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Documentation of Uncertainty of Information (UoI) Management Software

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14. ABSTRACT
This technical note documents the structure of a software system for an efficient management of uncertainty of information (UoI) to potentially aid in decision-making. This UoI is generated from reasoning modules.

15. SUBJECT TERMS
Military Information Sciences, artificial intelligence, AI, agent-based systems, uncertainty of information, UoI, reasoner, Sentry Agents, SAGE

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1. Introduction

This technical note documents software for management of uncertainty of information[1] (UoI) from reasoning modules. It describes the generation and ingestion of UoI from one or more reasoning modules. Following ingestion, relevant information is extracted and interpreted to compose a comprehensive message. This message is dynamically generated and made available to potentially aid in decision-making. The generated message conforms to the enhanced tactical inferencing[2,3] (ETI) schema. Sentry Agents[4] (SAGE) framework from the U.S. Naval Research Laboratory has been utilized to develop specialized software agents.

2. Implementation Details

This section describes the main classes that are present in the software.

2.1 Class InfoSimulation

This class is a SAGE-based behavior that can be used to exchange messages amongst agents and simulate network traffic.

Class InfoSimulation method summary

Modifier and type	Method and description
boolean	**action**(nrl.sage.BehaviorInterface.Result result) This method is responsible for the exchange of messages between the agents. **Parameters:** result - Result object to carry information about the result of method execution. **Returns:** Boolean value indicating the result of method execution.
boolean	**message**(nrl.sage.BehaviorInterface.Message message, nrl.sage.BehaviorInterface.Result result) This method is called each time a message is received by the agent. **Parameters:** message - Java class that represents a message sent between SAGE agents for communication. result - Java class that represents the outcome of the execution of the message method. **Returns:** Boolean value indicating the result of method execution.
void	**readFile**() This method is called to read file contents from a Jar file and save it in an internal store.
boolean	**setUp**(nrl.sage.BehaviorInterface.Result result) This method is first called when agent becomes active.

	Parameters: result - SAGE Result object to carry information about the result of method execution. **Returns:** Boolean value indicating the result of method execution.
boolean	**tearDown**(nrl.sage.BehaviorInterface.Result result) This method is called when agent becomes inactive. **Parameters:** result - SAGE Result object to carry information about the result of method execution. **Returns:** Boolean value indicating the result of method execution.

2.2 Class InfoUoIReasoner

This class is SAGE-based behavior that performs reasoning based on the incoming information received from other agents.

Class InfoUoIReasoner method summary

Modifier and type	Method and description
boolean	action(nrl.sage.BehaviorInterface.Result result) This method is called by the agent after it becomes active. **Parameters:** result - SAGE Result object to carry information about the result of method execution. **Returns:** Boolean value indicating the result of method execution.
boolean	boolean message(nrl.sage.BehaviorInterface.Message message, nrl.sage.BehaviorInterface.Result result) This method is called each time a message is received by the agent. The message is parsed to check for topic and extract the payload that is used to monitor and gauge certain attributes of message exchange between other agents. These attributes are then used to compute a UoI taking certain factors/attributes into consideration. **Parameters:** message - Java class that represents a message sent between SAGE agents for communication. result - Java class that represents the outcome of the execution of the message method. **Returns:** Boolean value indicating the result of method execution.
int	generateUoIfromLatency(double latency) This method is used to compute a UoI value given the latency attribute. **Parameters:** latency - a measure for delay **Returns:** int denoting the UoI value
int	int generateUoIfromMessageLoss(double messageLoss) This method is used to compute a UoI value given the latency attribute. **Parameters:** messageLoss - A measure for loss of messages during message exchange. **Returns:**

	int denoting the UoI value
boolean	boolean tearDown(nrl.sage.BehaviorInterface.Result result) **Returns:** Boolean indicating the result of method execution.

2.3 Class CommsToMasterUoI

This application is responsible for establishing a connection to the SAGE server using the SAGE Remote Interface to send messages to the SAGE agent. This application can be used by external applications to send data to a SAGE-based agent in a predefined format.

Class CommsToMasterUoI method summary

Modifier and type	Method and description
boolean	connectToSage(java.lang.String info) This method uses the SAGE Remote Interface. It instantiates a remote connection object to connect to the SAGE server instance at the specified IP/port. **Returns:** Boolean indicating failure/success of connection.
boolean	performInputChecks() This method is responsible for verifying the data is in an acceptable format before ingestion. **Returns:** Boolean indicating the result of method execution.
void	printHelp() This method prints out the format of the data accepted by this application.
boolean	processText(txt) This method verifies the format of the text as "Topic;Message" pair. **Parameters:** txt – indicates text to be processed
boolean	sendMsg() This method instantiates a SAGE Message object, assigns appropriate value, and communicates the Message to the appropriate SAGE agent. **Returns:** Boolean indicating the result of method execution.
boolean	sendToMasterUoI(String stringToMaster) This method is responsible for verification of the message in an appropriate format. Once verified, it invokes and send the message to SAGE agent. **Parameters:** stringToMaster – String to be verified and communicated to the other agent.

2.4 Class MasterUoIReasoner

This class is implemented as a SAGE-based behavior. It stores and manages UoI from heterogeneous modules or sources that generate UoI. It can compose a comprehensive message with the current UoI(s) received from different modules.

Class MasterUoIReasoner method summary

Modifier and type	Method and description
boolean	**action**(nrl.sage.BehaviorInterface.Result result) This method is called by the agent after it becomes active. **Parameters:** result - SAGE Result object to carry information about the result of method execution. Returns: Boolean indicating the result of method execution.
String	constructETIMessage() This method constructs an eXtensible Markup Language (XML)-based message that conforms to ETI message schema. The ETIMessageGenerator class is used for message generation. The generated message outlines UoI and related information from all the active UoI generating modules. **Return:** String - XML-based ETI message.
ArrayList<String>	getCurrentInfoStats() This method provides the current UoI information from the Information reasoning module. **Parameters:** ArrayList - containing UoI and related information generated from Information reasoning module.
ArrayList<String>	getCurrentNetworkStats() This method provides the current Network UoI information. **Parameters:** ArrayList - containing UoI and related information generated from Network Reasoning module.
ArrayList<String>	getCurrentSpotReportStats() This method provides the current Spot report UoI information. **Parameters:** ArrayList - containing UoI and related information generated from Spot report Reasoning module.
double[]	getLastestUoI() This method provides the current UoI information. **Returns:** double [] array of current UoIs from different modules.
boolean	message(nrl.sage.BehaviorInterface.Message message, nrl.sage.BehaviorInterface.Result result) This method is called each time a message is received by the agent. The message is parsed to check for topic and extract the payload. The topic can indicate status check on UoI or addition of new UoI values. **Parameters:** message - Java class that represents a message sent between SAGE agents for communication.

	result - Java class that represents the outcome of the execution of the message method.
void	sendMessagetoTakAgent(java.lang.String targetNodeName, java.lang.String targetAgentName, java.lang.String sourceAgentName, java.lang.String topic, java.lang.String msg) This method is used to send a message to SAGE-based agent. **Parameters:** targetNodeName - SAGE Node name where the target agent belongs. targetAgentName - Name of agent to which the message has to be sent. sourceAgentName - Agent Name of the message sender topic - Topic of the message msg - Message payload
boolean	setUp(nrl.sage.BehaviorInterface.Result result) This method is first called when agent becomes active. **Parameters:** result - SAGE Result object to carry information about the result of method execution.
boolean	tearDown(nrl.sage.BehaviorInterface.Result result) This method is called when agent becomes inactive. **Specified by:** tearDown in class nrl.sage.BehaviorInterface.SageBehavior **Parameters:** result - SAGE Result object to carry information about the result of method execution.
boolean	writetoCurrentDirectory(java.lang.String msg) This is a utility method to write string to current working directory. **Parameters:** String to be written to a file **Returns:** Boolean indicating the result of method execution.

2.5 Class ETIMessageGenerator

This class generates ETI Messages. ETI Message is an XML-based message conforming to a schema that outlines information generated by reasoning module(s).

Class ETIMessageGenerator field summary

Field Name	Field Detail
ETIMessage	ETI Message object
rm	Reasoning Module object contained within ETI Message object
Header	Header of ETI Message

Class ETIMessageGenerator field summary

Modifier and type	Method and description
void	addReasoningModule(String modName, String timestring, String uoiVal, String rec, String just, String color, String tax) This method can be used to add UoI information from a reasoning module within the ETI Message. It creates a new reasoning module object, sets the information related to the reasoning module object. An ETI Message can contain one to several reasoning module objects. **Parameters:** modName - name of the Reasoning module timestring - represents the time UoI value was generated by the Reasoning Module. uoiVal - represents the UoI value rec - represents the recommendation from the Reasoning module based on the UoI value. just - represents the justification for the recommendation from the Reasoning module. color – denotes the color depending on the UoI value tax - denotes the taxonomy of Uncertainty that contributes to the generation of UoI value
String	String generateETIinXML() This method generates the ETI Message in XML from the ETIMessage object.
String	String generateETImEssageinCoT() This method generates the ETI Message in XML from the ETIMessage object. The ETI Message in XML is then encapsulated within a basic Cursor on Target (CoT) message.
String	String getHeader() Retrieves the header of ETIMessage **Returns:** header
void	public void setHeader(String hdr) Set header of ETIMessage **Parameters:** hdr - header

3. Conclusion

This technical note describes an initial version of a software to manage UoI. It utilizes remote interfaces from the SAGE framework for integration among heterogenous software systems. This software will continue to be augmented; thus, this note will need to be updated to reflect any new capability added in the future.

4. References

1. Gershon N. Visualization of an imperfect world. IEEE Comput Graph Appl. 1998;18(4):43–45.

2. Raglin A, Richardson J, Mittrick M, Metu S, Caylor J. Enhanced tactical inferencing (ETI): a decision recommendation framework. Proceedings of SPIE Defense + Commercial Sensing; 2022 June 6; Orlando, FL. SPIE. https://doi.org/10.1117/12.2622319

3. Raglin A, Metu S, Lott D. Challenges of simulating uncertainty of information. Proceedings, Part I of 22nd International Conference on Human–Computer Interaction; 2020 July 19–24; Copenhagen, Denmark. Springer; c2020. p. 255–261.

4. U.S. Naval Research Laboratory. SAGE user guide 3.0.3. Naval Research Laboratory (US); c2024. https://usnavalresearchlaboratory.github.io/sageframework/

List of Symbols, Abbreviations, and Acronyms

CoT	Cursor on Target
ETI	enhanced tactical inferencing
SAGE	Sentry Agents
UoI	uncertainty of information
XML	eXtensible Markup Language

1 (PDF)	DEFENSE TECHNICAL INFORMATION CTR DTIC OCA
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