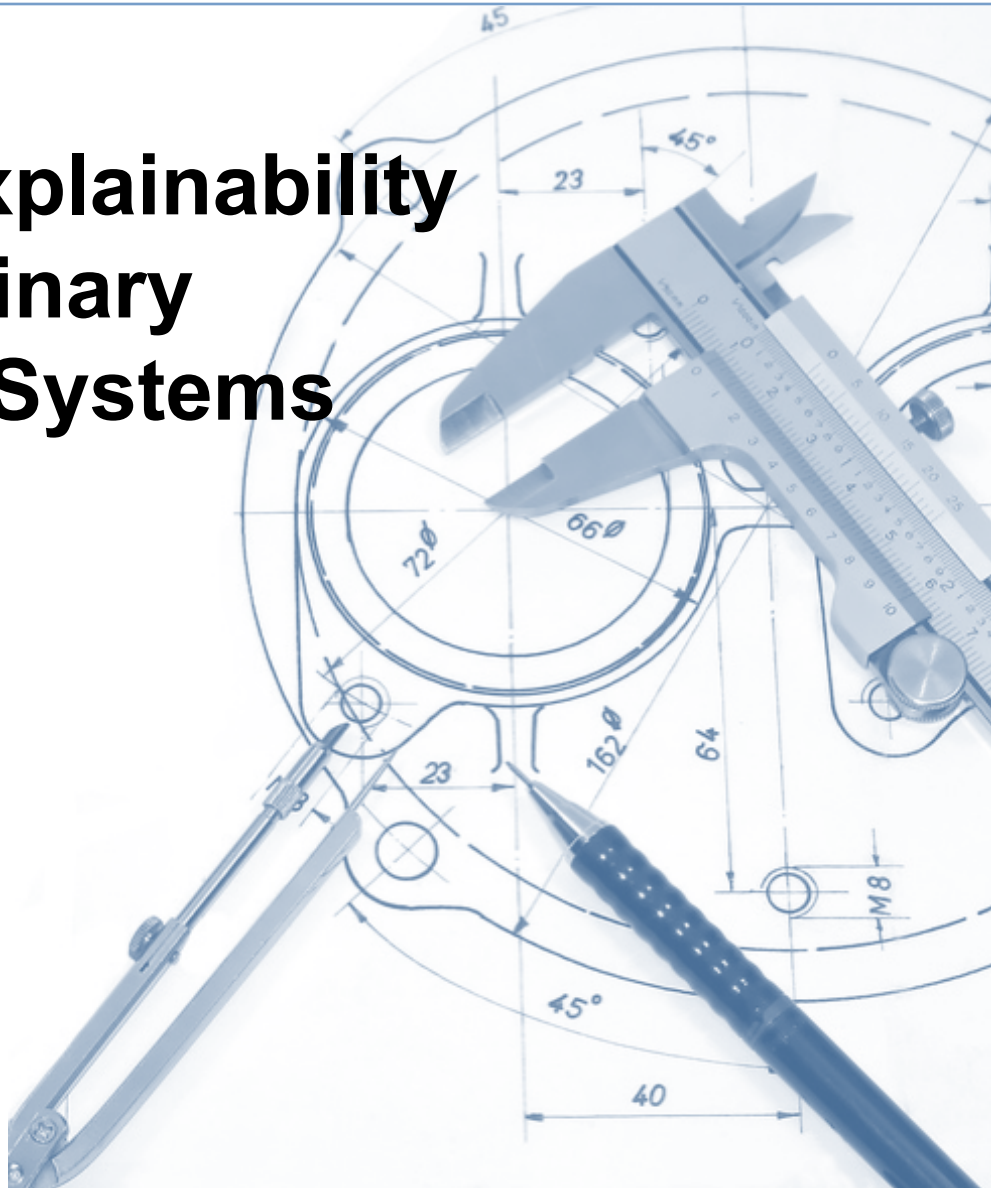
SE SOFTWARE ENGINEERING

RWTH AACHEN UNIVERSITY

Model-Driven Explainability for Multi-Disciplinary Cyber-Physical Systems Engineering

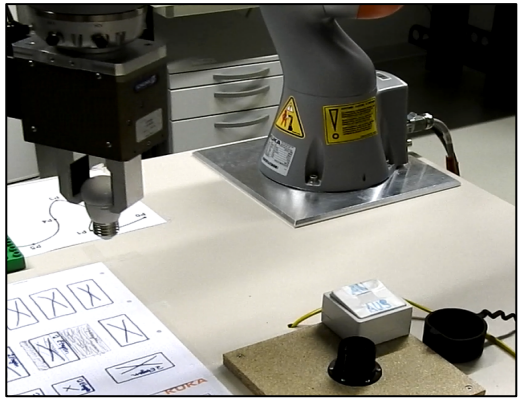


Andreas Wortmann
Software Engineering
RWTH Aachen

http://www.se-rwth.de/
@andwor

About me

- Since 2011 working with robotics
  - knowledge-based (Golog, …)
  - imperative (ROS, SmartSoft)
  - educational & industrial
- PhD'16 on extensible ADLs for CPS
- Currently work in model-driven systems engineering
- Language-oriented systems engineering
  - build proper software languages efficiently
  - tailor, reuse, integrate existing languages
  - across different technological spaces



The sad state of software explainability

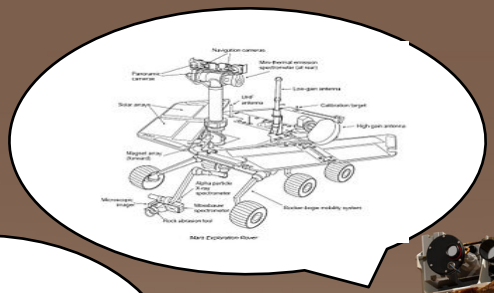
- Stack traces too technical for many purposes

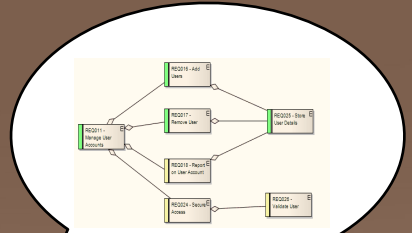
```
Run <Stacktrace>
W: java.lang.Throwable: stack dump
W:      at java.lang.Thread.dumpStack(Thread.java:490)
W:      at com.google.samples.apps.topeka.activity.SignInActivity.onCreate(SignInActivity.java:53)
W:      at android.app.Activity.performCreate(Activity.java:6237)
W:      at android.app.Instrumentation.callActivityOnCreate(Instrumentation.java:1107)
W:      at android.app.ActivityThread.performLaunchActivity(ActivityThread.java:2369)
W:      at android.app.ActivityThread.handleLaunchActivity(ActivityThread.java:2476)
W:      at android.app.ActivityThread.-wrap11(ActivityThread.java)
W:      at android.app.ActivityThread$H.handleMessage(ActivityThread.java:1344)
W:      at android.os.Handler.dispatchMessage(Handler.java:102)
W:      at android.os.Looper.loop(Looper.java:148)
W:      at android.app.ActivityThread.main(ActivityThread.java:5417) <1 internal calls>
W:      at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:726)
W:      at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:616)
```

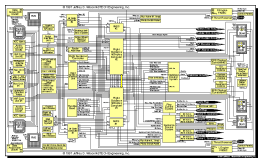
- Log files too verbose, not abstract enough, not reader-specific

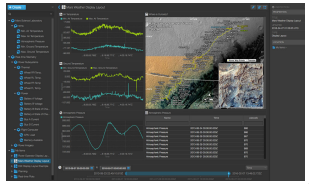
Log File Detail

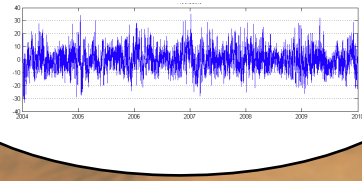
Line	Seq No.	Date	Source	Thread...	Severity	Event Id	Text
1	8	5/09/2011 12:09:25....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 194.28.7...
2	10	5/09/2011 12:09:28....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 194.28.7...
3	12	5/09/2011 12:12:40....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 222.36.7...
4	14	5/09/2011 12:14:55....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 64.62.19...
5	16	5/09/2011 12:19:08....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 49.238.2...
6	18	5/09/2011 12:19:10....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 49.238.2...
7	20	5/09/2011 12:25:54....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 81.89.5.5...
8	22	5/09/2011 12:28:10....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 115.68.2...
9	24	5/09/2011 12:28:13....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 115.68.2...
10	26	5/09/2011 12:35:04....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 146.145....
16	38	5/09/2011 13:19:09....	WinGate NAT	248	Info	2	Authorisation failure: NAT STATUS: firewall block: TCP src 124.114....

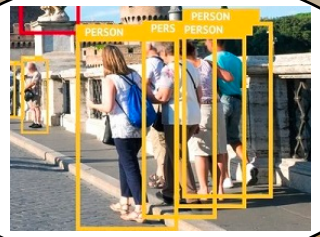

Navigation cameras
Mini-thermal emission spectrometer (all rear)
Panoramic cameras
Low-gain antenna
Solar array
UHF antenna
Calibration target
High-gain antenna
Magnet array (dumped)
Alpha particle X-ray spectrometer
Microscopic imager
Moessbauer spectrometer
Rock abrasion tool
Rocker-bogie mobility system
Mars Exploration Rover

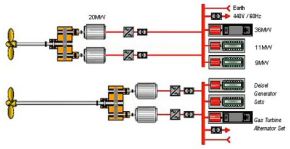

REQ016 - Add Users
REQ011 - Manage User Accounts
REQ017 - Remove User
REQ025 - Store User Details
REQ015 - Report on User Account
REQ024 - Secure Access
REQ026 - Validate User

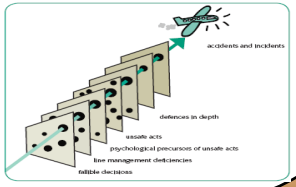


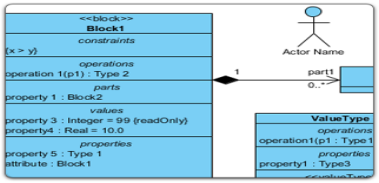


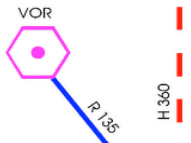

40
30
20
10
0
-10
-20
-30
-40
2004
2005
2006
2007
2008
2009
2010


PERSON
PERSON
PERSON
PERSON


20MW
Earth
440V / 60hz
36MW
11MW
9MW
Diesel Generator Set2
Gas Turbine Alternator Set


accidents and incidents
defences in depth
unsafe acts
psychological precursors of unsafe acts
line management deficiencies
fallible decisions


<<block>>
Block1
constraints
{x > y}
operations
operation 1(p1) : Type 2
parts
property 1 : Block2
values
property 3 : Integer = 99 {readOnly}
property4 : Real = 10.0
properties
property 5 : Type 1
attribute : Block1
Actor Name
1
part1
0..*
ValueType
operations
operation1(p1 : Type1
properties
property1 : Type3


VOR
R 135
H 360


Security Policy
User Education, Application Updates & Passwords
Web Security & Filtering
Hosting Security
Email Security & Filtering
Firewalls
Anti Malware
Disaster Recovery
Data Backup
Your Data
Local & Off Site
Business Continuity
Clients, Servers & Mobile Devices
Gateway & Patching & Backup
Spam, Viruses, Phishing & Backup
POAs, Smart Phones & Laptops
Browsing & On-Line Activities

Software language engineering gives us better tools to explicate intent and purpose than pure code

- ”The limits of my language are the limits of my world” (Wittgenstein)
- Stakeholders of CPS speak different languages and give explanations in different languages
  - ➢ so do their software modules
- Understanding emergent system behavior requires understanding all related modules
- In a way that supports
  - reasoning about facts (what)
  - contrasting observations (why)
  - Enquiring intentions (how)
- Suitable modeling languages can support CPS explainability at run time and at design-time

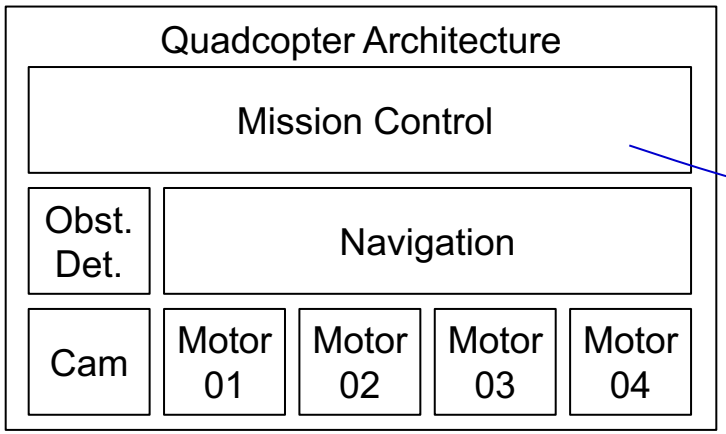
Towards explanation languages for multi-disciplinary cyber-physical systems

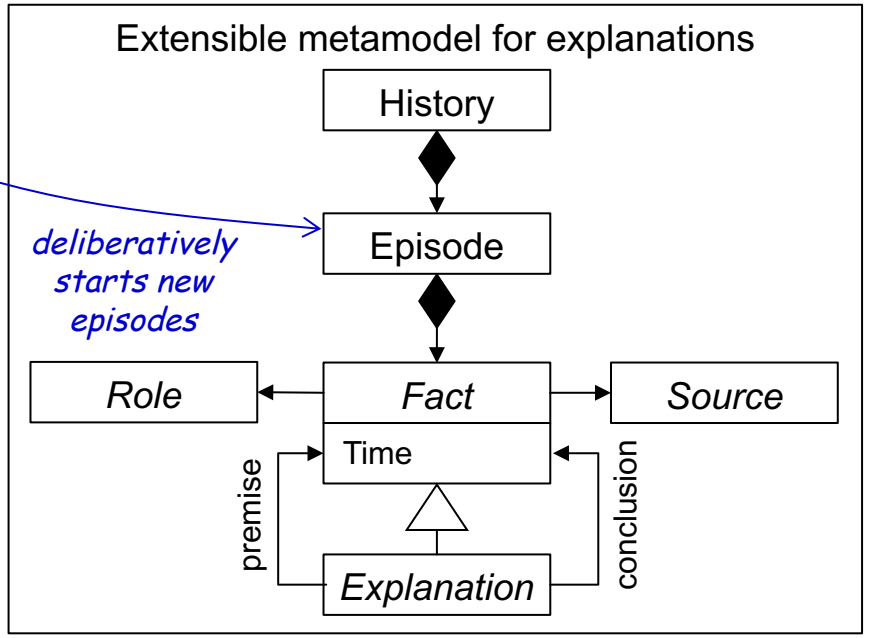
- Modeling languages that describe explanation (parts)
  - to explain behavior based on lower level facts and explanations (F&E)
- Either general (e.g., ATL) or domain-specific explanation languages[1]
  - former better integratable, latter better accessible, demand integration
- Systems produce histories = ordered lists of F&Es in suitable languages
- F&E yield meta information (source, purpose) to reason about system behavior (*e.g., "show all crash-related info but abstract from battery"*)
- Such explanation should be
  - receiver-specific (propulsion expert no interest in HMI explanation parts)
  - message-specific (e.g., by giving meaning stack trace segments)
  - time-specific (e.g., truncate irrelevant explanation parts)
- Across models of different domains
- Throughout the complete system lifecycle

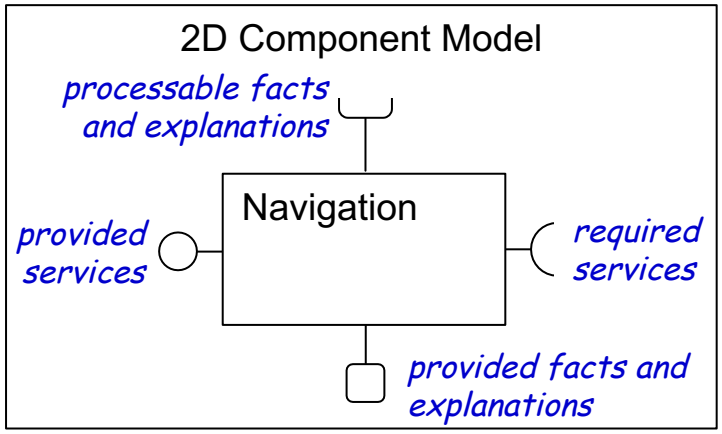
[1] K. Hölldobler, B. Rumpe, A. Wortmann. Software Language Engineering in the Large: Towards Composing and Deriving Languages. In: Computer Languages, Systems & Structures, 54, 2018.

A 2D component model to explain the behavior of a package delivery quadcopter

- Systems engineering leverages component-based notions
- Explanations as 1st level concerns in component (meta) model



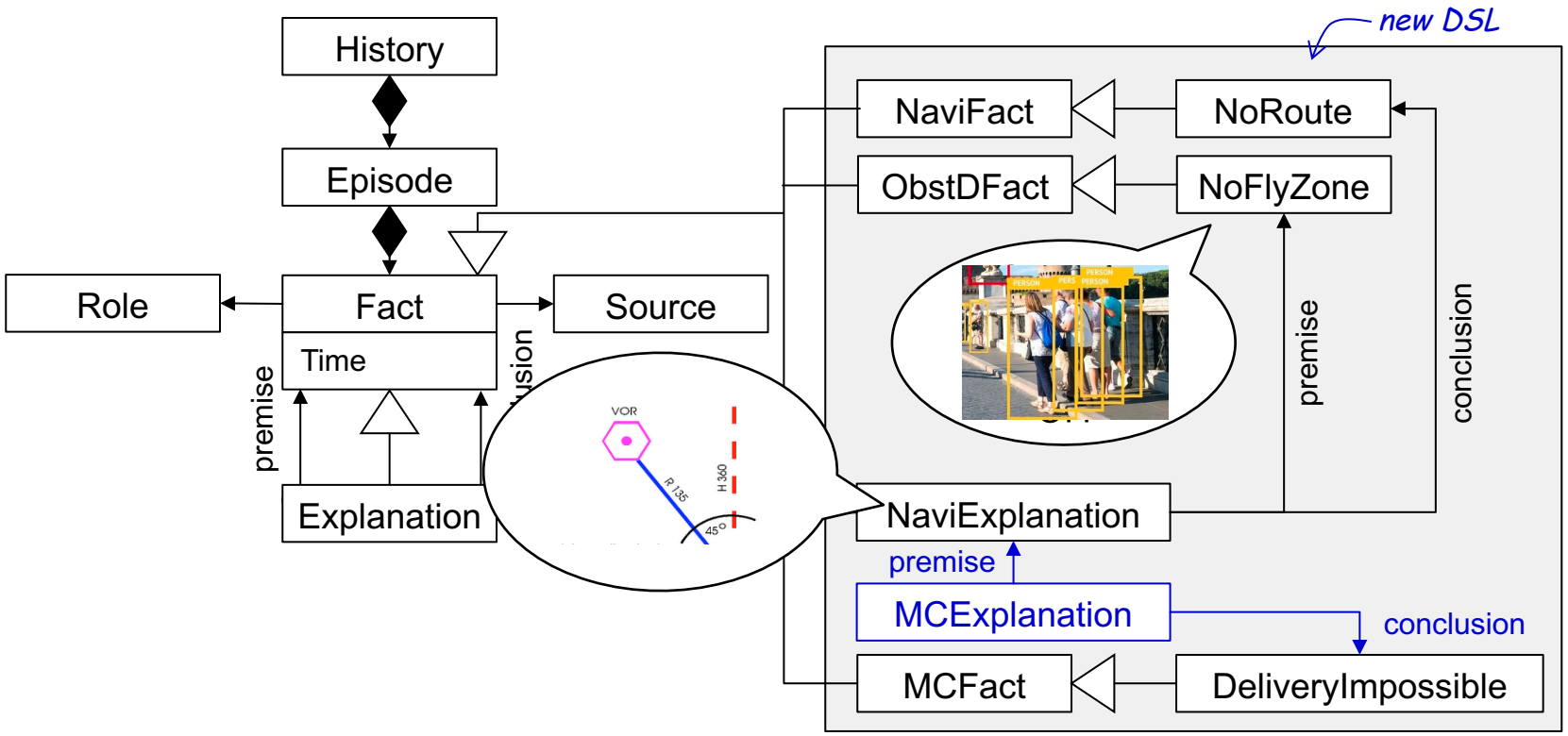




- Architecture supports operating on F&E
- Metamodel supports tailoring to domain-specific F&E

A 2D component model to explain the behavior of a package delivery quadcopter

- Domain-specific instantiation of the quadcopter explanation language (e.g., language embedding[1] or merging[2])



[1] K. Hölldobler, B. Rumpe, A. Wortmann. Software Language Engineering in the Large: Towards Composing and Deriving Languages. In: Computer Languages, Systems & Structures, 54, 2018.

[2] Degueule, T., Combemale, B., Blouin, A., Barais, O., & Jézéquel, J. M. Melange: A meta-language for modular and reusable development of DSLs. In Proceedings of the 2015 SLE. 2015.

There are many challenges in explainable software for cyber-physical systems…

- Capturing and integrating facts & explanations of different domains
- Efficient adaptation between F&E of different components
  - normal system integration activity?
- Automatically deriving explanations
- A posteriori explainer integration into existing (legacy) systems
- Automated abstraction and history truncation of explanations
- Cooperative / partial explanations

⇨ … to achieve any of these, we first need explicit explanations

Our answers to workshop-related questions

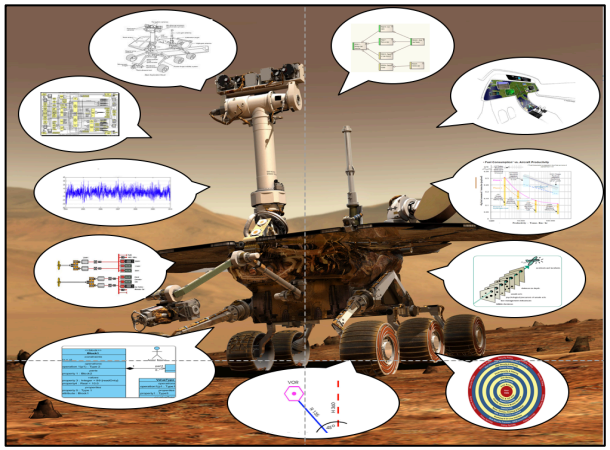
- ES4CPS problems that we are interested in
  - making explanations explicit
  - leveraging explicit explanations at run time
  - querying explanations (facts, contrasts, …)

- ES4CPS expertise that we can contribute
  - modular software language engineering
  - smart manufacturing, automotive software testing, robotics
  - formal systems modeling (focus, mona, isabelle)

- External expertise that we need
  - domain-specific insights into explanations
  - multi-disciplinary modeling
  - reasoning about explanations

Andreas Wortmann
Software Engineering
RWTH Aachen

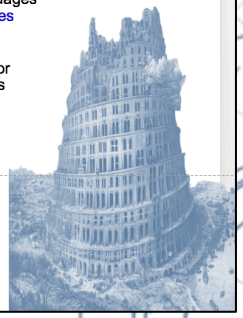
Thank You



Andreas Wortmann
Software Engineering
RWTH Aachen
Slide 6

Software language engineering gives us better tools to explicate intent and purpose than pure code

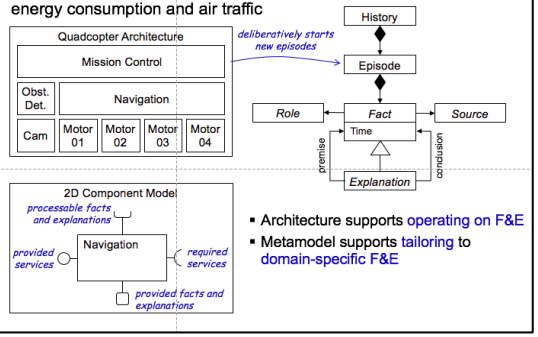
- "The limits of my language are the limits of my world"
- Stakeholders of CPS speak different languages and give explanations in different languages
  - ➢ so do their software modules
- Understanding (emergent) system behavior requires understanding all related modules
- In a way that supports
  - reasoning about facts ("why is X?")
  - contrasting observations ("why X instead of Y?")
  - Enquiring intentions ("how would you do X?")
- Suitable modeling languages can support CPS explainability at run time and at design-time



Andreas Wortmann
Software Engineering
RWTH Aachen
Slide 7

A 2D component model to explain the behavior of a package delivery quadcopter

- Quadcopter operates in the context of modules observing energy consumption and air traffic

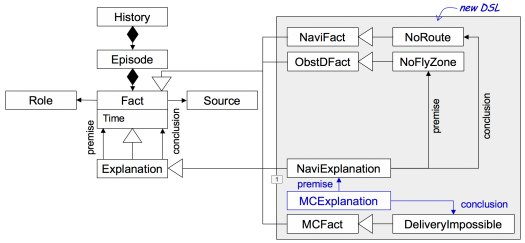


- Architecture supports operating on F&E
- Metamodel supports tailoring to domain-specific F&E

Andreas Wortmann
Software Engineering
RWTH Aachen
Slide 8

A 2D component model to explain the behavior of a package delivery quadcopter

- Domain-specific instantiation of the quadcopter explanation language (e.g., language embedding[1] or merging[2])



[1] K. Hölldobler, B. Rumpe, A. Wortmann. Software Language Engineering in the Large: Towards Composing and Deriving Languages. In: Computer Languages, Systems & Structures, 54, 2018.

[2] Degueule, T., Combemale, B., Blouin, A., Barais, O., & Jézéquel, J. M. Melange: A meta-language for modular and reusable development of DSLs. In Proceedings of the 2015 SLE. 2015.

Publications
wortmann.ac

Videos
wortmann.ac/videos

Twitter
@andwor