BRECCIA: Unified Probabilistic Dynamic Geospatial Intelligence

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***Abstract*— The study and analysis of geospatial data has progressed from simple Geographic Information Systems (GIS) (spatially organized layers of digital data with associated functional elements to broader geocomputation systems (see [1]). Applied to Geospatial Intelligence analysis, this involves the combination of information expressed in logical form (as sentences or statements), computational form (as numerical models of physics or other processes), as geographic information, and as sensor data (as measurements from transducers). Each of these forms has its own way to describe uncertainty or error: e.g., frequency models, algorithmic truncation, floating point roundoff, Gaussian distributions, etc. We propose *BRECCIA*, a multi-agent Geospatial Intelligence analysis system, which receives information from humans (as logical sentences), simulations (e.g., weather or environmental predictions), and sensors (e.g. cameras, weather stations, microphones), etc., where each piece of information has an associated uncertainty; *BRECCIA* then provides responses to user queries based on a probabilistic logic system which determines a coherent overall response to the query and the probability of that response, thus, ameliorating the human interaction with a complicated set of processes. In addition, *BRECCIA* attempts to identify concrete mechanisms (proposed actions) to acquire new data dynamically in order to reduce the uncertainty of the query response. The basis for this is a novel low-complexity approach to probabilistic logic analysis.**

Current knowledge-based GEOINT systems do not incorporate a broad notion of uncertainty quantification, although such a capability would allow decision makers to make more informed decisions, or to acquire more data before coming to conclusions. In addition, it would be better if system responses were provided with an explanation of how they were derived, as well as how the uncertainty was determined. In addition, intelligence, surveillance and reconnaissance support systems should generate dynamic path planning solutions which can dynamically include constraints on time, energy, or uncertainty reduction to inform the deployment of data measurement systems. The application studied here is Unmanned Aerial Vehicle (UAV) surveillance and reconnaissance in urban areas. Some work has been done in this general area (e.g., see [3] for a novel guidance law in windy urban environments combining pursuit and line-of-sight laws, and [5] for a multi-cost UAV mission path planner). Exploiting Dynamic Data Driven Application Systems (DDDAS) for large-scale, geographically distributed scenarios promises significant advantages, and we develop an approach that combines various types of information with associated uncertainty to enable model-driven active data acquisition (see [2] for an introduction to DDDAS).

Figure 1 shows our proposed overall organization of a dynamic data-driven GEOINT application system. Typical georeferenced visual and data products include: maps, charts, digital files, imagery and vector information. Value added items include: data verification, correction, updates, densification, reformatting, orthorectification, map finishing, seismic activity, intelligence reports, and additional categories of content [4].

This research has led to two major research results: (1) the efficient combination of formal probabilistic logic methods with state-of-the-art physics-based uncertainty quantification methods, and (2) uncertainty driven active information data acquisition, demonstrated by UAV path planning, to optimize performance or to resolve contradictory information. In summary, *BRECCIA* is a dynamic, multi-agent uncertainty monitoring and reduction system; that is, uncertainty can arise due to a change in local conditions (e.g., the weather may make movement difficult) or new information may be available (e.g., obscurants in the air, new interesting sites). As a consequence, steps are taken to reduce the uncertainty of assessments, and transparent and precise reasons are offered to the user to explain uncertainty conditions and how they may be resolved.

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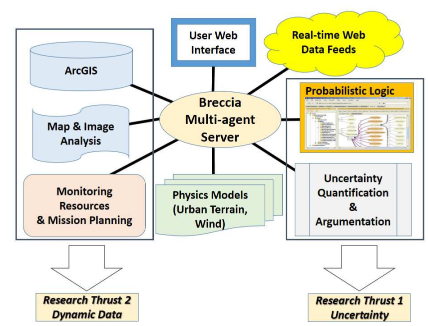

Fig. 1. *BRECCIA*: Uncertainty Quantified GEOINT and Planning.