CWI

Centrum Wiskunde & Informatica

Quality Evaluation of Automotive Software Systems

Yanja Dajsuren

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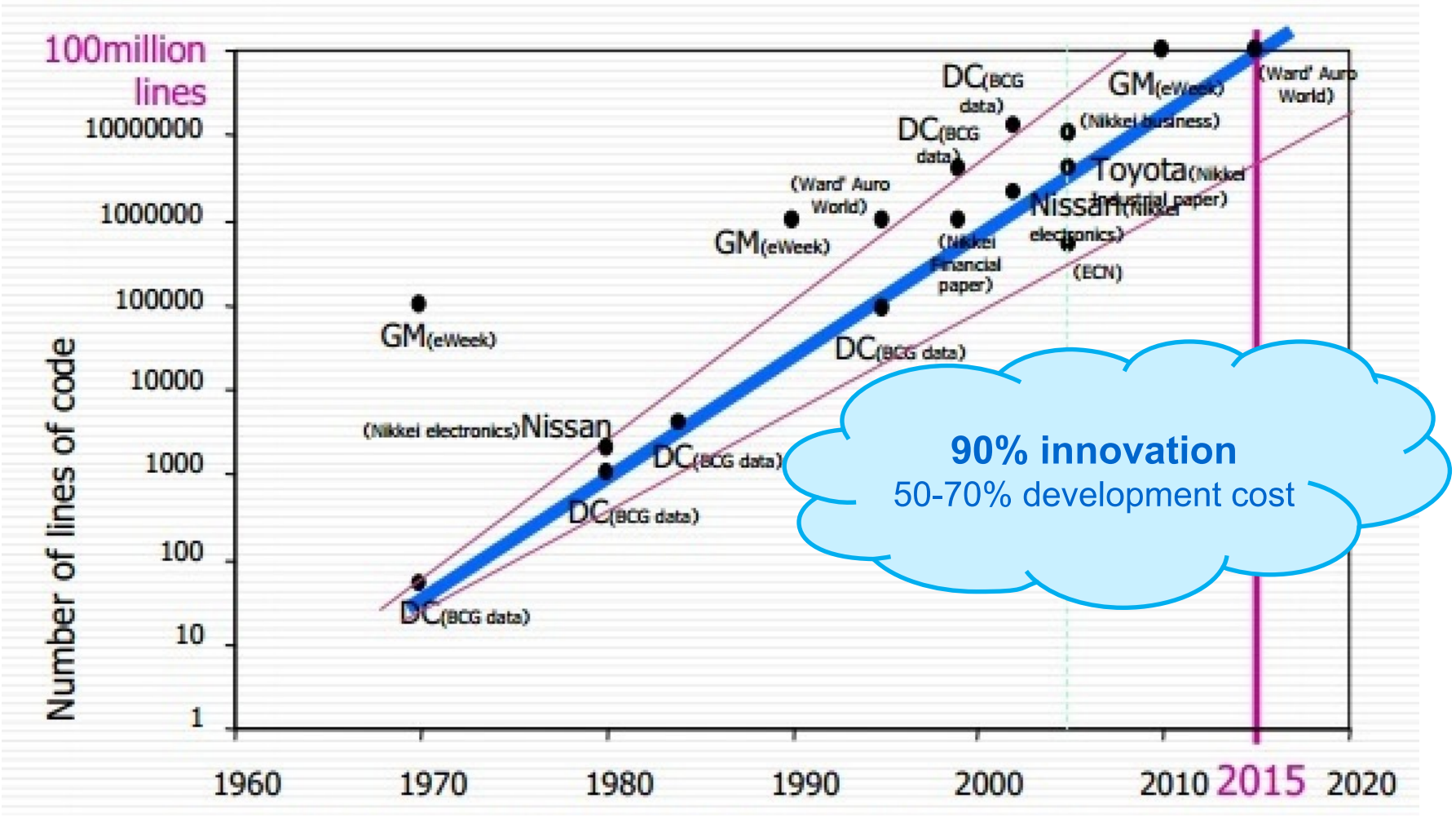
Professional background

- **CWI**
  Postdoc
- **Eindhoven University of Technology**
  - PhD candidate, HIT project
- **Virage Logic,**
  - Senior scientist
- **NXP Semiconductors**
  - Senior scientist
- **Philips Research**
  - Research scientist
- **National University of Mongolia**
  - Lecturer, Software engineer



Electronic Spark Timing (EST) System (1 ECU)

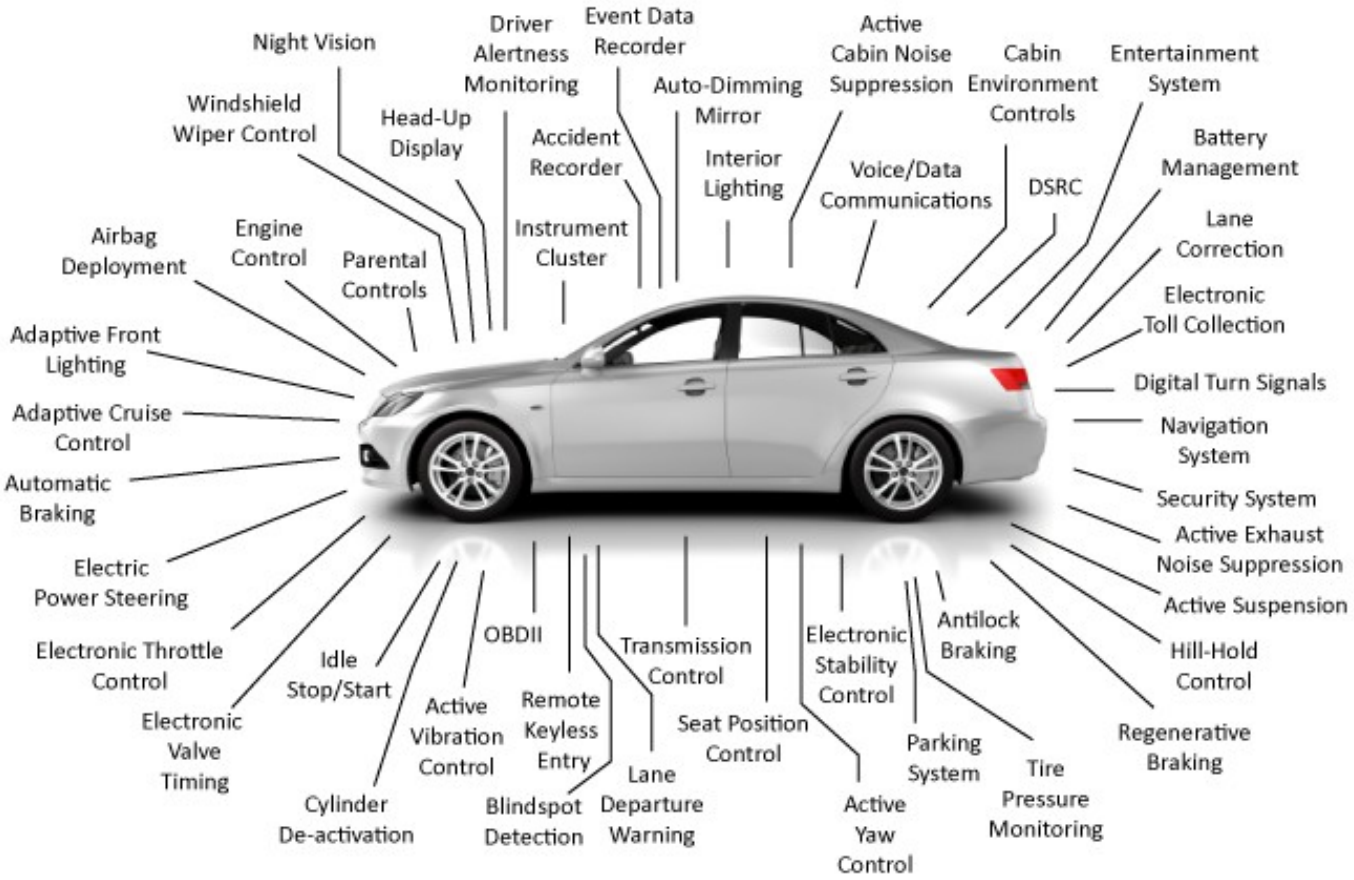
2000 functions enabled by software (70-100 ECUs)

Software problem that could cause

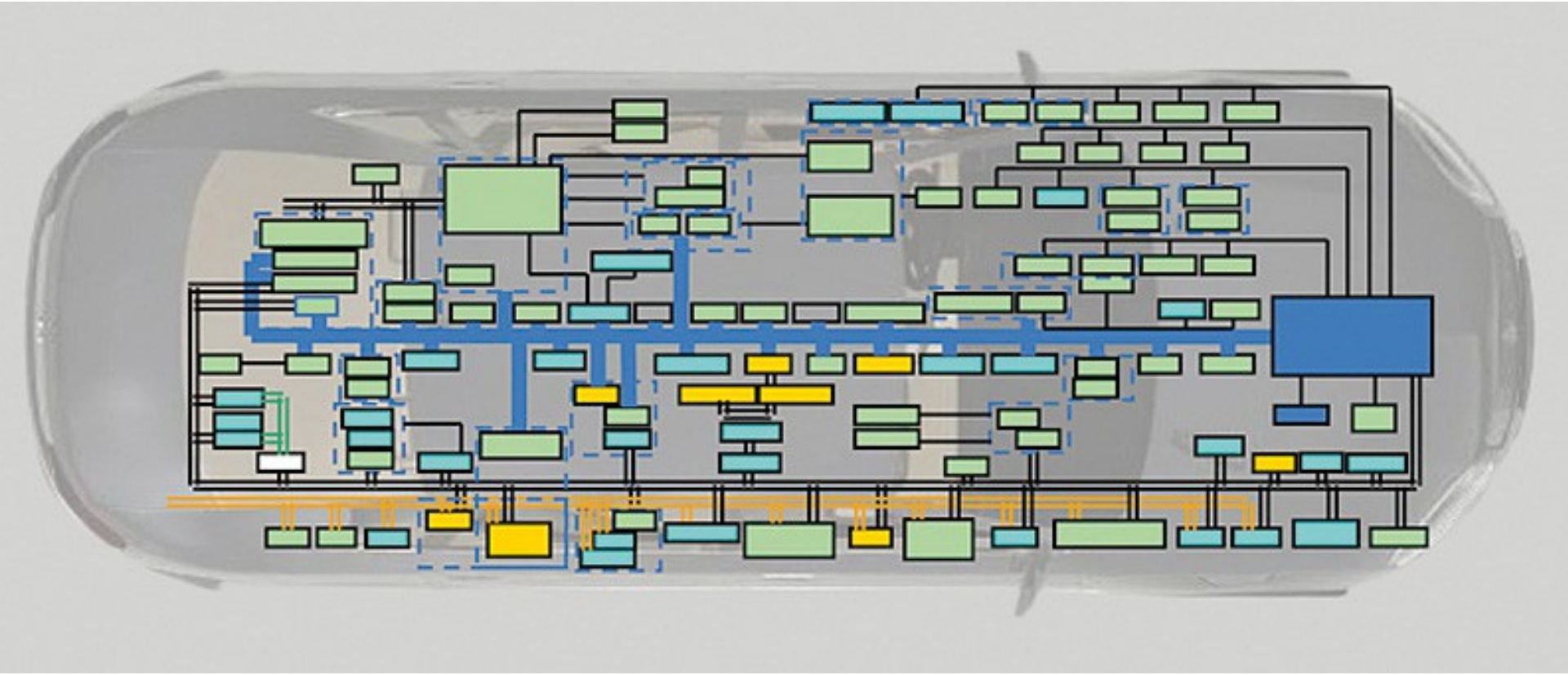
- **the cars to stop suddenly**
- **accelerate without warning**
- **overheats/damages power electronics**
- **…**

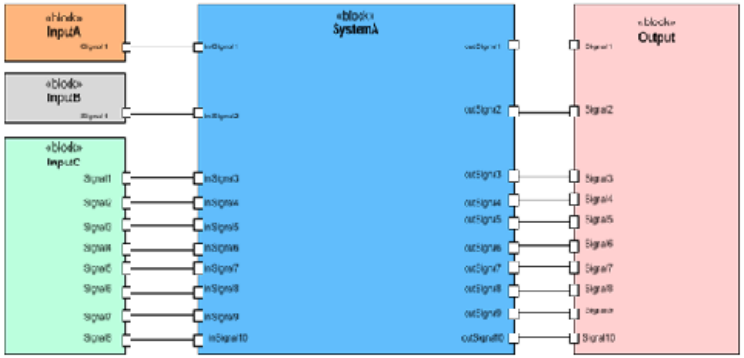
YEAR	TOTAL RECALLS ISSUED	TOTAL NO. OF VEHICLES AND EQUIPMENT RECALLED IN MILLIONS
1990	269	18.5
1991	282	14.4
1992	217	13.6
1993	264	11
1994	290	9.9
1995	348	19
1996	341	19.5
1997	312	16.7
1998	408	19.2
1999	440	55.6
2000	626	44.6
2001	527	22.4
2002	506	25.3
2003	600	22.9
2004	698	33
2005	645	20.4
2006	613	14.1
2007	713	20.6
2008	781	22.6
2009	571	18
2010	723	23
2011	657	17.5
2012	657	18.1
2013	714	27
2014 YTD	*500	**56

Source: National Highway Traffic Safety Administration

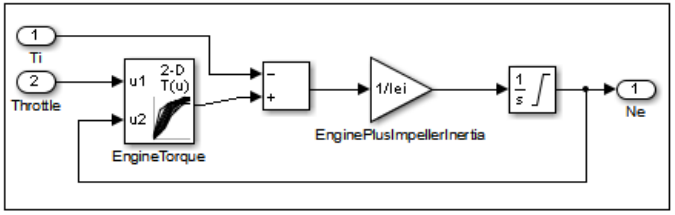


http://www.cvel.clemson.edu/auto/systems/auto-systems.html





Architecture Model



Design Model

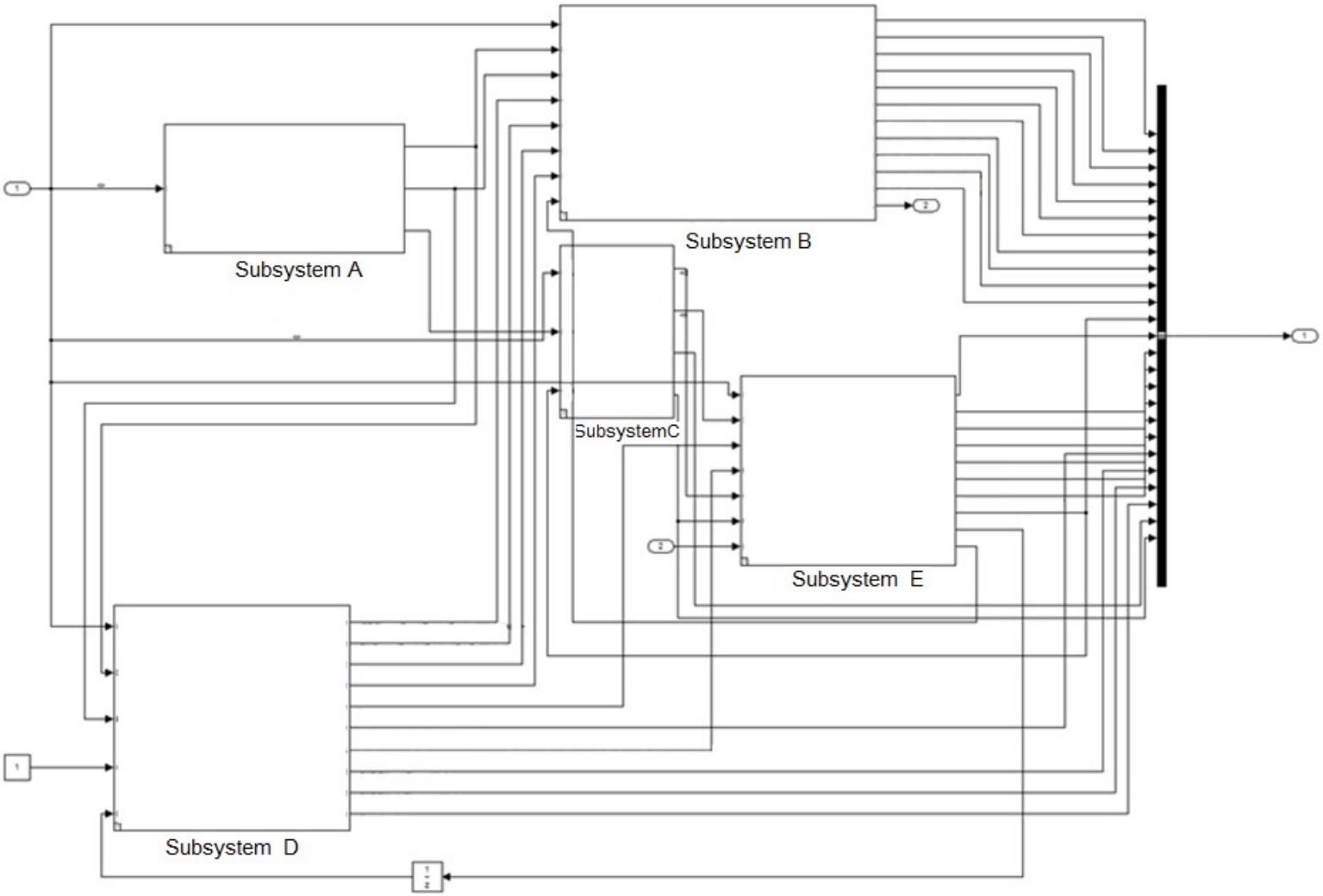
```
int LongestCommonSubsequenceLength( const std::string &first,
                                    const std::string &second ) {
  const std::string &longer  = first.size() > second.size() ? first  : second;
  const std::string &shorter = first.size() > second.size() ? second : first;

  int longer_len  = longer.size();
  int shorter_len = shorter.size();

  std::vector<int> previous( shorter_len + 1, 0 );
  std::vector<int> current(  shorter_len + 1, 0 );
  int foo =

  for ( int i = 0; i < longer_len; ++i ) {
    for ( int j = 0; j < shorter_len; ++j ) {
      if ( toupper( longer[ i ] ) == toupper( shorter[ j ] ) )
        current[ j + 1 ] = previous[ j ] + 1;
      else
        current[ j + 1 ] = std::max( current[ j ], previous[ j + 1 ] );
    }

    for ( int j = 0; j < shorter_len; ++j ) {
      previous[ j + 1 ] = current[ j + 1 ];
    }
  }

  return current[ shorter_len ];
}
```

Source Code

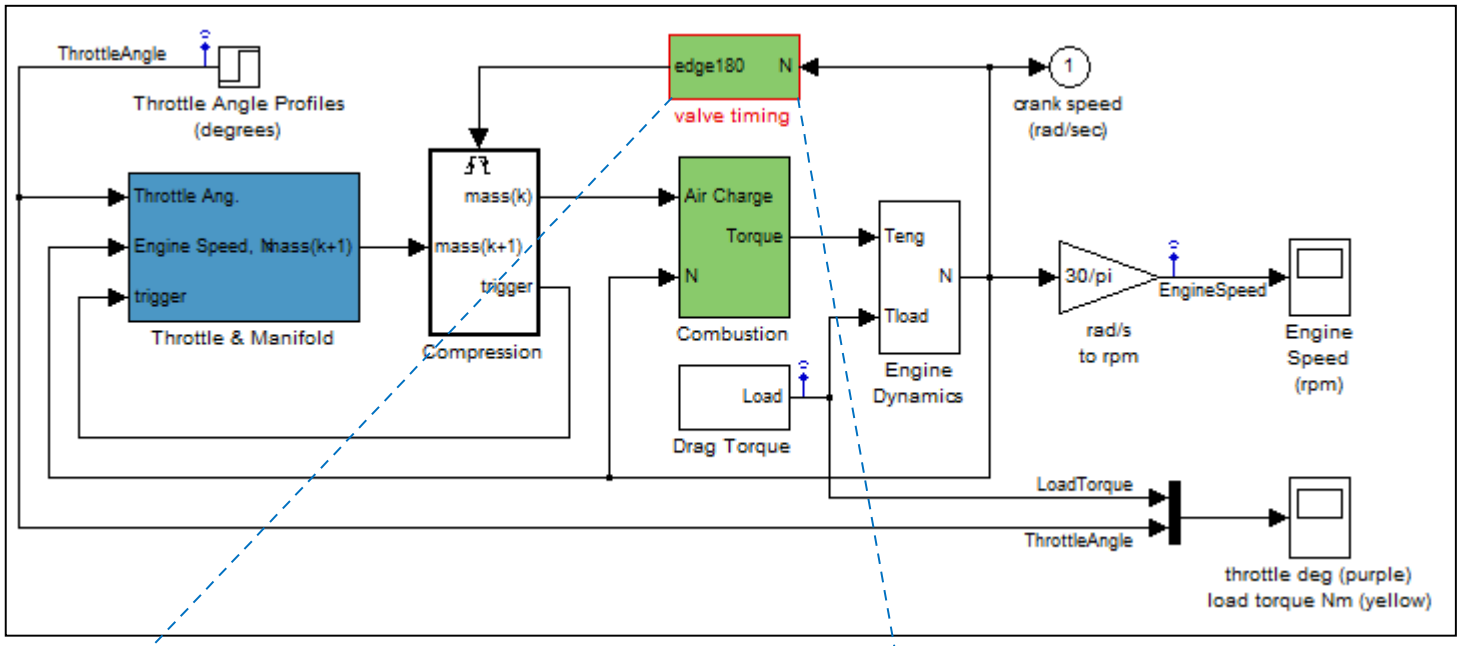
Quality Metrics

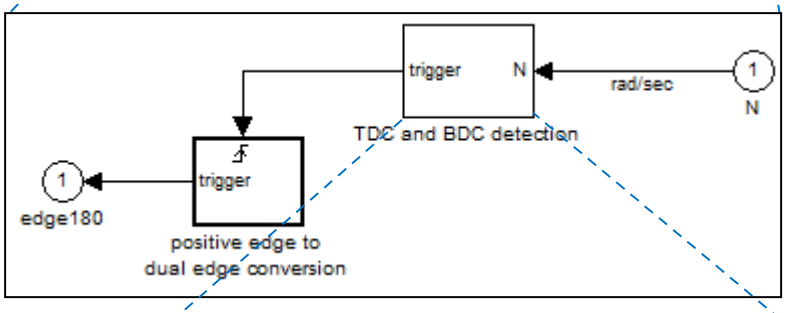
Quality Tool

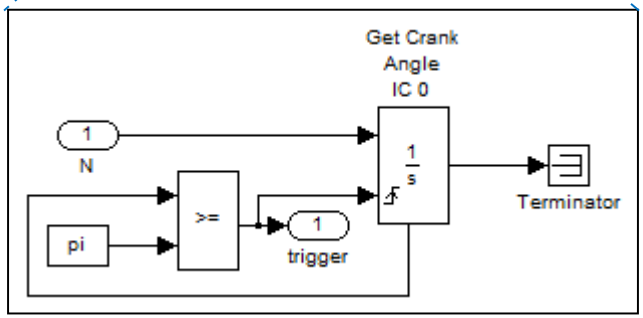
How to define and evaluate the quality of automotive software models?



Modularity Measurement Example







hValve timing subsystem:

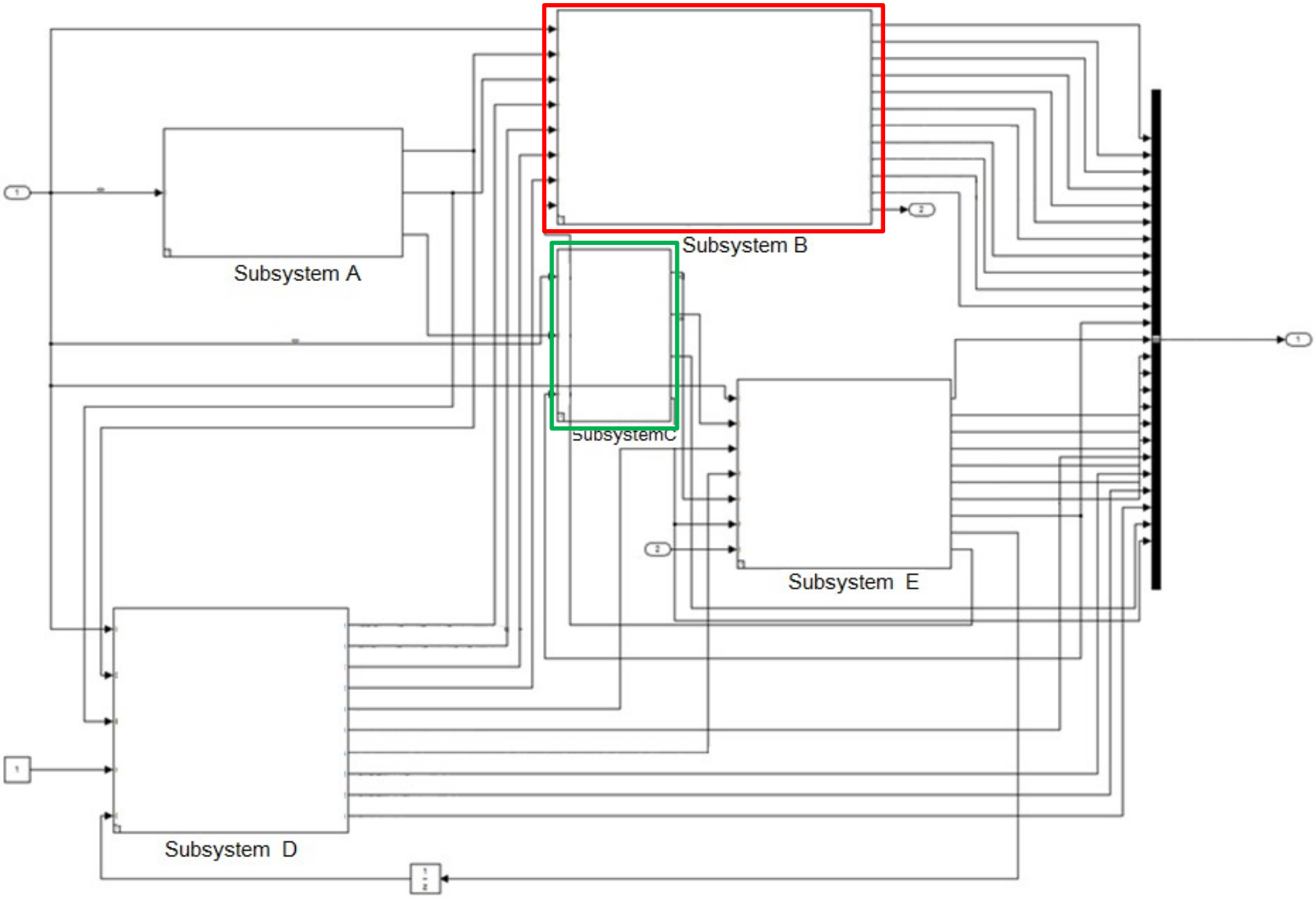
- Coupling Between Subsystems (CBS) = 2
- Number Of Subsystems (NOS) = 2
- Depth of a Subsystem (DoS) = 2

Measurement and Visualization Toolchain

- Measurement tool for Simulink model developed
- Based on ConQAT Simulink Parser

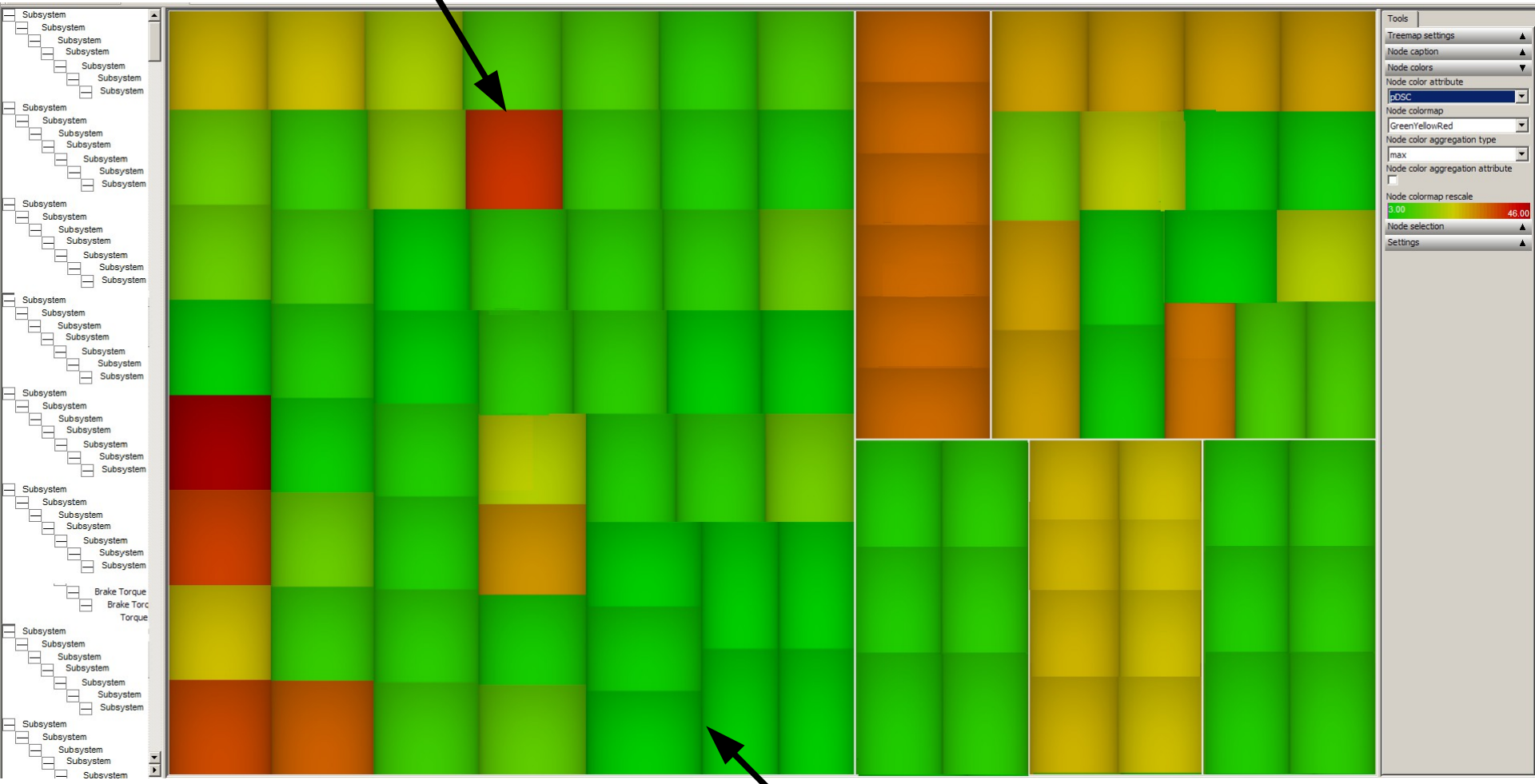
- Interface with SQuAVisit Visualization tool
- Extended with Simulink input

Simulink Model Example



Quality Visualization

Subsystem C

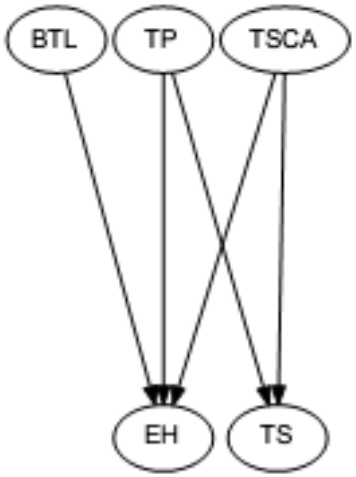


Subsystem B

Quality Metrics Evaluation

Expert evaluation

Subsystem	*Experts*	
	ABC	DEF
EH	337	557
ED	797	868
SM	775	358
IDA	987	778
GS	767	768
TP	987	888
TS	371	777
BTL	987	887
CC	781	876
TSCA	987	888
TRC	785	783



Statistical Analysis

Module	CBS	DSC	NIP	NoP	NIS	NOS	NCS	DoS	NBS	NrDef
Subsystem1	29	38	29	6	24	6	39	7	25	41
Subsystem 2	35	49	31	14	31	14	30	6	29	17
Subsystem3	5	39	31	4	31	4	63	7	33	10
Subsystem4	38	44	32	6	32	6	11	5	7	9
Subsystem5	53	62	44	9	44	9	39	9	26	7
Subsystem6	35	45	28	9	28	9	51	7	34	7
Subsystem7	34	38	30	4	30	4	39	8	29	5
Subsystem8	22	37	17	5	17	5	17	5	13	4
Subsystem9	20	25	15	5	15	5	11	5	7	4
Subsystem10	38	47	29	9	29	9	9	4	6	3
Subsystem11	19	23	15	4	15	4	29	7	9	2
Subsystem12	16	25	7	9	7	9	9	5	6	2
Subsystem13	34	37	31	3	31	3	34	7	23	2
Subsystem14	18	25	11	7	11	7	23	6	14	2
Subsystem15	20	26	14	6	14	6	10	4	7	1
Subsystem16	38	43	33	5	33	5	12	4	8	1
Subsystem17	29	32	26	3	26	3	24	6	19	1
Subsystem18	24	33	15	9	15	9	16	5	12	1
Subsystem19	5	9	1	4	1	4	2	2	2	1
Subsystem20	34	45	28	11	28	11	25	7	7	1
Subsystem21	15	25	10	5	15	5	0	1	0	0
Subsystem22	12	21	8	4	13	4	0	1	0	0
Subsystem23	9	12	6	3	6	3	0	1	0	0
Subsystem24	12	16	8	4	8	4	0	1	0	0
Subsystem25	10	14	6	4	6	4	6	4	4	0
Subsystem26	8	14	4	4	6	4	0	1	0	0
Subsystem27	2	3	1	1	1	1	0	1	0	0
Subsystem28	15	17	14	1	15	1	7	3	6	0
Subsystem29	11	13	9	2	9	2	12	5	7	0
Subsystem30	12	19	8	4	11	4	0	1	0	0
Subsystem31	57	66	48	9	48	9	35	6	26	0
Subsystem32	23	31	15	8	15	8	10	4	6	0
Subsystem 33	10	16	5	5	6	5	0	1	0	0
Subsystem34	10	16	5	5	6	5	0	1	0	0
Subsystem35	10	16	5	5	6	5	0	1	0	0
Subsystem36	10	16	5	5	6	5	0	1	0	0
Subsystem37	9	13	5	4	5	4	0	1	0	0
Subsystem38	9	13	5	4	5	4	0	1	0	0
Subsystem39	9	13	5	4	5	4	0	1	0	0
Subsystem40	9	12	7	2	8	2	0	1	0	0
Subsystem41	6	13	5	1	11	1	0	1	0	0

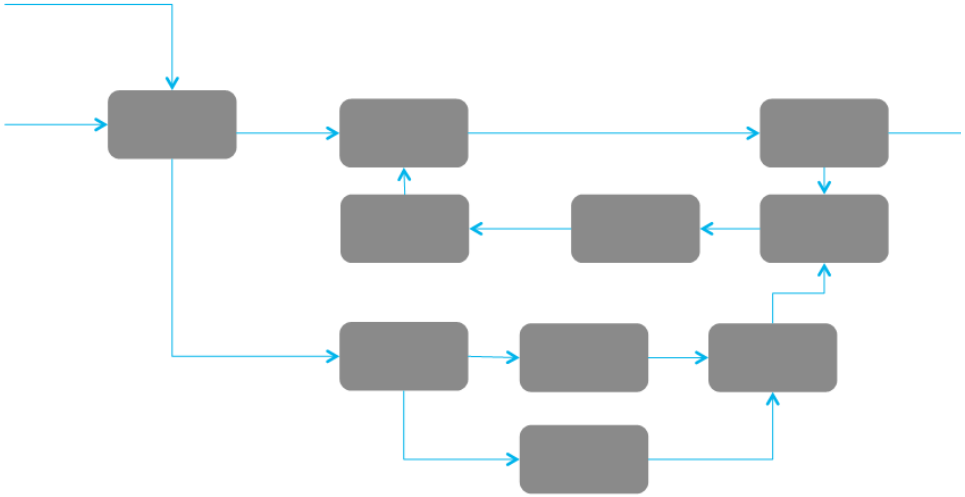
Summary

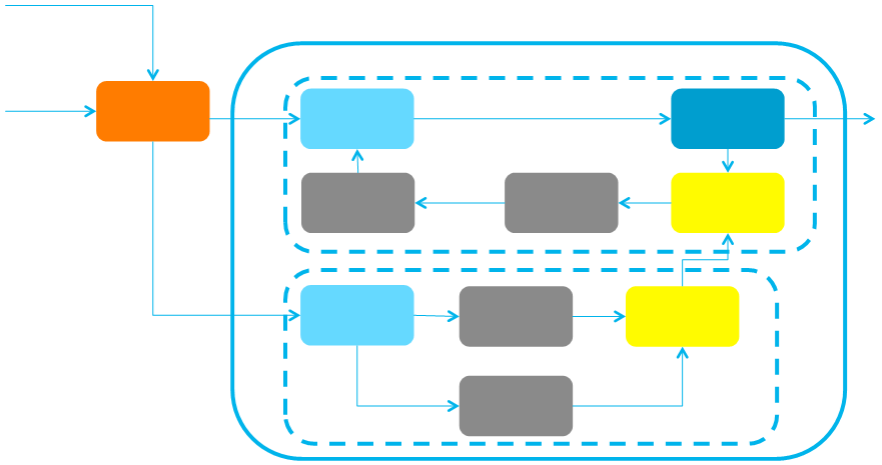
- Quality metrics (e.g. modularity) are defined
- Java tool developed which calculates metrics
- "Problematic modules" have at least one metric with a high value
- Visualisations are used for architecture and design model reviews

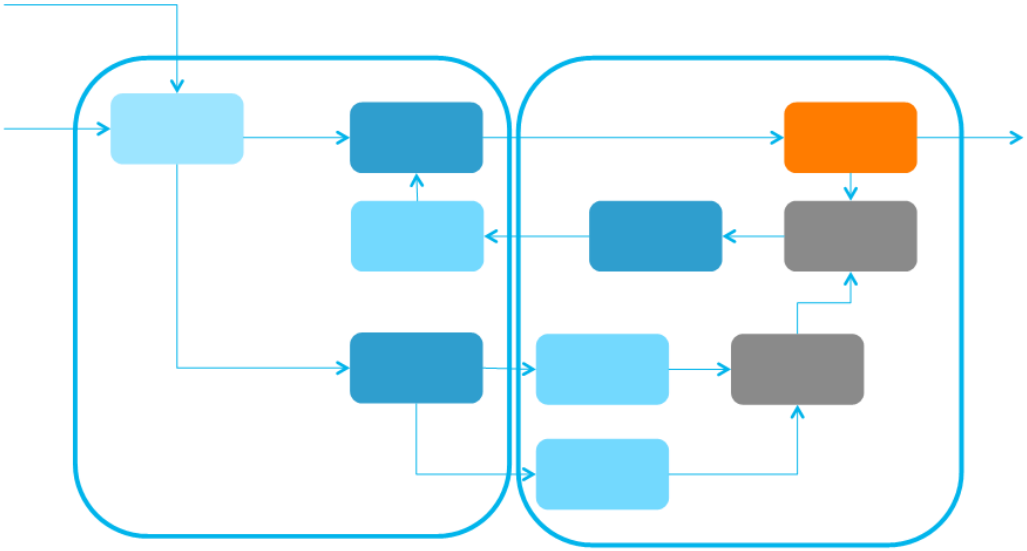
Ongoing work...

System Decomposition

(Collaboration with Eric Bouwers, SIG/Squla)



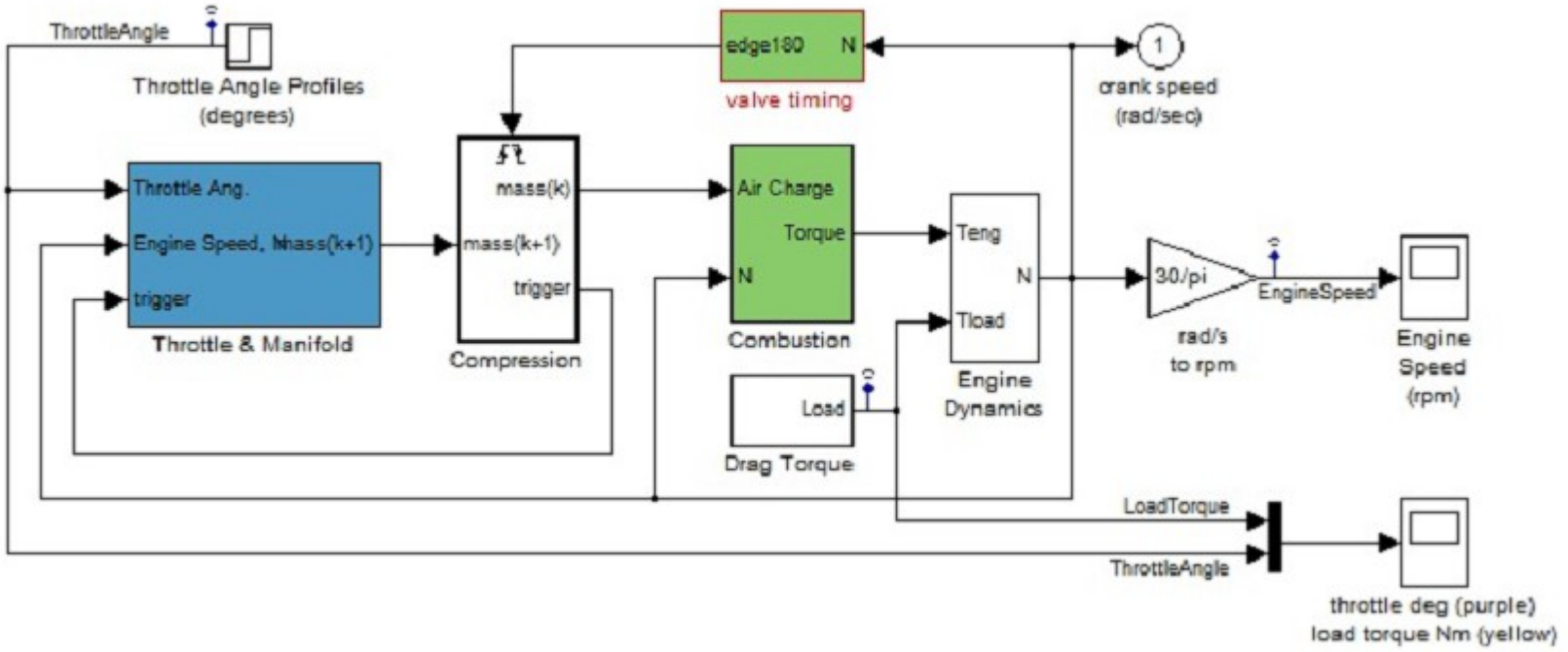




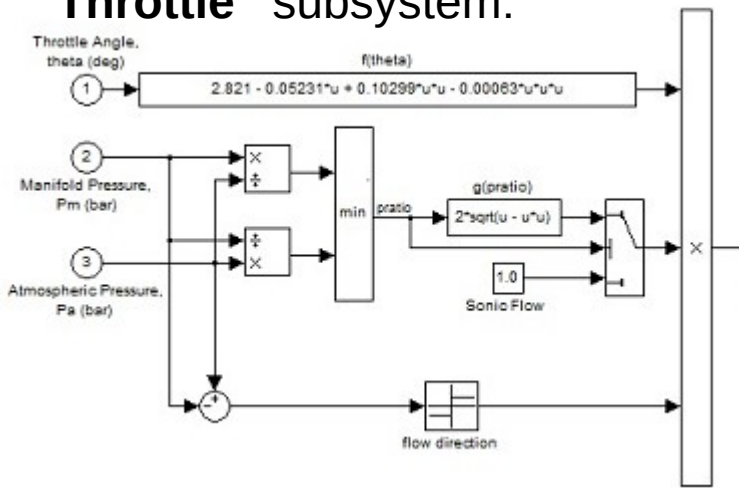
Which one is better?

Evaluating Automotive Model Decomposition

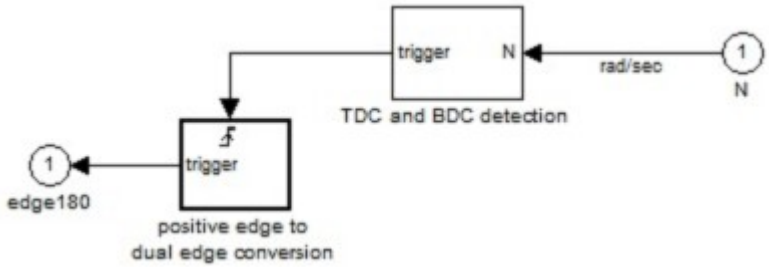
Mathworks **“sldemo engine”** engine model:



“Throttle” subsystem:

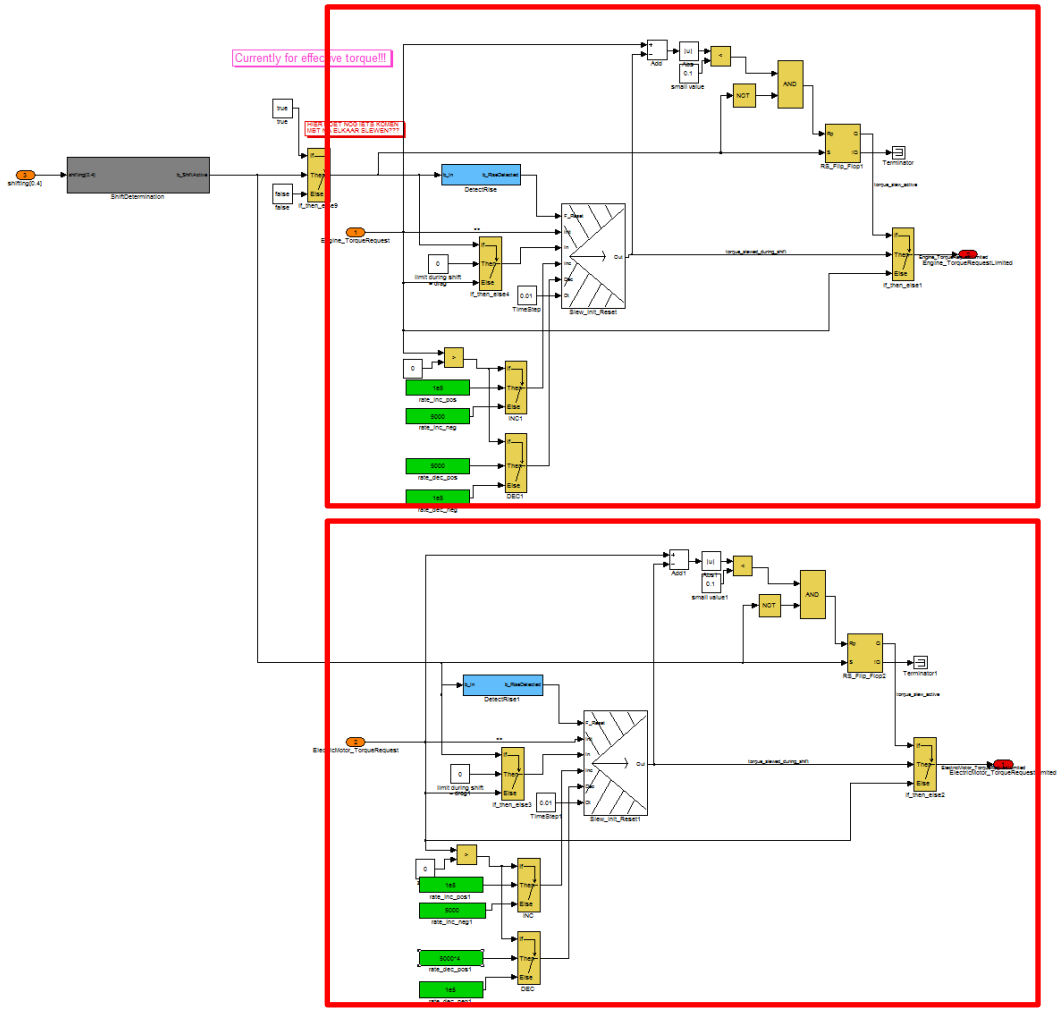


“valve timing” subsystem:

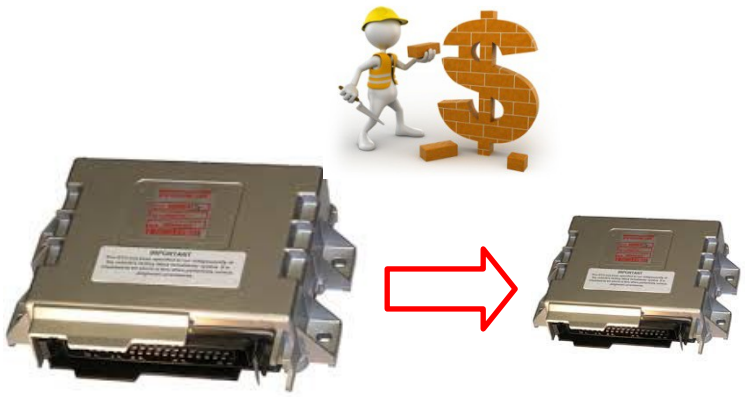


Model Clone Detection

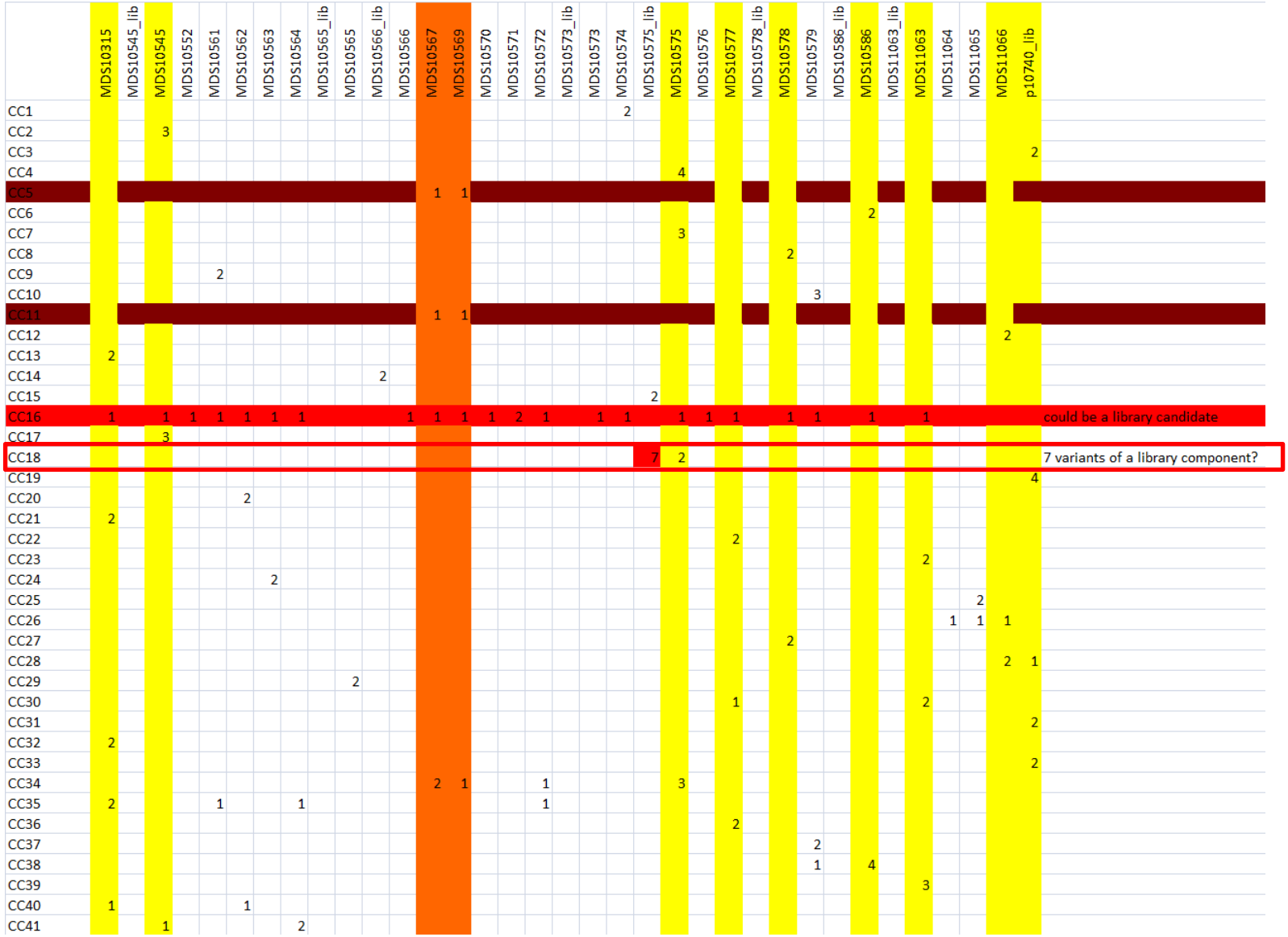
(Collaboration with Hamid Abdul Basit, Lahore University)



- Model clones may have the effect of increasing code size and duplication of errors.
- Number of duplicates affects reusability as well.

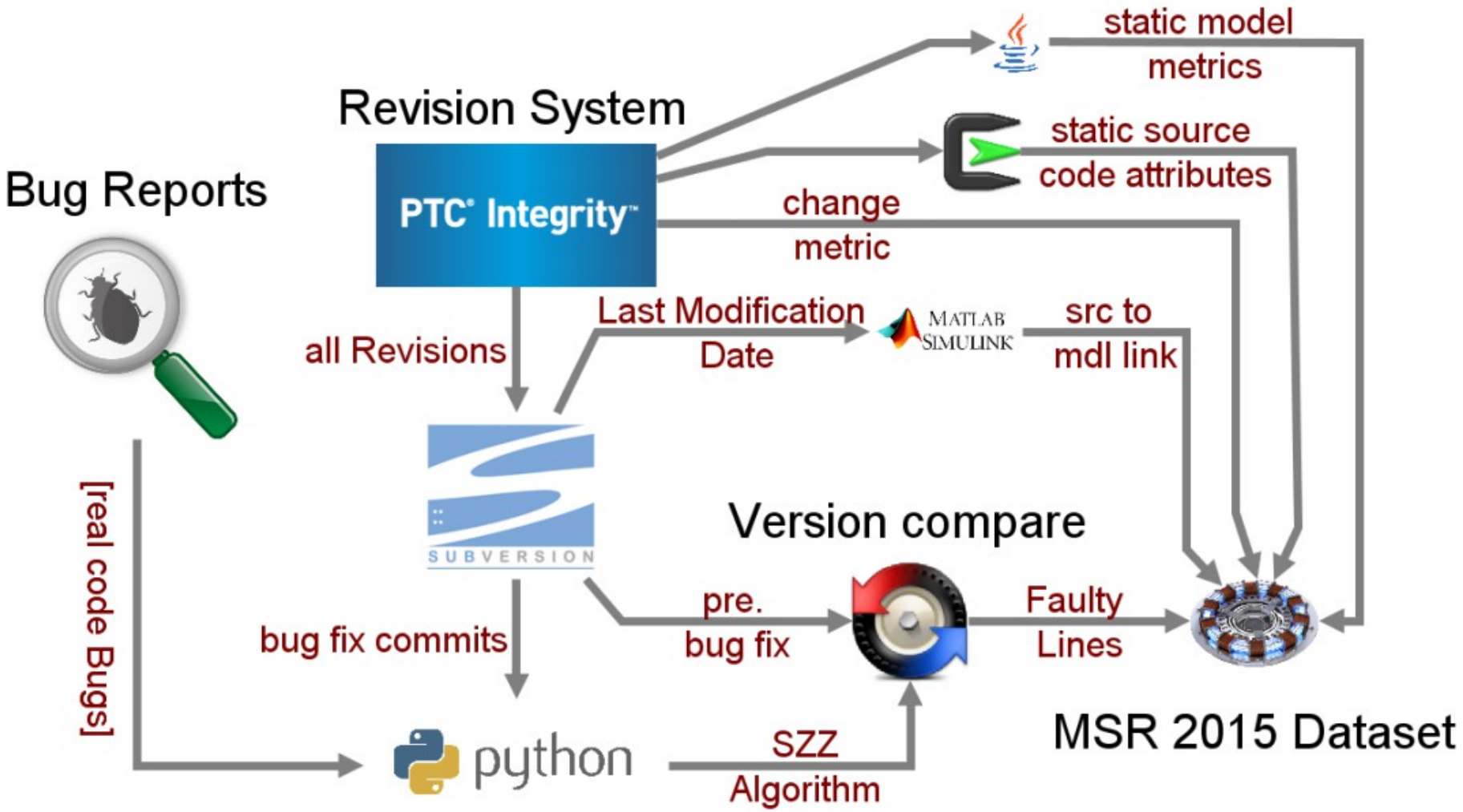


Clones + Variability



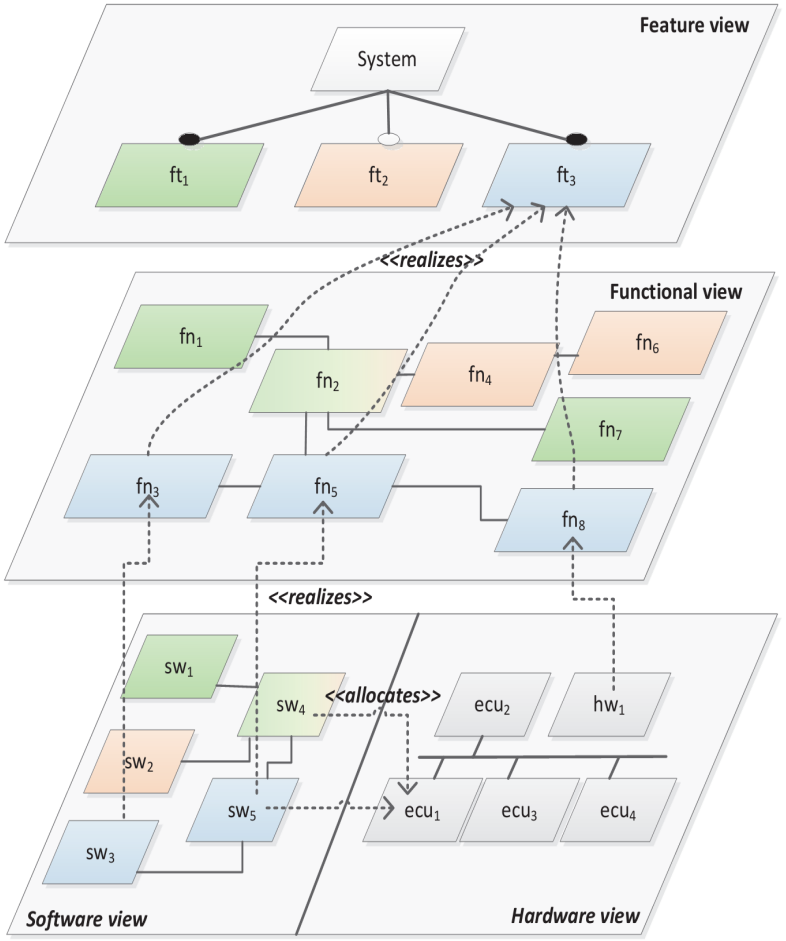
Fault Prediction + Model Metrics

(Collaboration with Harald Altinger, Audi)



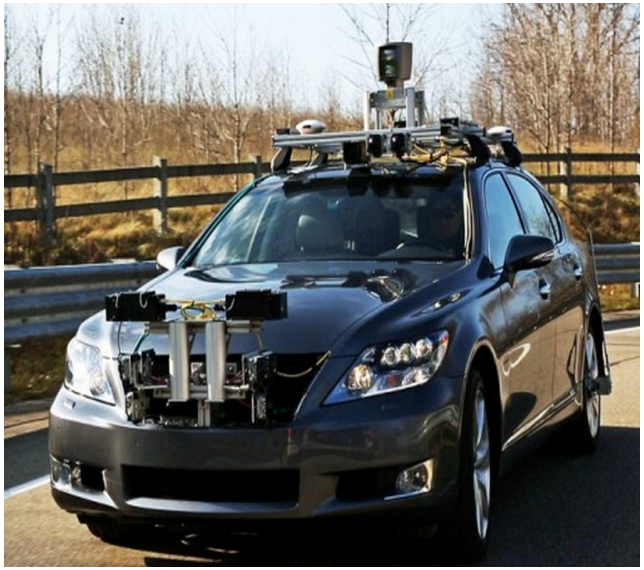
Future Work

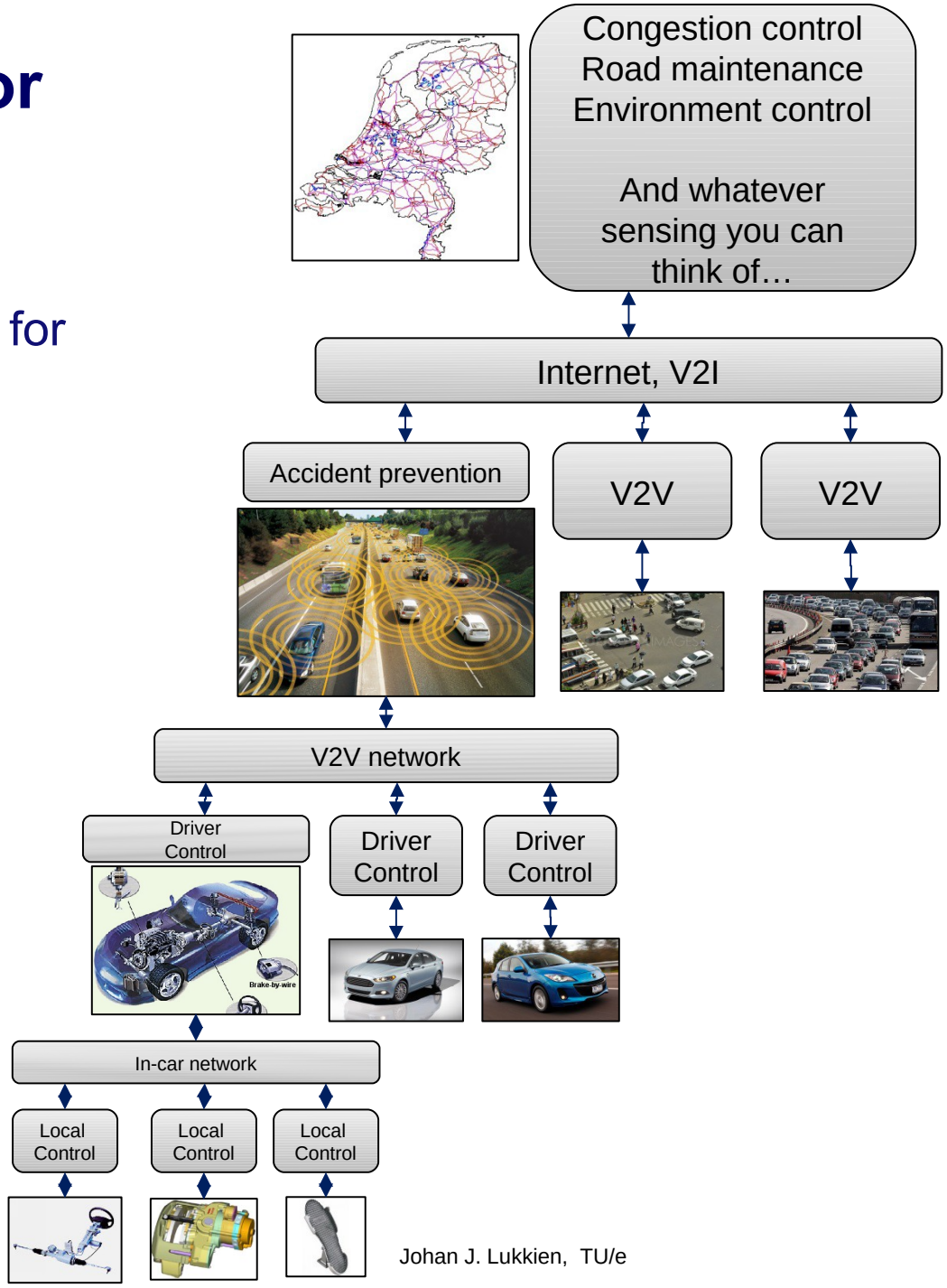
- Aggregating design metrics to architecture metrics
- Applying consistency checking tools to industrial models
- Defining automotive product line and component models



Interesting Topics for Future Research

- System/software architecture for ITS and autonomous cars
- Safety, security mechanisms
- ...





Contact for comments and collaboration:

Tel: +31(0)20 592 4007
Email: y.dajsuren@cwi.nl
Address:
Centrum Wiskunde&Informatica
Science Park 123
1098 XG Amsterdam