robert P.; Pelican, Michael J.; Krebsbach, Kurt D.; Dunfee, Edmund H.; Aug. 2002; In English; Original contains color images

Contract(s)/Grant(s): F30602-98-C-0212; DARPA Order G428

Report No.(s): AD-A407314; AFRL-IF-RS-TR-2002-207; No Copyright; Avail: CASI; A03, Hardcopy

The goal of this effort was to begin extending the Cooperative Intelligent Real-Time Control Architecture (CIRCA) with abilities to automatically monitor its own performance and adapt in real-time, forming Self-Adaptive CIRCA (SA-CIRCA). CIRCA is a coarse-grain architecture designed to control autonomous systems which require both intelligence, deliberative planning activity and highly reliable, hard-real-time reactions to safety threats. CIRCA allows systems to provide performance guarantees that ensure they will remain safe and accomplish mission-critical goals while also intelligently pursuing long-term, non-critical goals. The SA-CIRCA project took several steps towards extending this architecture with the ability to reason accurately about its own real-time behavior, and adapt that behavior in response to performance feedback. Due to a change in the direction of this research, the SA-CIRCA project was only partially funded. As a result, the development of the architecture and demonstrations was not completed. Major issues investigated during this project include formally verifying real-time control plans, dynamically decomposing long-term plans into sub-goals, and building real-time control plans using probabilistic information to reason about most-likely states first. The primary technical products of this research project are two versions of CIRCA's controller-synthesis (or planning) algorithm. The first version automatically generates reactive control plans and verifies their correctness using formal model-checking methods. The second version does not use model checking to verify its plans, but uses a novel form of probabilistic reasoning to restrict its planning effort to the most-likely future system state.

DTIC

Self Adaptive Control Systems; Real Time Operation; Architecture (Computers); Autonomy

20020087758 NASA Ames Research Center, Moffett Field, CA USA

IDEA: Planning at the Core of Autonomous Reactive Agents

Muscettola, Nicola; Dorais, Gregory A.; Fry, Chuck; Levinson, Richard; Plaunt, Christian; Clancy, Daniel, Technical Monitor; [2002]; In English; Workshop on On-Line Planning and Scheduling, 23-27 Apr. 2002, Toulouse, France; Copyright; Avail: CASI; A02, Hardcopy; Distribution as joint owner in the copyright

Several successful autonomous systems are separated into technologically diverse functional layers operating at different levels of abstraction. This diversity makes them difficult to implement and validate. In this paper, we present IDEA (Intelligent Distributed Execution Architecture), a unified planning and execution framework. In IDEA a layered system can be implemented as separate agents, one per layer, each representing its interactions with the world in a model. At all levels, the model representation primitives and their semantics is the same. Moreover, each agent relies on a single model, plan database, plan runner and on a variety of planners, both reactive and deliberative. The framework allows the specification of agents that

operate, within a guaranteed reaction time and supports flexible specification of reactive vs. deliberative agent behavior. Within the IDEA framework we are working to fully duplicate the functionalities of the DS1 Remote Agent and extend it to domains of higher complexity than autonomous spacecraft control.
Author
Autonomy; Spacecraft Control; Control Systems Design

20020074730 NASA Goddard Space Flight Center, Greenbelt, MD USA
ANTS: Applying A New Paradigm for Lunar and Planetary Exploration
Clark, P. E.; Curtis, S. A.; Rilee, M. L.; Solar System Remote Sensing; 2002, 15-16; In English; No Copyright; Avail: CASI; A01, Hardcopy

ANTS (Autonomous Nano- Technology Swarm), a mission architecture consisting of a large (1000 member) swarm of picoclass (1 kg) totally autonomous spacecraft with both adaptable and evolvable heuristic systems, is being developed as a NASA advanced mission concept, and is here examined as a paradigm for lunar surface exploration. As the capacity and complexity of hardware and software, demands for bandwidth, and the sophistication of goals for lunar and planetary exploration have increased, greater cost constraints have led to fewer resources and thus, the need to operate spacecraft with less frequent human contact. At present, autonomous operation of spacecraft systems allows great capability of spacecraft to ‘safe’ themselves and survive when conditions threaten spacecraft safety. To further develop spacecraft capability, NASA is at the forefront of development of new mission architectures which involve the use of Intelligent Software Agents (ISAs), performing experiments in space and on the ground to advance deliberative and collaborative autonomous control techniques. Selected missions in current planning stages require small groups of spacecraft weighing tens, instead of hundreds, of kilograms to cooperate at a tactical level to select and schedule measurements to be made by appropriate instruments onboard. Such missions will be characterizing rapidly unfolding real-time events on a routine basis. The next level of development, which we are considering here, is in the use of autonomous systems at the strategic level, to explore the remote terranes, potentially involving large surveys or detailed reconnaissance.
Author
Mission Planning; Unmanned Spacecraft; Lunar Surface; Lunar Exploration; Remote Sensing

20020073819 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA
Novel Model-Based Diagnosis Approaches for Advanced IVHM Systems
Fijany, Amir; Vatan, Farokh; Baroth, Ed; Barrett, Anthony; Mackey, Ryan; 2nd JANNAF Modeling and Simulation Subcommittee Meeting; April 2002; Volume 1, 255-265; In English; Copyright; Avail: CPIA, 10630 Little Patuxent Pkwy., Suite 202, Columbia, MD 21044-3320

Over the past decade, the number of Earth orbiters and deep space probes has grown dramatically and is expected to continue growing in the future as miniaturization technologies drive spacecraft to become more numerous and more complex. This rate of growth has brought a new focus on autonomous and self-preserving systems that depend on fault diagnosis. The current manned systems, also heavily rely on Integrated Vehicle Health Management (IVHM) systems to increase reliability and reduce cost of operation. In this paper, we propose a two-fold approach to overcome these two limitations and to develop a new and powerful diagnosis engine. First, we propose a novel and compact reconstruction of General Diagnosis Engine (GDE), as one of the most fundamental approaches to model-based diagnosis. We then present a novel algorithmic approach for calculation of minimal diagnosis set. Using a powerful yet simple representation of the calculation of minimal diagnosis set, we map the problem onto two well-known problems, that is, the Boolean Satisfiability and 0/1 Integer Programming problems. The mapping onto Boolean Satisfiability enables the use of very efficient algorithms with a super-polynomial rather than an exponential complexity for the problem. The mapping onto 0/1 Integer Programming problem enables the use of variety of algorithms that can efficiently solve the problem for up to several thousand components. These new algorithms significantly improve over the existing ones, enabling efficient diagnosis of large complex systems. In addition. the latter mapping allows, for the first time, to determine the bound on the solution, i.e., the minimum number of faulty components, before solving the problem. This is a powerful insight that can be exploited to develop yet more efficient algorithms for the problem.
Author
Systems Health Monitoring; Error Analysis; Autonomy; Algorithms

20020073806 NASA Ames Research Center, Moffett Field, CA USA
Overview of Intelligent Systems and Operations Development
Pallix, J.; Dorais, G.; Penix, J.; 2nd JANNAF Modeling and Simulation Subcommittee Meeting; April 2002; Volume 1, 179-187; In English; Copyright; Avail: CPIA, 10630 Little Patuxent Pkwy., Suite 202, Columbia, MD 21044-3320

To achieve NASA's ambitious mission objectives for the future, aircraft and spacecraft will need intelligence to take the correct action in a variety of circumstances. Vehicle intelligence can be defined as the ability to 'do the right thing' when faced with a complex decision-making situation. It will be necessary to implement integrated autonomous operations and low-level adaptive flight control technologies to direct actions that enhance the safety and success of complex missions despite component failures, degraded performance, operator errors, and environment uncertainty. This paper will describe the array of technologies required to meet these complex objectives. This includes the integration of high-level reasoning and autonomous capabilities with multiple subsystem controllers for robust performance. Future intelligent systems will use models of the system, its environment, and other intelligent agents with which it interacts. They will also require planners, reasoning engines, and adaptive controllers that can recommend or execute commands enabling the system to respond intelligently. The presentation will also address the development of highly dependable software, which is a key component to ensure the reliability of intelligent systems.
Author
Aerospace Vehicles; Adaptive Control; Artificial Intelligence; Autonomy

20020073805 Air Force Research Lab., Wright-Patterson AFB, OH USA
Autonomous Systems: Don't Be Surprised If They Say No
Clough, Burce; 2nd JANNAF Modeling and Simulation Subcommittee Meeting; April 2002; Volume 1, 167-177; In English; Copyright; Avail: CPIA, 10630 Little Patuxent Pkwy., Suite 202, Columbia, MD 21044-3320

The aerospace research community is working hard at developing UAV (Unmanned Aerial Vehicle) control technology that requires as little human supervision as possible. 'Humans are expensive, let's give the machines the capability of making their own decisions - that'll save us money' are cries heard across the globe. Such autonomy comes at a price - if one gives UAVs the capability of making decisions in a noisy, latent data world then one should expect them to make decisions you might not. If you give free-will why would one not expect it to be executed? (Let's face it - human pilots don't always act deterministic, right?) 'But that's okay', some muse, we can test it before hand to insure it makes the right decisions.' Wrong - the proposed complex distributed control architectures using large blocks of complicated software will have too many paths to exhaustively test (assuming one finds them all) affordably. If one adds in the non-determinism inherent in multi-intelligent agent negotiation, biologically inspired control technology, and real-time adaptive systems it's enough to make any controls engineer run from the table screaming 'Not only don't I really know what's in it, I don't really know what it will do!'. This paper examines the challenges in allowing UAVs to have autonomy, while insuring they don't do anything stupid.
Author
Pilotless Aircraft; Artificial Intelligence; Autonomy; Errors

20020066822
Intelligent Agents: The Measure of their Intelligence
Arlabosse, Francois; AIP Conference Proceedings; September 02, 2002; ISSN 0094-243X; Volume 627, Issue no. 1, 349-358; In English; COMPUTING ANTICIPATORY SYSTEMS: CASYS 2001 - Fifth International Conference, 13-18 August, 2001, Liege, Belgium; Copyright

This paper presents an original attempt for testing the level of autonomy of intelligent physical agents. After a short review of the architectural problematic of designing such artefacts, we try to situate the place of uncertainty modelling in mobile robotic and complex control systems. We then briefly describe a design for giving to an industrial control problem the highest level of autonomy for performing its tasks. We give some hints how to extend these tests on physical agents exhibiting adaptive behaviours. Future works for applying this methodology will be illustrated. [copyright] 2002 American Institute of Physics
Author (AIP)
Artificial Intelligence; Mobility; Planning; Robots

20020039172 Research Inst. for Advanced Computer Science, Moffett Field, CA USA
Verification and Validation of Model-Based Autonomous Systems
Pecheur, Charles; Koga, Dennis, Technical Monitor; [2001]; In English; 1st Annual NASA Office of Safety and Mission Assurance Software Assurance Symposium, 5-7 Sep. 2001, Morgantown, WV, USA; No Copyright; Avail: CASI; A03, Hardcopy

This paper presents a three year project (FY99 to FY01) on the verification and validation of model based autonomous systems. The topics include: 1) Project Profile; 2) Model-Based Autonomy; 3) The Livingstone MIR; 4) MPL2SMV; 5)

Livingstone to SMV Translation; 6) Symbolic Model Checking; 7) From Livingstone Models to SMV Models; 8) Application In-Situ Propellant Production; 9) Closed-Loop Verification Principle; 10) Livingstone PathFinder (LPF); 11) Publications and Presentations; and 12) Future Directions. This paper is presented in viewgraph form.
CASI
Autonomy; Program Verification (Computers); Systems Engineering; Models

20020029290 Sandia National Labs., Albuquerque, NM USA
Adaptive Sensor Optimization and Cognitive Image Processing Using Autonomous Optical Nueroprocessors
Cameron, S. M.; Oct. 01, 2001; In English
Report No.(s): DE2001-789525; SAND2001-3304; No Copyright; Avail: Department of Energy Information Bridge

Measurement and signal intelligence demand has created new requirements for information management and interoperability as they affect surveillance and situational awareness. Integration of on-board autonomous learning and adaptive control structures within a remote sensing platform architecture would substantially improve the utility of intelligence collection by facilitating real-time optimization of measurement parameters for variable field conditions. A problem faced by conventional digital implementations of intelligent systems is the conflict between a distributed parallel structure on a sequential serial interface functionally degrading bandwidth and response time. In contrast, optically designed networks exhibit the massive parallelism and interconnect density needed to perform complex cognitive functions within a dynamic asynchronous environment. Recently, all-optical self-organizing neural networks exhibiting emergent collective behavior which mimic perception, recognition, association, and contemplative learning have been realized using photorefractive holography in combination with sensory systems for feature maps, threshold decomposition, image enhancement, and nonlinear matched filters. Such hybrid information processors depart from the classical computational paradigm based on analytic rules-based algorithms and instead utilize unsupervised generalization and perceptron-like exploratory or improvisational behaviors to evolve toward optimized solutions. These systems are robust to instrumental systematics or corrupting noise and can enrich knowledge structures by allowing competition between multiple hypotheses. This property enables them to rapidly adapt or self-compensate for dynamic or imprecise conditions which would be unstable using conventional linear control models. By incorporating an intelligent optical neuroprocessor in the back plane of an imaging sensor, a broad class of high-level cognitive image analysis problems including geometric change detection, pattern recognition, and correlated feature extraction can be realized in an inherently parallel fashion without information bottle necking or external supervision. Using this approach, we believe that autonomous control systems embodied with basic adaptive decision-theoretic capabilities can be developed for imaging and surveillance sensors to improve discrimination in stressing operational environments.
NTIS
Image Processing; Automatic Control; Digital Systems; Image Enhancement; Optical Measurement

20020019414 Space and Naval Warfare Systems Center, San Diego, CA USA
Autonomous Vehicles and the Net-Centric Battlespace
Fletcher, B.; Apr. 2000; In English
Report No.(s): AD-A397125; No Copyright; Avail: CASI; A02, Hardcopy

Autonomous vehicles are playing increasing roles in the air/land/sea network of today's battlespace. As the Navy's lead laboratory for command, control, communications, ocean surveillance, and the integration of multiple-platform systems, Space and Naval warfare Systems Center San Diego has a unique perspective on the development and utilization of vehicles for these applications. A variety of autonomous systems and their roles will be discussed including remote sensor platforms, communication relays, and work platforms. As these capabilities are developed autonomous vehicles will become an integral component of the C4ISR (command, control, communications, computers, intelligence surveillance, reconnaissance) network.
DTIC
Autonomy; Remote Sensors; Military Vehicles; Command and Control; Technology Utilization

20020016483 Army Communications-Electronics Command, Fort Monmouth, NJ USA
Using Continuous-Planning Techniques to Achieve Autonomy and Coordination Among Multiple Unmanned Aerial Vehicles
Powell, Gerald M.; Juner 2001; In English
Report No.(s): AD-A396781; CECOM-R-01-12; No Copyright; Avail: CASI; A03, Hardcopy

Existing Unmanned Aerial Vehicle (UAV) systems exhibit shortcomings in providing continuous, responsive, timely, and

detailed information and targeting support to Army tactical commander's combat operations in an Army XXI battlespace. To synchronize Tactical UAV (TUAV) missions with supported operations, time is the critical element. Anything that can reduce TUAV planning time, while maintaining plan effectiveness, will expedite execution of a TUAV1s mission. Autonomous flight with some ability to avoid and evade certain threats would increase survivability further. This paper begins by presenting some of the recent successes achieved by artificial intelligence (AI) planners and schedulers on complex real-world problems. It then attempts to show how NASA's demonstrated utility of a dynamic Al planning system prototype for conducting autonomous distributed planning and execution for a team of rovers engaged in missions to achieve science goals during planetary operations can be generalized and applied to a team of TUAVs. Last, it discusses some data collection opportunities that should appear due to the ability to place increasingly more processing and data storage capabilities onboard TUAVs and some of the key challenges to use those capabilities to produce more timely and immediately usable interpretations.
DTIC
Artificial Intelligence; Military Operations; Pilotless Aircraft; Planning; Military Technology

20020015592 Naval Research Lab., Washington, DC USA
Fuzzy Logic Resource Management and Coevolutionary Game-based Optimization
Smith, James F., III; Rhyne, Robert D., II; Sep. 28, 2001; In English
Report No.(s): AD-A396561; NRL/FR/5741--01-10001; No Copyright; Avail: CASI; A03, Hardcopy

A fuzzy logic expert system has been developed that automatically allocates electronic attack (EA) resources in real-time. This expertise-based resource manager is made up of four trees: the isolated platform tree, the multi-platform tree, the fuzzy parameter selection tree, and the fuzzy strategy tree. The initial version of the algorithm was optimized using a genetic algorithm using fitness functions constructed based on expertise. A new approach is being explored that involves embedding the resource manager in an electronic game environment. The game allows a human expert to play against the resource manager in a simulated battle space with each of the defending platforms being exclusively directed by the fuzzy resource manager and the attacking platforms being controlled by the human expert or operating autonomously under their own logic. This approach automates the knowledge discovery problem. The theory of coevolutionary optimization is introduced, reoptimization criteria and stopping criteria are discussed, an algorithm for automatically constructing coevolutionary fitness functions is introduced, and examples are provided to show the effectiveness of coevolutionary optimization. A measure of effectiveness (MOE) for validation is discussed. Finally. the effectiveness of the resource manager and the optimization procedures is shown through a demanding example.
DTIC
Resources Management; Expert Systems; Fuzzy Systems

20020006871 National Defence Research Establishment, Stockholm, Sweden
Optimization of Missile Performance, Activity Report
Hamberg, J.; December 2000; In Swedish
Report No.(s): PB2001-108211; FOA-R-00-01801-314-SE; No Copyright; Avail: CASI; A03, Hardcopy

Recent technological, political, and economic developments have led to major revisions of military philosophy, internationally as well as nationally, leading to a general 'upgrading of theory.' Careful mathematical modeling and analysis is done in areas where it has heretofore been considered unfeasible or otherwise not worthwhile. Autonomous systems play an increasingly important role, as does precision engagement under extreme conditions. The systems have to satisfy new demands on economical, environmental, and humanitarian concerns. This process calls for a total revision of the established ways of modeling, designing, guiding, and controlling systems, in particular moving systems. Future missile research will have to make use of a larger part of nonlinear systems theory and the correct description and modeling of the underlying physics. Likewise, more systematic and high-level methods of modeling and simulation will be necessary. One of the main objectives of the project is a general competence generation in order to meet the future need of modeling, simulation, and assessment. This activity is mainly theoretical and mathematical by nature.
NTIS
Evaluation; Nonlinear Systems; Missiles

20010111908 Argonne National Lab., IL USA
Structured beam projection for semi-automatic teleoperation
Park, Y.; Oct. 17, 2000; In English
Report No.(s): DE2001-766348; ANL/TD/CP-103157; No Copyright; Avail: Department of Energy Information Bridge

This paper presents a robotic architecture that facilitates semi-automatic teleoperation of a dual-arm manipulator system. The architecture is built upon reactive behavior agents tightly coupling sensing and action, where emergent behaviors correlate human intervention with sensor-based autonomous operation. Reactive agents are devised for perceptual and motor behaviors, and a structured light system is adopted to provide a visual reference to both behavioral agents and the human operator. The technical feasibility of the robotic behaviors is evaluated through simulation of the collaborative motion of a dual-arm manipulator. The presented sensor based semi-automatic teleoperation may improve human perception and simplify human action, and thus improve the efficiency and precision of teleoperation.
NTIS
Manipulators; Computer Programs; Architecture (Computers); Robotics; Teleoperators

20010110015 University of Central Florida, Orlando, FL USA
Lyapunov-Based Sensor Failure Detection And Recovery For The Reverse Water Gas Shift Process
Haralambous, Michael G.; 2000 Research Reports: NASA/ASEE Summer Faculty Fellowship Program; October 2001, 73-83; In English; No Copyright; Avail: CASI; A03, Hardcopy

Livingstone, a model-based AI software system, is planned for use in the autonomous fault diagnosis, reconfiguration, and control of the oxygen-producing reverse water gas shift (RWGS) process test-bed located in the Applied Chemistry Laboratory at KSC. In this report the RWGS process is first briefly described and an overview of Livingstone is given. Next, a Lyapunov-based approach for detecting and recovering from sensor failures, differing significantly from that used by Livingstone, is presented. In this new method, models used are in terms of the defining differential equations of system components, thus differing from the qualitative, static models used by Livingstone. An easily computed scalar inequality constraint, expressed in terms of sensed system variables, is used to determine the existence of sensor failures. In the event of sensor failure, an observer/estimator is used for determining which sensors have failed. The theory underlying the new approach is developed. Finally, a recommendation is made to use the Lyapunov-based approach to complement the capability of Livingstone and to use this combination in the RWGS process.
Author
Error Analysis; Artificial Intelligence; Autonomy; Failure; Detection; Liapunov Functions

20010097311 NASA Ames Research Center, Moffett Field, CA USA
Model Checking the Remote Agent Planner
Khatib, Lina; Muscettola, Nicola; Havelund, Klaus; Norvig, Peter, Technical Monitor; [2001]; In English; No Copyright; Avail: CASI; A02, Hardcopy

This work tackles the problem of using Model Checking for the purpose of verifying the HSTS (Scheduling Testbed System) planning system. HSTS is the planner and scheduler of the remote agent autonomous control system deployed in Deep Space One (DS1). Model Checking allows for the verification of domain models as well as planning entries. We have chosen the real-time model checker UPPAAL for this work. We start by motivating our work in the introduction. Then we give a brief description of HSTS and UPPAAL. After that, we give a sketch for the mapping of HSTS models into UPPAAL and we present samples of plan model properties one may want to verify.
Author
Scheduling; Program Verification (Computers); Systems Analysis; Planning; Computer Techniques; Algorithms

20010084994 Agilent Labs., USA
Calibration of Hubble Space Telescope Focal-Length Variations Using the Embedding Technique
Barford, Lee; Tufillaro, Nicholas; Usikov, Daniel; Marochnik, Leonid; McCutcheon, Robert; 2001 Flight Mechanics Symposium; June 2001, 485-495; In English; No Copyright; Avail: CASI; A03, Hardcopy

A modeling method that allows one to rapidly build data-driven models of nonlinear components is discussed. The models are constructed from input/output time domain data and their ‘embeddings’. The notion of models built from embedded data is described in the Taken’s Embedding Theorem and has been extensively explored for modeling systems in the physics literature. The authors from Agilent Laboratories are developing practical methods to extend these results to non-autonomous systems by creating tools that allow engineers to rapidly build models for driven nonlinear components. These models can be used in simulation, process control, diagnostics, and sensor calibration. Using these methods a ‘black-box’ data-driven model is generated to calibrate Hubble Space Telescope (HST) focal-length changes on a 5-minute time grid for the period from 1995-1999. These models are built using a program, CHAOS, developed by Agilent Laboratories. The data-driven model predicts the focus for the measured points about 36% better than the Full-Temperature Model (FTM) constructed from a

detailed knowledge of the telescope structure. As demonstrated by this HST focal-length calibration, data-driven models, such as those generated with the CHAOS package, have great potential for application to a wide spectrum of HST/Next Generation Space Telescope (NGST) calibration problems. In particular, for sensor calibration applications, blackbox nonlinear models can be generated rapidly, which have similar or better performance than models built from a detailed understanding of the system structure.
Author
Calibrating; Computerized Simulation; Focusing

20010082908 NASA Ames Research Center, Moffett Field, CA USA
An Overview of NASA's Intelligent Systems Program
Cooke, Daniel E.; Norvig, Peter, Technical Monitor; [2001]; In English; IEEE Aerospace Conferences; No Copyright; Avail: CASI; A02, Hardcopy

NASA and the Computer Science Research community are poised to enter a critical era. An era in which - it seems - that each needs the other. Market forces, driven by the immediate economic viability of computer science research results, place Computer Science in a relatively novel position. These forces impact how research is done, and could, in worst case, drive the field away from significant innovation opting instead for incremental advances that result in greater stability in the market place. NASA, however, requires significant advances in computer science research in order to accomplish the exploration and science agenda it has set out for itself. NASA may indeed be poised to advance computer science research in this century much the way it advanced aero-based research in the last.
Author
NASA Programs; Artificial Intelligence

20010081322 NASA Ames Research Center, Moffett Field, CA USA
Verification of Plan Models Using UPPAAL
Khatib, Lina; Muscettola, Nicola; Haveland, Klaus; Lau, Sonic, Technical Monitor; [2001]; In English; No Copyright; Avail: CASI; A03, Hardcopy

This paper describes work on the verification of HSTS, the planner and scheduler of the Remote Agent autonomous control system deployed in Deep Space 1 (DS1). The verification is done using UPPAAL, a real time model checking tool. We start by motivating our work in the introduction. Then we give a brief description of HSTS and UPPAAL. After that, we give a mapping of HSTS models into UPPAAL and we present samples of plan model properties one may want to verify. Finally, we conclude with a summary.
Author
Real Time Operation; Remote Control; Scheduling

20010024738 NASA Kennedy Space Center, Cocoa Beach, FL USA
Smarter Software For Enhanced Vehicle Health Monitoring and Inter-Planetary Exploration
Larson, William E.; Goodrich, Charles H.; Steinrock, Todd, Technical Monitor; [2001]; In English; 38th Space Congress, 1-4 May 2000, Cape Canaveral, FL, USA; No Copyright; Avail: CASI; A02, Hardcopy

The existing philosophy for space mission control was born in the early days of the space program when technology did not exist to put significant control responsibility onboard the spacecraft. NASA relied on a team of ground control experts to troubleshoot systems when problems occurred. As computing capability improved, more responsibility was handed over to the systems software. However, there is still a large contingent of both launch and flight controllers supporting each mission. New technology can update this philosophy to increase mission assurance and reduce the cost of inter-planetary exploration. The advent of model-based diagnosis and intelligent planning software enables spacecraft to handle most routine problems automatically and allocate resources in a flexible way to realize mission objectives. The manifests for recent missions include multiple subsystems and complex experiments. Spacecraft must operate at longer distances from earth where communications delays make earthbound command and control impractical. NASA's Ames Research Center (ARC) has demonstrated the utility of onboard diagnosis and planning with the Remote Agent experiment in 1999. KSC has pioneered model-based diagnosis and demonstrated its utility for ground support operations. KSC and ARC are cooperating in research to improve the state of the art of this technology. This paper highlights model-based reasoning applications for Moon and Mars missions including in-situ resource utilization and enhanced vehicle health monitoring.
Author
Autonomy; Software Engineering; Mars Exploration; Computer Systems Programs; Artificial Intelligence; Moon

20010004725 SRI International Corp., Menlo Park, CA USA
Representation, Modeling, and Recognition of Outdoor Scenes
Fischler, Martin A.; Bolles, Robert C.; Aug. 2000; In English
Contract(s)/Grant(s): DACA76-92-C-0008
Report No.(s): AD-A381358; No Copyright; Avail: CASI; A05, Hardcopy

The goal of this project is to advance the state-of-the-art in scene interpretation for autonomous systems that operate in natural terrain. In particular, techniques are being developed for representing knowledge about complex cultural and natural environments so that a computer vision system can successfully plan, navigate, recognize, and manipulate objects, and answer questions or make decisions relevant to this knowledge. The results to date include the development of new representations and techniques for rapidly modeling terrain from multiple images, and for the recognition and reliable labeling of such scene attributes and components as color, texture, shadows, and a variety of linear structures (skyline, ridgelines, road, etc.). The most recent results are detailed in three papers included as appendices to this report.
DTIC
Computer Vision; Scene Analysis; Models; Terrain; Pattern Recognition

20010000882 NASA Ames Research Center, Moffett Field, CA USA
Verification and Validation of Autonomy Software at NASA
Pecheur, Charles; April 2000; In English
Report No.(s): NASA/TM-2000-209602; A-00V0022; NAS 1.15:209602; No Copyright; Avail: CASI; A03, Hardcopy

Autonomous software holds the promise of new operation possibilities, easier design and development and lower operating costs. However, as those system close control loops and arbitrate resources on board with specialized reasoning, the range of possible situations becomes very large and uncontrollable from the outside, making conventional scenario-based testing very inefficient. Analytic verification and validation (V&V) techniques, and model checking in particular, can provide significant help for designing autonomous systems in a more efficient and reliable manner, by providing a better coverage and allowing early error detection. This article discusses the general issue of V&V of autonomy software, with an emphasis towards model-based autonomy, model-checking techniques and concrete experiments at NASA.
Author
Program Verification (Computers); Autonomy; Computer Systems Programs

20000116209 NASA Ames Research Center, Moffett Field, CA USA
A Unified Approach to Model-Based Planning and Execution
Muscettola, Nicola; Dorais, Gregory A.; Fry, Chuck; Levinson, Richard; Plaunt, Christian; Norvig, Peter, Technical Monitor; [2000]; In English; Intelligent Agent Systems, Jul. 2000, Venice, Italy; No Copyright; Avail: CASI; A02, Hardcopy

Writing autonomous software is complex, requiring the coordination of functionally and technologically diverse software modules. System and mission engineers must rely on specialists familiar with the different software modules to translate requirements into application software. Also, each module often encodes the same requirement in different forms. The results are high costs and reduced reliability due to the difficulty of tracking discrepancies in these encodings. In this paper we describe a unified approach to planning and execution that we believe provides a unified representational and computational framework for an autonomous agent. We identify the four main components whose interplay provides the basis for the agent's autonomous behavior: the domain model, the plan database, the plan running module, and the planner modules. This representational and problem solving approach can be applied at all levels of the architecture of a complex agent, such as Remote Agent. In the rest of the paper we briefly describe the Remote Agent architecture. The new agent architecture proposed here aims at achieving the full Remote Agent functionality. We then give the fundamental ideas behind the new agent architecture and point out some implication of the structure of the architecture, mainly in the area of reactivity and interaction between reactive and deliberative decision making. We conclude with related work and current status.
Author
Applications Programs (Computers); Computer Systems Programs; Decision Making; Modules; Planning

20000116204 NASA Ames Research Center, Moffett Field, CA USA
Remote Agent Experiment
Benard, Doug; Dorais, Gregory A.; Gamble, Ed; Kanefsky, Bob; Kurien, James; Millar, William; Muscettola, Nicola; Nayak, Pandu; Rouquette, Nicolas; Rajan, Kanna; Norvig, Peter, Technical Monitor, et al.; [2000]; In English; Technology Validation, 8-9 Feb. 2000, Pasadena, CA, USA; No Copyright; Avail: CASI; A03, Hardcopy

Remote Agent (RA) is a model-based, reusable artificial intelligence (At) software system that enables goal-based spacecraft commanding and robust fault recovery. RA was flight validated during an experiment on board of DS1 between May 17th and May 21th, 1999.
Author
Artificial Intelligence; Applications Programs (Computers); Assembling; Expert Systems; Modules

20000085886 NASA Goddard Space Flight Center, Greenbelt, MD USA
The MAP Autonomous Mission Control System
Breed, Juile; Coyle, Steven; Blahut, Kevin; Dent, Carolyn; Shendock, Robert; Rowe, Roger; [2000]; In English, 19-23 Jun. 2000, Toulouse, France; No Copyright; Avail: CASI; A02, Hardcopy

The Microwave Anisotropy Probe (MAP) mission is the second mission in NASA's Office of Space Science low-cost, Medium-class Explorers (MIDEX) program. The Explorers Program is designed to accomplish frequent, low cost, high quality space science investigations utilizing innovative, streamlined, efficient management, design and operations approaches. The MAP spacecraft will produce an accurate full-sky map of the cosmic microwave background temperature fluctuations with high sensitivity and angular resolution. The MAP spacecraft is planned for launch in early 2001, and will be staffed by only single-shift operations. During the rest of the time the spacecraft must be operated autonomously, with personnel available only on an on-call basis. Four (4) innovations will work cooperatively to enable a significant reduction in operations costs for the MAP spacecraft. First, the use of a common ground system for Spacecraft Integration and Test (I&T) as well as Operations. Second, the use of Finite State Modeling for intelligent autonomy. Third, the integration of a graphical planning engine to drive the autonomous systems without an intermediate manual step. And fourth, the ability for distributed operations via Web and pager access.
Derived from text
Autonomy; Automatic Control; Microwave Probes; Background Radiation; Angular Resolution

20000069233 Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA USA
The Impact of Autonomous Systems Technology on JPL Mission Software
Doyle, Richard J.; Proceedings of the Twenty-Fourth Annual Software Engineering Workshop; March 2000; In English; Original contains color illustrations; No Copyright; Avail: CASI; A03, Hardcopy

This paper discusses the following topics: (1) Autonomy for Future Missions- Mars Outposts, Titan Aerobot, and Europa Cryobot / Hydrobot; (2) Emergence of Autonomy- Remote Agent Architecture, Closing Loops Onboard, and New Millennium Flight Experiment; and (3) Software Engineering Challenges- Influence of Remote Agent, Scalable Autonomy, Autonomy Software Validation, Analytic Verification Technology, and Autonomy and Software Software Engineering.
Author
Computer Programming; Software Engineering; Computer Programs

20000055731 NASA Ames Research Center, Moffett Field, CA USA
Formal Analysis of the Remote Agent Before and After Flight
Havelund, Klaus; Lowry, Mike; Park, SeungJoon; Pecheur, Charles; Penix, John; Visser, Willem; White, Jon L.; Lfm2000: Fifth NASA Langley Formal Methods Workshop; June 2000; In English; No Copyright; Avail: CASI; A03, Hardcopy

This paper describes two separate efforts that used the SPIN model checker to verify deep space autonomy flight software. The first effort occurred at the beginning of a spiral development process and found five concurrency errors early in the design cycle that the developers acknowledge would not have been found through testing. This effort required a substantial manual modeling effort involving both abstraction and translation from the prototype LISP code to the PROMELA language used by SPIN. This experience and others led to research to address the gap between formal method tools and the development cycle used by software developers. The Java PathFinder tool which directly translates from Java to PROMELA was developed as part of this research, as well as automatic abstraction tools. In 1999 the flight software flew on a space mission, and a deadlock occurred in a sibling subsystem to the one which was the focus of the first verification effort. A second quick-response 'cleanroom' verification effort found the concurrency error in a short amount of time. The error was isomorphic to one of the concurrency errors found during the first verification effort. The paper demonstrates that formal methods tools can find concurrency errors that indeed lead to loss of spacecraft functions, even for the complex software required for autonomy. Second, it describes progress in automatic translation and abstraction that eventually will enable formal methods tools to be inserted directly into the aerospace software development cycle.
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Subject Terms

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