DOCTOR
OF
PHILOSOPHY

NEW DATA FUSION ALGORITHMS FOR DISTRIBUTED MULTISENSOR-MULTITARGET ENVIRONMENTS
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Multisensor data fusion combines data from multiple sensor systems to achieve improved performance and provide more inferences than could be achieved using a single sensor system. One of the most important aspects of data fusion is data association. This dissertation develops new algorithms for data association, including measurement-to-track association, track-to-track association and track fusion, in distributed multisensor-multitarget environment with overlapping sensor coverage. The performance of the proposed algorithms is compared to that of existing techniques. Computational complexity analysis is also presented. Numerical results based on Monte Carlo simulations and real data collected from the United States Coast Guard Vessel Traffic Services system are also presented. The results show that the proposed algorithms significantly reduce the computational complexity and achieve considerable performance improvement over those reported in the literature.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Sensors

KEWWORDS: Fuzzy Techniques, Multisensor-Multitarget Data Fusion, Data Association, Track-to-Track-Association, Track Fusion, Distributed Decision Fusion

ACTIVE NARROWBAND DISTURBANCE REJECTION ON AN ULTRA QUIET PLATFORM
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Vibration isolation on spacecraft is needed for imaging sensors, microgravity experiments, and other sensitive payloads. The preferred method thus far has been passive isolation because of its simplicity and low cost. Active vibration isolation and disturbance rejection will soon be more common as space qualified sensors, actuators and processors become more capable and affordable, and performance requirements increase. Spacecraft disturbances are typically periodic vibrations which are most effectively controlled through feedforward techniques. A popular choice of feedforward control methods for disturbance rejection is the Multiple Error Least Mean Squares (LMS) algorithm which requires a separately measured disturbance-correlated signal in its implementation. A new technique called “Clear Box” makes extensive use of identification to bring out information that is normally hidden or not used by traditional control methods. It allows operation in an information-rich environment with built-in fault tolerance, the ability to

control unanticipated disturbances, and the ability to select which modes to control (if saturation of the actuators is a possibility or concern), all without the need for a separately measured disturbance-correlated signal. Experiments using both Multiple Error LMS and Clear Box on an Ultra Quiet Platform provide an effective demonstration of the advantages of the Clear Box Algorithm, including a new Adaptive Basis Method which allows control of rapidly varying frequencies.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Vibration Isolation, Narrowband Disturbances, Deterministic Disturbances, Disturbance Rejection, UQP, Clear Box, LMS, Filtered-x LMS, Multiple Error LMS, Active Control, Feedforward Control, System Identification, Adaptive Basis

THE SHORT WAVE INFRARED SIGNATURE OF VOLCANIC ASH: REMOTE DETECTION AND CHARACTERIZATION

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The reflection spectrum of volcanic ash plumes differs significantly from that of water or ice clouds in the short-wave infrared from 2.0 to 3.5 microns. This difference can be exploited by broad-band multi-spectral radiometers to distinguish silicate rich plumes that pose a hazard to aviation from the meteorological background. In this work, ash plume signatures of andesitic and basaltic composition are compared to models of altostratus, stratus, cumulus, stratocumulus, and cirrus cloud types. A catalog of ash and cloud signatures is presented based on Mie scattering calculations and multi-stream radiative transport models for multiple particle size distributions, viewing geometries, plume altitudes, and optical thicknesses. A three band algorithm is developed based on the model data and the specifications of a research and development sensor system. The ratio of reflected energy at 3.1μm to that at 2.1μm is used to discriminate volcanic ash from water based clouds and the ratio of bands at 2.7μm and 3.1μm is used to preclude false detection due to ice clouds. Model based threshold predictions are made for the research sensor system and used to characterize multispectral observations. The December 1998 eruptions of Popocatepetl volcano were observed by the research sensor system and three ash plumes were successfully using the predicted criteria.

DoD KEY TECHNOLOGY AREAS: Sensors, Battlespace Environments

KEYWORDS: Aviation Hazard Avoidance, Volcanic Ash, Remote Sensing, Infrared, Popocatepet

LAYER-BASED CODING, SMOOTHING, AND SCHEDULING OF LOW-BIT-RATE VIDEO FOR TELECONFERENCING OVER TACTICAL ATM NETWORKS

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This work investigates issues related to distribution of low-bit-rate video within the context of a teleconferencing application deployed over a tactical ATM network. The main objective is to develop mechanisms that support transmission of low bit rate video streams as a series of scalable layers that

progressively improve quality. The hierarchical nature of the layered video stream is actively exploited along the transmission path from the sender to the recipients to facilitate transmission.

A new layered coder design tailored to video teleconferencing in the tactical environment is proposed. Macroblocks selected due to scene motion are layered via subband decomposition using the fast Haar transform. A generalized layering scheme groups the subbands to form an arbitrary number of layers. As a layering scheme suitable for low-motion video is unsuitable for static slides, the coder adapts the layering scheme to the video content. A suboptimal rate control mechanism that reduces the *k*-dimensional rate-distortion problem resulting from the use of multiple quantizers tailored to each layer to a 1-dimensional problem by creating a single rate-distortion curve for the coder in terms of a suboptimal set of *k*-dimensional quantizer vectors is investigated. Rate control is thus simplified into a table lookup of a codebook containing the suboptimal quantizer vectors. The rate controller is ideal for real-time video and limits fluctuations in the bit-stream with no corresponding visible fluctuations in perceptual quality.

A traffic smoother prior to network entry is developed to increase queuing and scheduler efficiency. Three levels of smoothing are studied: frame, layer, and cell interarrival. Frame level smoothing occurs via rate control at the application. Interleaving and cell interarrival smoothing are accomplished using a leaky bucket mechanism inserted prior to the adaptation layer or within the adaptation layer. Simulations indicate that smoothing lowers bandwidth requirements for a given quality of service and that interleaving cells from different layers enhances the effectiveness of priority-based scheduling schemes.

A new cell-scheduling scheme is proposed that exploits the layered video hierarchy to allow more graceful degradation in visual quality during periods of cell loss. Quality of service at the connection level is maintained using an optimal scheduling algorithm that accounts for the cell loss rate and cell transfer delay requirements for each connection. Within the connection, a prioritization scheme denies service to cells from lower priority layers during periods of congestion and cells deemed non-viable due to group of blocks (GOB) corruption to increase the probability that cells from higher priority layers are transmitted. Simulations indicate that protecting higher priority layers requires accepting a corresponding decrease in throughput. Depending on the prioritization scheme used, cell loss rates for the base video layer can either be maintained at the desired rate or improved by an order of magnitude relative to no prioritization. Cell discarding allows the scheduler to recover bandwidth from non-viable cells although the impact within the connection depends on the service discipline. As the GOB size increases, cell discarding is improved if cells from different layers are interleaved to reflect spatial dependency between the base layer and the enhancement layers.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software, Modeling and Simulation

KEYWORDS: Layered Video, Low-bit-rate Video Compression, Video Teleconferencing, Traffic Smoothing, and Scheduling Algorithms