Abstract

Holistic Modeling of Drone Behavior for Analyzing Safety and Security Aspects in Complex Environments

Timur Topal[1], Maximilian De Muirier[1], Konstantin Gosch[2], Sehrish Shafeeq[3], Jutta Abulawi[1], Jan Mietzner[1], Tim Tiedemann[1], Christian Renner[2], Mathias Fischer[3]

[1]*University of Applied Sciences Hamburg, {firstname.lastname}@haw-hamburg.de;*
[2]*Hamburg University of Technology, {firstname.lastname}@tuhh.de;*
[3]*University of Hamburg, {firstname.lastname}@uni-hamburg.de;*

Safe operation of drones in complex urban environments is a pivotal challenge for future innovative air mobility (IAM) solutions. Hence, analyzing and addressing associated safety and security aspects – while covering a wide range of use cases and misuse cases – is of major interest. The governance of complex systems and associated safety and security aspects requires a holistic approach [1]. Suitable modeling and simulation techniques are needed to support system design by representing real-world solutions and scenarios with sufficient fidelity to support the exploration and analysis of design decisions during the development process [2]. Conventional model-based system engineering (MBSE) concepts focus on modeling system behavior and architecture to define systems which meet stakeholder requirements, but they do not support model-based exploration of safety and security aspects in early stages of system design. More recently, approaches for integrating standardized risk analysis methods, such as fault tree analysis or failure mode and effects analysis, in early system design phases have been suggested [3], [4].

To operate IAM solutions in complex environments, sophisticated system architectures are needed which include peripheral subsystems such as

- Sensor subsystem(s) for situational awareness and collision avoidance, e.g., based on radar and/or lidar sensors,
- Navigation and cooperative localization subsystem(s), e.g., satellite-aided and/or transponder-based,
- Wireless communication subsystem(s) for drone-to-drone and/or drone-to-X communication, e.g. based on secure data exchange protocols [5].

In our contribution, we aim to adopt a holistic approach to modeling drone behavior in complex environments. We will use a generic drone architecture and consider the aforementioned three subsystems in detail. A central system model shall be digitally connected to partial models representing drone subsystems and the operating environment. To reflect the state of the art in multidisciplinary system development, partial models will be created in various modeling environments, and some of these models will only describe subsystem behavior, but do not necessarily contain any architectural description. For some subsystems, no dedicated models may be provided

by the subsystem developers at all. Our holistic approach shall therefore be capable of integrating the heterogenous models as well as information on subsystems for which no models exist. The resulting federated model shall realistically represent the interactions of the drone subsystems with each other and with the environment. In this way, the drone behavior and its reactions to internal failures as well as to external threats can be continuously explored while its design is evolving. Fig.1 illustrates the projected reference implementation.

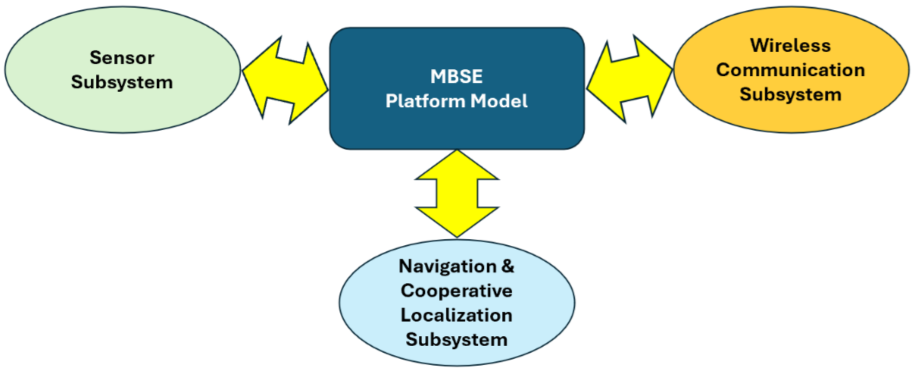

Fig. 1 – Drone behavior model composed of core MBSE platform model and three peripheral subsystems

In our contribution, we will present first results addressing two main challenges:

- A flexible modeling framework needs to be defined. It shall provide elements to holistically represent the overall system and associated threats. A capability is required to capture the behavior of subsystems which are not being developed with a model-based approach.
- Suitable bidirectional interfaces between the central system model and associated partial models of subsystems are required, to realistically represent the overall drone behavior. As all these models are created in different modeling environments (e.g., different tools, different modeling languages, different modeling methods), it is a major challenge to establish the required live bidirectional links. At the same time, the partial models need to be variable and parameterized to allow for the exploration of various system configurations.

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Biography

Jan Mietzner

Jan Mietzner was with Airbus DS (Ulm, Germany) from 2009 to 2017, where he was a technical project manager for radar developments. Since September 2017, he has been a full professor for communications engineering at the University of Applied Sciences (HAW) Hamburg. His research interests concern theoretical and practical issues of wireless communications, radar, and jamming systems.