Simulation-based Development of ADAS and Automated Driving with the Help of Machine Learning

Dr. Andreas Kuhn

MathWorks®
MATLAB EXPO 2017 DEUTSCHLAND
Fields of Competence
- Artificial Intelligence
- Data Mining
- Big Data Analytics
- Modeling and simulation
- Predictive Model based Control
- Distributed Control
- Signal Classification
- Swarm Intelligence
- (Embedded) Software
- Decision Support Systems
- Robustness and Complexity Management

Big Data Analytics & AI & Simulation

Failure prediction

Data driven development process

Anomalies and Incident Detection

Automotive safety

Vehicle and traffic automation

Industry 4.0, Digitalization

(Mobile) Robotics
Automated Guided Vehicle

Contact: A-5400 Hallein, Hallburgstraße 5, +43 6245 74063, office@andata.at, www.andata.at
Advanced Driver Assistant Systems and Automated Driving

Avoiding collisions by informing, warning, braking, steering, automated manoeuvres

- Which sensors are necessary for valid decisions in automated driving?
- What sensefull functions can be carried out with a given set of sensors?

© 2017, ANDATA
Problem Statement

- Number, diversity and complexity of safety systems increases steadily
- Do we still underestimate the complexity of integral safety systems?
- What is the minimum/best set of test cases to sufficiently describe/specify/evaluate the system behaviour?
- How can we be sure?
Sources of Complexity

- Human beings are part of the control loop now!
- Systems have to anticipate the anticipation of other traffic participants
- It’s about the difference between **subjective** and **objective danger** rather than about objective danger only
Sources of Complexity

- The problem is of stochastic nature!
- There are a lot of possibilities how a given situation can evolve
  - Action/reaction of driver/pedestrian
  - Scatter of environmental conditions
  - Uncertain vehicle conditions
- There is not one single certain Time to Collision (TTC)
- Time to Collision is a stochastic random variable
- Conditional probabilities: Bayes!

\[ p(TTC) \]

© 2017, ANDATA
Sources of Complexity

• The problem is mathematically instable!

  ➢ Even small changes in the initial/boundary conditions may lead to completely different collision conditions
Sources of Complexity

• Conflicting requirements
• Incomplete information
Consequences

• Taking a **probabilistic/stochastic** point of view
• Consequent **Top-Down** instead of Bottom-Up **system development**
• Analysis of **field effectiveness** instead of test effectiveness
• Increasing integration of **simulation** based development (scenario based approach)
• Broad application of **data driven** approaches (Big Data Analytics and Artificial Intelligence)

➢ Combined into **Integral Development Process**
➢ Almost completely carried out in MATLAB
The Core Principle for Algorithm Development

- Example based representation of functional requirements

Sensor signals

Time window

Algorithm

Desired action

Market driven > Requirements/Spec

Field of Effect

Sensors

Algo

Action

Effect! > Visible to customer

Neural Networks, Machine Learning

Functional requirement for algorithm:
- Which action to take when
- in which situations
- based on which sensors/information

© 2017, ANDATA
Example Based Representation of Functional Requirements

Sensor signals → Control Unit → Control Algorithm → Actorics

Situation_1

Situation_2

... ...

Situation_n

Warning

Braking

© 2017, ANDATA
Data Acquisitions from Fleet Data

© 2017, ANDATA
Scenario-Management and Development/Approval of Actions
Action Specification Based on „Decision Points“ with „Big Data Analytics“
Folding Various Decision Variables (e.g. collision probabilities)
Effectiveness Rating von Different System Variants
What is a requirements conflict for a control algorithm?

- In different situations, which induce the same sensor image, different actions are desired!

**Cluster analysis**

\[
\begin{align*}
&LC_{NF,1} \\
&LC_{NF,2} \\
&NoAct \\
&LC_{NF,n} \\
&MustAct \\
&LC_{MF,n} \\
\end{align*}
\]

**Numerical Conflict Analysis**
## ANDATA Solution Traffic Control

### Problem description
- Model based predictive control of traffic flows

### Solution approach
- Scenario- & data based specification of function
- Functional algorithms with Artificial Intelligence
- Multi-level, stochastic simulation
- System-Engineering
- Pattern recognition
- Machine Learning
- Virtual sensors
- Effectiveness rating
- ...

### Tools
- MATLAB
- Neural Networks Toolbox
- Statistics and Machine Learning Toolbox
- Div. ANDATA Toolboxes für MATLAB

© 2017, ANDATA
Problem description
• Development of control algorithms for mobile robots in industrial environments

Solution approach
• Scenario based approaches
• Sensor signal modeling
• Kinematic simulation
• „Intelligent“ algorithms for mapping, localization, path planning

Tools
• MATLAB, Simulink/Stateflow
• Neural Networks Toolbox
• Statistics and Machine Learning Toolbox
• MATLAB Compiler, MATLAB Coder
• var. ANDATA Toolboxes for MATLAB
ANDATA Software and Tools

**STIPULATOR**
- Data collection, preparation and normalization
- Data cleaning
- Sensor models
- Signal preparation
- Requirements definition ("labelling", etc.)

**BRAINER**
- Data analysis
- Training, adaption and evaluation of Machine Learning models
- Meta modelling, feature selection, etc.

**SCENE INSPECTOR**
- Scenario management
- Multilevel stochastic simulation
- Execution of distributed simulations

**EXPECTATOR**
- Data plausibilization
- Anomalies and incident detection

© 2017, ANDATA
Summary

- Scenario Management
- Operational Requirements Management
  - Conflict analysis
  - Proof of feasibility of the requirements
- Sensor concept evaluation and rating
- Effectiveness rating of system concept
- Design of experiments (What is the minimum test set to assure safe system functionality?)
- Virtual sensors, e.g. for estimation of collision probabilities
- Fast prototypical implementation
- Conform separation between specification and implementation
- Anomalies detection as quality assurance for simulation
- ...

➢ Extreme Development Procedures
  ➢ Extremely quick, efficient, effective

➢ Uniform, integral product development process for traffic automation

➢ Carried out completely in MATLAB

© 2017, ANDATA, several granted and pending patents
Conclusion

Extreme product development procedures with Big Data Analytics and Artificial Intelligence are not research anymore!

- Just do it! Tools are available for decades now
- MATLAB / Simulink / Neural Networks Toolbox

© 2017, ANDATA, several granted and pending patents
Thanks, for listening!

The singularity is near, let’s be prepared!

© 2017, ANDATA