A preprocessing and automated algorithm selection system for image registration

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ABSTRACT

Image registration is a technique for precisely aligning the content of two or more images. It is often used as a pre-processing stage for further analysis, such as automatic target recognition, change detection, and environmental remote sensing. However, there are many different registration algorithms available to the image analyst, and it's difficult to know which one is the best one to use for a particular pair of images. These various algorithms also have a multitude of settings and parameters that must be given proper values for best results. Consequently, it is often difficult to know which algorithm will perform the best in a given situation, under constraints of time or accuracy. We propose constructing an expert system, with rules based on experimental results, that will automatically select the appropriate registration algorithm and perform appropriate preprocessing steps to prepare the images for registration.

Keywords: Image Registration, Data Fusion, Image Processing, Expert Systems

BACKGROUND

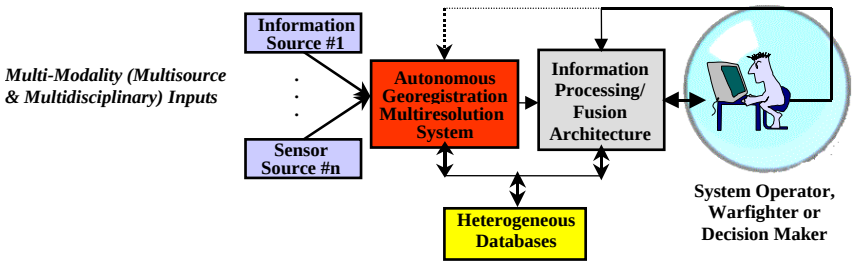
Accurate and automated geo-registration is of much interest to the US Air Force as well as other military organizations. A wealth of sensor information collected or derived from both imaging and non-imaging sensors comes in various forms. These can include: synthetic aperture radar (SAR) imagery, electro-optical/infrared (EO/IR) imagery, multispectral imagery (MSI), hyperspectral imagery (HSI), measurement and signal intelligence (MASINT), human intelligence (HUMINT), target status (detection, location, classification, identification, etc.) data confidence levels, sensor platform position, SIGINT, GMTI, and so on. We generally classify such *multi-modality* sensor data into two main categories: image intelligence (IMINT) and non-image intelligence (non-IMINT). Taken together, these can be referred to as Multi-INT. The wealth of Multi-INT sensor data is creating information overload issues. Exacerbating this is that current auto-registration technologies and techniques may not produce accurate or precise results especially for multi-modality sensor inputs. Further, such auto-registration techniques may not run in a time-efficient manner to support real time or near-real time information fusion and downstream targeting tasks. In time-critical situations, the amount of information and how it is processed can adversely affect the decision process.

SPATIAL MULTISENSOR AUTONOMOUS REGISTRATION TOOLKIT (SMART)

The overarching objective of our effort is to develop and integrate a complete suite of data registration algorithms in the form of a software toolkit for the spatial alignment of Multi-INT (image, SIGINT, GMTI and other) data collected from the battlespace. This will be accomplished by leveraging and further extending the results of our basic research and exploratory development. We will continue to diversify and enhance the initial proof-of-concept capability to support additional functionality, knowledge, information, sensors, and sources. We will continue to build upon our recent findings and current research to further identify potential problem areas and refine solutions associated with the selected registration algorithms and their use in the integrated toolkit framework. This includes a fleshing out of the expert system rule base to provide a complete, robust capability to perform Multi-INT data preprocessing and for brokering the selection of algorithms to ensure that accurate results are obtained efficiently.

To address the issues of registration performance, and overcome the limitations of individual registration algorithms, we are proposing a rule-based expert system known as the Spatial Multisensor Autonomous Registration Toolkit, or SMART.

Spatial Multi-sensor Autonomous Registration Toolkit (SMART)
Conceptual Diagram



SMART technologies will directly benefit a broad range of applications. The military application is the increased understanding of the air and ground stationary and moving targets in the battlespace environment. For example, *SMART* could be used to aid command-level decision tasks by producing reliable and consistent information that reduces target uncertainty. Once the registration capability (as part of an overall fusion and signal processing system) has been exercised (theater-level, order of battle, etc.), data may be fed back to command teams in the form of initial or revised recommendations. Tactical decisions can then be made to appropriately deploy military assets and react to or guard against hostile targets. The proposed capability can provide a means to derive important information about threat status and warfare-engagement issues. This methodology is clearly in support of real time warfighter and time-critical moving target detection scenarios.

The ability to incorporate large amounts of electronic flight information that can be managed with great ease and minimal training has the potential of revolutionizing the general aviation sector. The algorithms and techniques to be developed are also applicable to any commercial industry that evaluates large amounts of data from real-time to historical data in order to determine the current state of the environment and analyze or forecast future trends. Cross discipline applications include biologists, chemists, and other scientists, the virtual operating room, simulation control, commercial aircraft, air traffic control, and salvage, search and rescue management. Other potential civilian/dual use applications include: financial markets, traffic analysis in major cities, manufacturing and operations research applications, medical diagnostics, meteorology and weather forecasting; concealed weapons detection, computer vision, intelligent auto vehicle dashboard/head-up displays, airborne hyperspectral analysis, environmental monitoring, ordnance detection, and geographical information system (GIS) applications. Potential applications also include remote sensing, oil exploration, security systems, and extensions of this technology to integrating data beyond geo-registration domain to medical diagnostics, biophysical and drug-discovery applications, financial industry, internet search engines, application-specific information search engines, and other commercial applications such as emergency control centers, law enforcement, public safety, traffic control and manufacturing process control. The resulting technology may also have applications for such areas as traffic pattern monitoring and the identification of illegal activities in support of homeland defense.

We recognize that aside from the algorithm development and implementation, the viability of the software is the major key to the success of concepts like multisource autonomous data registration. In our approach, the design and implementation of the software toolkit will include an expert system based capability to select the most suitable algorithms. We also recognize that based on the problem to be solved, methodologies like control point mapping, wavelet coefficients, cross-correlation, and mutual information similarity measures, all represent methods that may be required to accomplish registration. Other methods developed by contractors under the DDB program to register Multi-INT data provide another set of algorithms to be included in our framework. In our expert system approach, rules will be used to guide the process of rapidly determining the best way to solve the automatic registration problem and guide the user through the solution process.

REGISTRATION ACCURACY

There are many factors that can affect registration accuracy. These are generally modality dependent and include:

- Radiometric/environmental and geometric factors (lens aberrations, distortions).
- Characteristic image content (extremes in sunlight/shadows and speckling/artifacts as in SAR images).