A semantic framework for UAV interoperability based on STANAG 4586 standard

MSc thesis presentation
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Outline

• Introduction
• Problem Description
• Proposed Framework
• Application
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• Simulation Results
• Conclusion
Introduction

• An Unmanned Aerial Vehicle (UAV) aims for the accomplishment of mission objectives.
  ▫ operates autonomously or under remote control
  ▫ alternative to manned aircrafts
    • cost effective
    • low risk
• However, a UAV is more than a mechanical device designed to accomplish a task.
  ▫ Is part of a combined service environment of various deployed UAV systems (UAS)
Problem Description

• Current UAS are “stove-piped”
  ▫ proprietary software and architecture
  ▫ system-specific datalinks
  ▫ unique communication protocols

• Heterogeneity of diverse UASs
  ▫ impedes communication
  ▫ hinders cooperation
  ▫ requires complex infrastructures

Interoperability is emerged as the most important policy to be achieved.
The concept of Interoperability

- Interoperability is characteristic of a system that can work with other systems
  - without restrictions
  - by the use of standards
- Armed Forces defines military interoperability
  - ability of nations to operate effectively together
  - achievement of a common task
- NATO proceeded to specification of STANAGs
  - address technical issues for UAV interoperability
NATO STANAG 4586

- The STANAG 4586 standard
  - specifies the architecture of an interoperable UAV Control System (UCS)
    - interfaces
    - functional elements
  - defines DLI and CCI interfaces
    - common data elements
    - generic message formats
  - Increases efficiency to mission accomplishment
    - mutual control
    - integration
    - joint utilization of information
Thesis Proposal

• **Objective**
  ▫ Implementation of a STANAG 4586 compliant Ground Control Station (GCS)
    • capable of communication with different UAVs and GCSs
    • via STANAG DLI protocol

• **Solution**
  ▫ A semantic framework for STANAG message (de)serializing
    • based on an OWL ontology
    • enables semantic interoperability between UAS elements
    • leveraged by STANAG 4586 specification
    • applicable by different UAV platforms e.g. ROS, JAUS, MAVLINK

• **Application**
  ▫ A proof-of-concept system implementation that sends STANAG messages to control a MAVLink protocol UAV (MAV)
    • STANAG to MAVLink translation
    • borrows from UCS architecture

• **Challenges**
  ▫ Analysis of STANAG 4586 specification
    • extensive documentation
    • avionics, military and technical terminology
  ▫ STANAG to MAVLink bridge implementation
    • familiarization with MAVLink protocol
    • STANAG to MAVLink message mapping
      • not direct match
      • much of STANAG information is redundant to MAVLink
Domain Knowledge

- **Methodology**
  - Knowledge acquisition
    - about concepts on the domain of UAV systems
    - collection of informational sources
      - NATO STANAG 4586 specification document
      - technical manuals and STANAGs e.g. STANAG 7085
  - Specification and vocabulary construction
    - name entities extraction for the ontology design
      - based on the terminology of STANAG 4586
      - best practices for the naming of terms
  - Conceptualization
    - Models the domain concepts and identifies the relations between them
    - Definition of axioms and constraints
      - Universal, existential, cardinality and hasValue restrictions
      - Equivalent and disjoint classes
      - Specialization and field-specific relation types e.g. identity, reversibility
  - Ontology evaluation
    - By domain experts and automated reasoning tools (e.g. FaCT++)
    - Criterions e.g. clarity, consistency, coherence and minimal encoding bias
Ontological Model

ONTO_STANAG_4586 ontology

- A common formal vocabulary for:
  - architecture of a UCS
  - messages exchanged with UAV/external agents
  - level of interoperability each communication achieves
  - operational elements of a UAS

- Developed for use in the message communication between a GCS and a UAV
  - describes the structure of a message type and the information it stores

- Expressed in OWL
  - added expressiveness compared to other representation languages e.g. UML
  - reliable check using OWL reasoners

- Edited using Protégé

- Some metrics: 116 concepts, classified in 25 main classes, related by 45 object properties and 30 data attributes
The ONTO_STANAG_4586 ontology
STANAGOntoLib (1/2)

- A Semantic Web library for (de)serializing DLI messages
  - an encoded STANAG message as result of serialization process
    - given the input control data
  - a structure with the message’s data as result of deserialization process
    - given the encoded STANAG packet

- Enables communication between diverse UAVs
  - by exchanging STANAG messages

- Exploits the ONTO_STANAG_4586 ontology
  - to extract the schema of a certain message type
    - by SPARQL queries execution
Implementation

- A Java library with dependencies of:
  - .owl file of ONTO_STANAG_4586 ontology
  - ONT-API framework
    - a implementation of OWL-API over Apache Jena
    - solves the request of SPARQL query execution on an OWL ontology graph

- Conformed to the STANAG 4586 specification for the representation of data
  - standards e.g. time or earth position references
  - packaging, i.e. byte ordering
  - format e.g. the ID number of a UAS element
  - metric units
System Architecture

[Diagram showing a system architecture with various components and protocols.]

Operator -> <device> -> <web browser> -> <<Application Server>> -> GlassFish Server Container

<execution environment> -> Android

DroneApp.apk

<<components>> STANAVLib.jar

Use

<device> -> <protocol> -> UDP/5445

MA/Link msg

<device> -> <protocol> -> HTTP

<device> -> <protocol> -> STANAO msg

<<components>> STANACOntoLib.jar

<<components>> ontology.owl

Use

Java SE

<<execution environment>> -> VSMProcessApp.jar
System Components

CUCSWebServer

- A web graphical interface that imitates a STANAG 4586 compliant GCS
  - enables operator to control different types of UAVs
  - by sending the appropriate DLI messages

- Integrates functionality of STANAGOntoLib

- Communicates with VSMProcessApp over UDP/IP
  - through transmission of STANAG packets
System Components

VSMProcessApp

- An intermediate processing node for vehicle-specific operation
  - STANAG to MAVLink message translation
    - First-half matching – from a STANAG message to a STAMAVMessage object

- A Java UDP client/server
  - receives encoded STANAG messages
  - transmits vehicle-specific packets

- Integrates
  - STANAGOntoLib
  - STAMAVLib

- Overcomes compatibility problems of STANAGOntoLib’s integration to an Android-based mobile device
**System Components**

**STAMAVLib**

- A STANAG to MAVLink mapping library
  - definition of STAMAVMessage class
    - a common interface
    - implements Java Serializable class
  - a translation bridge from STANAG to MAVLink
    - binary data unit with control data of a STANAG message

- Translation issues:
  - not a 1 to 1 matching
  - different parameters for each protocol
  - much of STANAG information is redundant to MAVLink

- Enables communication
System Components

DroneApp

- An android application that acts as a hand-held mobile GCS
  - communicates with the UAV’s autopilot
  - via MAVLink protocol
- Performs the “second half” of STANAG to MAVLink translation
  - from a STAMAVMessage object to a MAVLink message
- An UDP server:
  1. receives serialized STAMAVMessage packets
  2. implements the matchings based on the type of serialized object
  3. generates the MAVLink messages and sends them to the UAV
- Integrates
  - STAMAVLib
  - DroneKit SDK
- DroneApp GCS implements Waypoint sub-protocol of MAVLink
Evaluation

- Simulation of a flight mission in which operator controls a quadcopter MAVLink protocol UAV by sending STANAG messages
  - using SITL simulator
  - MAVProxy

- A predefined flight scenario
  - based on the capabilities of implemented software

- Experimentations check system’s:
  - proper functioning

- Positive flight tests validate system for:
  - feasibility
  - stability during protocol translation
Conclusion (1/2)

Contributions

• An ontology-based system by means of Semantic Web technologies
  ▫ addresses the achievement of interoperability among UAVs
  ▫ proposes an innovative approach to the development of a UCS

• ONTO_STANAG_4586 ontology
  ▫ comprehensive representation model
    • consistent and logically sound based on reasoning tools applied
    • first attempt in recent research
  ▫ applicable in the STANAG 4586 message communication

• STANAMGOnLib
  ▫ an important asset for compliance with STANAG 4586
    • enables the ability of interpreting STANAG messages
    • increases semantic interoperability
    • integrable as external library
Conclusion (2/2)

Contributions (cont’d)

• Verification of STANAG 4586 practicability
  ▫ achievable communication protocol, yet highly complex
    • heavily demanding in terms of compliance
    • strong investment
  ▫ a network-enabled architecture without considering constraints in communication

Future Work

• Extension of ONTO_STANAG_4586 ontology with domain knowledge of existing ontologies
• Integration of the already implemented STANAG to MAVLink bridge
  ▫ system performance improvement
Questions?
Thank you ☺