Supporting Virtual Aircraft Certification via Provenance

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Virtual Aircraft Certification

New aircraft designs need to be certified as airworthy by certification agencies such as the FAA in the USA or the EASA in the EU. The certification process involves numerous tests of physical aircraft prototypes and demonstrators. This is very costly can lead to costs of one billion dollar [1]. **Virtual certification** (or certification by analysis) instead aims to demonstrate compliance with the regulations via computational models using digital validation techniques.

Contribution

- We consolidate the published obligations towards manufacturers.
- We formulate technical requirements that satisfy these obligations.
- We present provenance models that fulfil these requirements.

Obligations

Certification agencies as well as Subject Matter Experts (SMEs) have obligations and restrictions the design and certification process. FAA [2] and EASA [3] require the following information to be stored:

- All relevant aspects of the method and simulation
- All information to retrace the decisions, to understand the assumptions, and limitations with rational support
- Description of the analytical models, input data and results, processes and tools
- Software and hardware overview and versions

Storage obligations only stated by EASA:

- Experience level of staff
- The data shall be stored as long as the aircraft model is in use
- The information shall be easy to access, read and understand

Storage obligations only stated by FAA:

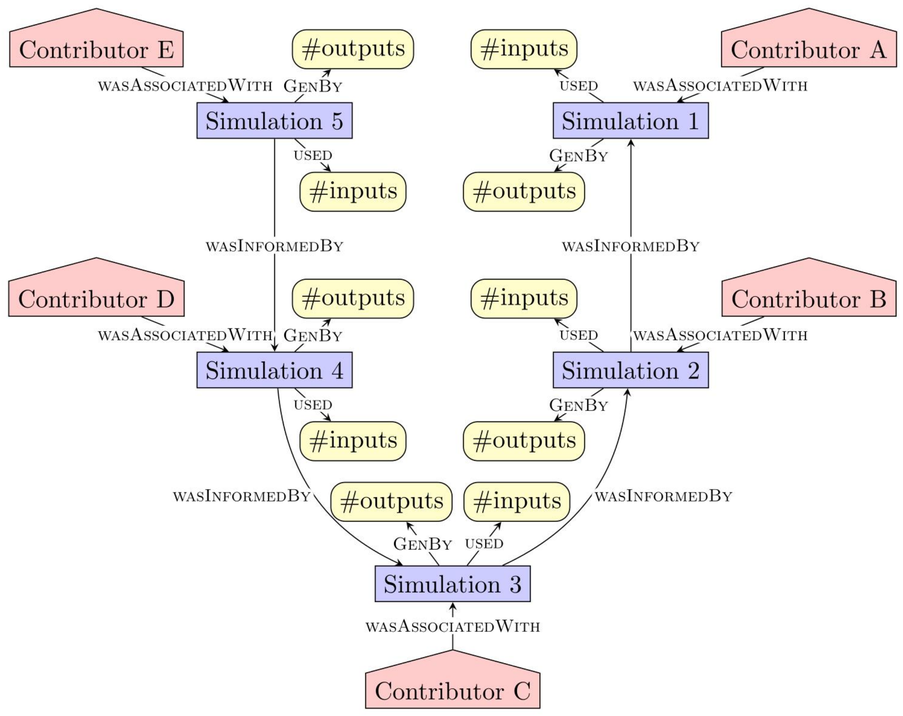
- The source of the external data
- General analysis control parameters with justifications

The SMEs have user-centric obligations, e.g. that it shall be possible to integrated it into existing systems with limited overhead. Further, trade secrets and intellectual property shall be protected.

Requirements

We have analyzed the obligations and identified the following requirements for a system supporting virtual certification:

- The system must store heterogeneous data in a structured way.
- Manual and automated data entry and retrieval are possible.
- The data must be stored in a human-readable way.
- No proprietary data formats nor software shall be required.
- Users can trace the origin of data artifacts and reproduce the computations producing them.
- The system must remain functional if only partial data is accessible.
- An interface for purpose-made analysis tooling is provided.



Example workflow provenance graph. This provenance graph shows the workflow between the contributors and is passed on to the certifier, who can then contact each agent to obtain its provenance graph of the simulations.

Provenance Models

To meet the identified requirements, we have created two provenance models: one to provide a high-level overview of the entire workflow and another to record the finer details of individual contributions.

Workflow Provenance Model

The workflow model records information about the relation of the individual simulation models. Each activity represents a top-level engineering step performed by some contributor, each of which is represented as an agent. The data exchanged between the contributors is represented by entities that hold a hash value of the data. Certifying agencies can use this model together with the simulation models to re-assemble the complete engineering workflow.

Simulation Provenance Model

The simulation model contains detailed descriptions of individual engineering steps. The simulation model remains with the contributor, as it contains detailed information about their working and must not be accessible to competitors. The only hard requirement is it models the data exchanged with other companies as entities.

Conclusions

Virtual design and certification of a complete aircraft is still a long-term goal of the aviation industry. **Integration of provenance can support regulatory compliance** by fulfilling many of the stated obligations and is therefore a promising approach. We have presented a **method for storing information relevant to virtual certification** such that the **intellectual properties of contributors are kept confidential**, but accessible to certifying agencies.
This will allow our system to simplify digital engineering and certification processes and thus make the development of novel aircraft and aircraft parts easier, cheaper and faster.

References

[1] T. Mauery *et al.*, “A guide for aircraft certification by analysis,” NASA, May 2021.
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[3] European Union Aviation Safety Agency, “Proposed Certification Memorandum on Modelling & Simulation – CS-25 Structural Certification Specifications.” Jul. 14, 2020. Available: https://www.easa.europa.eu/en/document-library/product-certification-consultations/proposed-certification-memorandum-modelling