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TECHNICAL REPORT

The Knowledge Matrix Approach to Intelligence Fusion

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Prepared for the United States Army

Approved for public release; distribution unlimited



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The research described in this report was sponsored by the United States Army under Contract No. W74V8H-06-C-0001.

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Published 2007 by the RAND Corporation
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Summary

As the military transforms into an information-based force, it will need processes and methods to collect, combine, and utilize the intelligence that is generated by its assets. The process known as *fusion* will play an important role in determining whether this intelligence is used in the most beneficial manner to support the military's vision of an information-centric force.

The process of fusion, combining pieces of information to produce higher-quality information, knowledge, and understanding, is often poorly represented in constructive models and simulations that are used to analyze intelligence issues. However, there have been efforts to rectify this situation by incorporating aspects of information fusion into combat simulations. This report describes one approach to capturing the fusion process in a constructive simulation, providing detailed examples to aid in further development and instantiation.

The analytical method proposed here is a sequential process of determining the quality of a piece of information and the likelihood that two pieces of information concern the same entity¹ or, indeed, two separate entities. The process entails putting the observations through a sequence of operations to determine whether they (1) are close enough geographically² with respect to their separate errors in location to be of the same entity, (2) have consistent identities that would not prevent them from being considered the same entity, and (3) contain information content of high enough quality to warrant the combination.

Once two observations have passed these three tests, a combination process determines the fused product. In cases in which additional information about an entity is generated—for example, knowledge of the location of a superior unit gleaned from knowing where the subordinate is—the process is able to capture the information in the common operational picture (COP). Higher-level fusion, such as the generation of aggregates, is also captured in the fusion process.

The fusion process provides a means of adding information to the COP and, in doing so, quantifies the quality of individual and combined intelligence, as well as higher-order fusion products. The fusion process described in this report is, for the most part, an implicit representation of the generation of battlefield intelligence and can be used in a constructive simulation or fusion model to better understand the dynamics of intelligence-gathering systems and their effect on intelligence metrics. Where explicit representations of fusion also exist, such as in the case of the generation of location information, both representations are included. The process includes descriptions of stochastic as well as deterministic representations. The representations

¹ *Entity* is used loosely in this report. We include in this definition all common entities, such as vehicles and buildings, as well as more nebulous entities, such as events and relationships.

² *Close enough* can also include temporality for moving objects.

in this report are largely reflective of intelligence fusion in the physical domain; other aspects of the human and information domains (e.g., intent) are included, though in-depth exploration of these is outside the scope of this work.

The approach described in this report is largely reflective of the work of Keithley (2000), and our research group has incorporated it into a stochastic, agent-based simulation to help with the analysis of C4ISR systems and concepts for the Army. However, we describe here much of the method and calculus involved to aid in further development and inclusion into future military simulations.