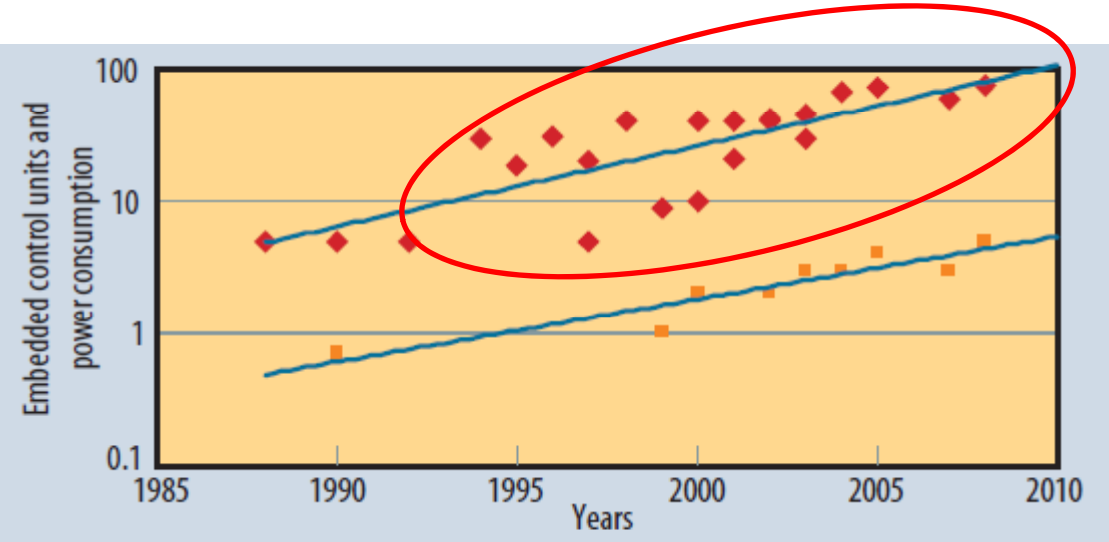
CompSize: Automated Size Estimation of Embedded Software Components

Kenneth Lind
Saab Automobile AB/Chalmers University of Technology

Rogardt Heldal, Tony Heimdahl
Chalmers University of Technology

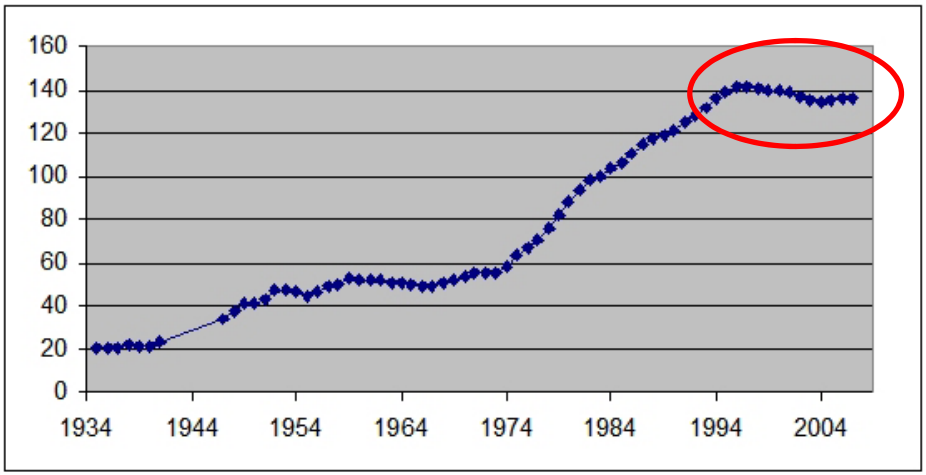
Tigran Harutyunyan
University of Gothenburg

Motivation

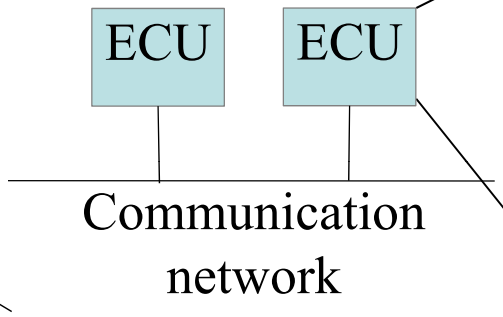


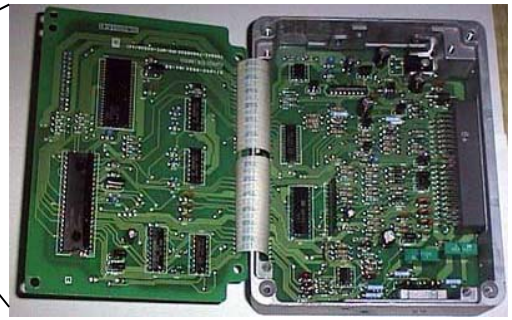
No of computers in high-end cars; Ebert, C, Jones, C, ”Embedded Software: Facts, Figures, and Future”, IEEE Computer, Apr. 2009, pp. 42-52

New car prices; US Bureau of Labor Statistics, Consumer Price Index (http://www.bls.gov/cpi/)



Background





20 – 80 ECUs

Piece cost: 20 – 50 USD
Design cost: ~1 MUSD

- Flexibility for future requirements obtained through spare resources like processor capacity and memory space.

Background

Too much spare resources =>

Unnecessary piece cost

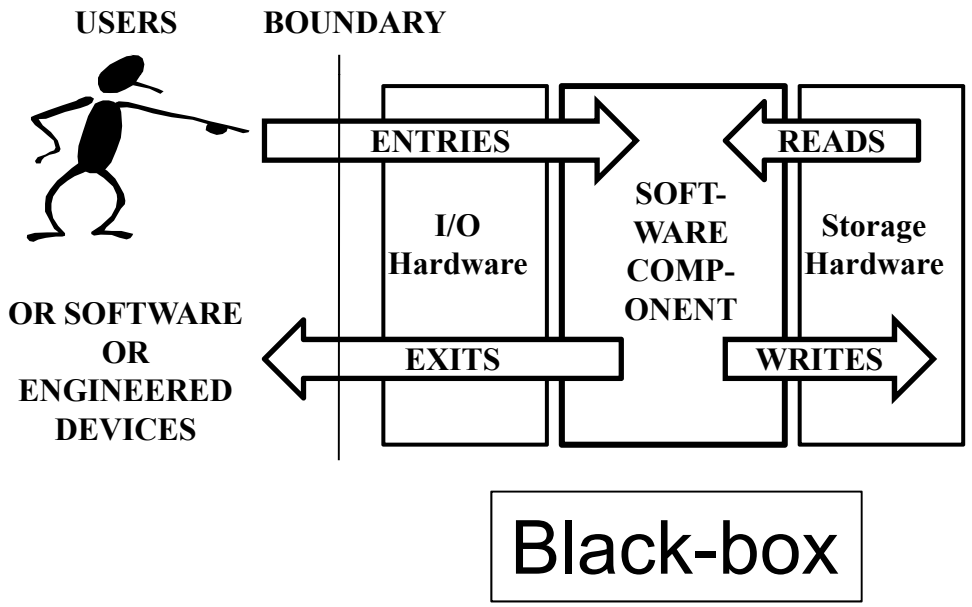
Too little spare resources =>

Premature redesign

Need for decision support!

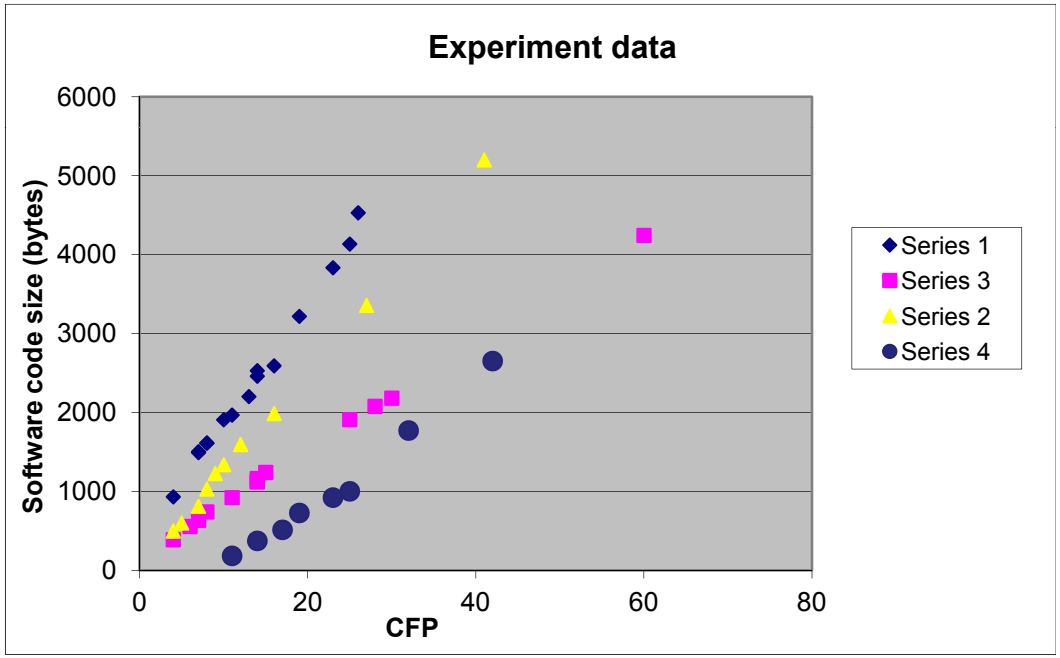
Background

- Memory size in ECU estimated based on requirement specifications and historical data.
- COSMIC Function Points measured from Component Diagrams and textual requirements.



Background

- Categorization based on factors like (in our domain)
  - Functionality type
  - Quality constraints
  - Methods & tools
- Memory size in ECU estimated within 15% accuracy before application software is available.



Publications

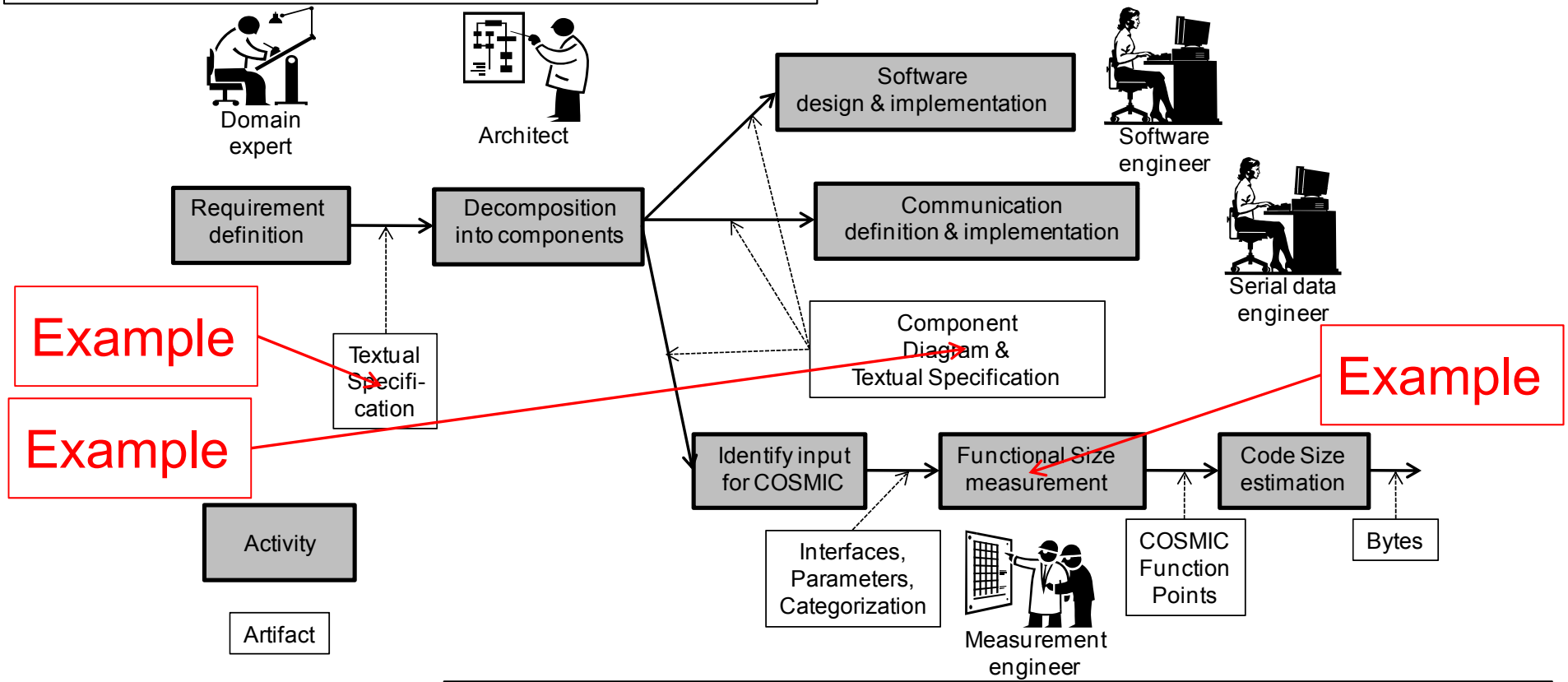
This presentation is based on two publications:

- Lind, K., Heldal, R., Harutyunyan, T., and Heimdahl, T.: CompSize: Automated Size Estimation of Embedded Software Components, Intl. Workshop on Software Measurement (IWSM), Japan, November 3-4, (2011)

- Lind, K., and Heldal, R.: A Model-Based and Automated Approach to Size Estimation of Embedded Software Components, ACM/IEEE 14th Intl. Conf. on Model Driven Engineering Languages and Systems (MoDELS), New Zealand, October 16-21, (2011)

Problem

Manual estimation approach



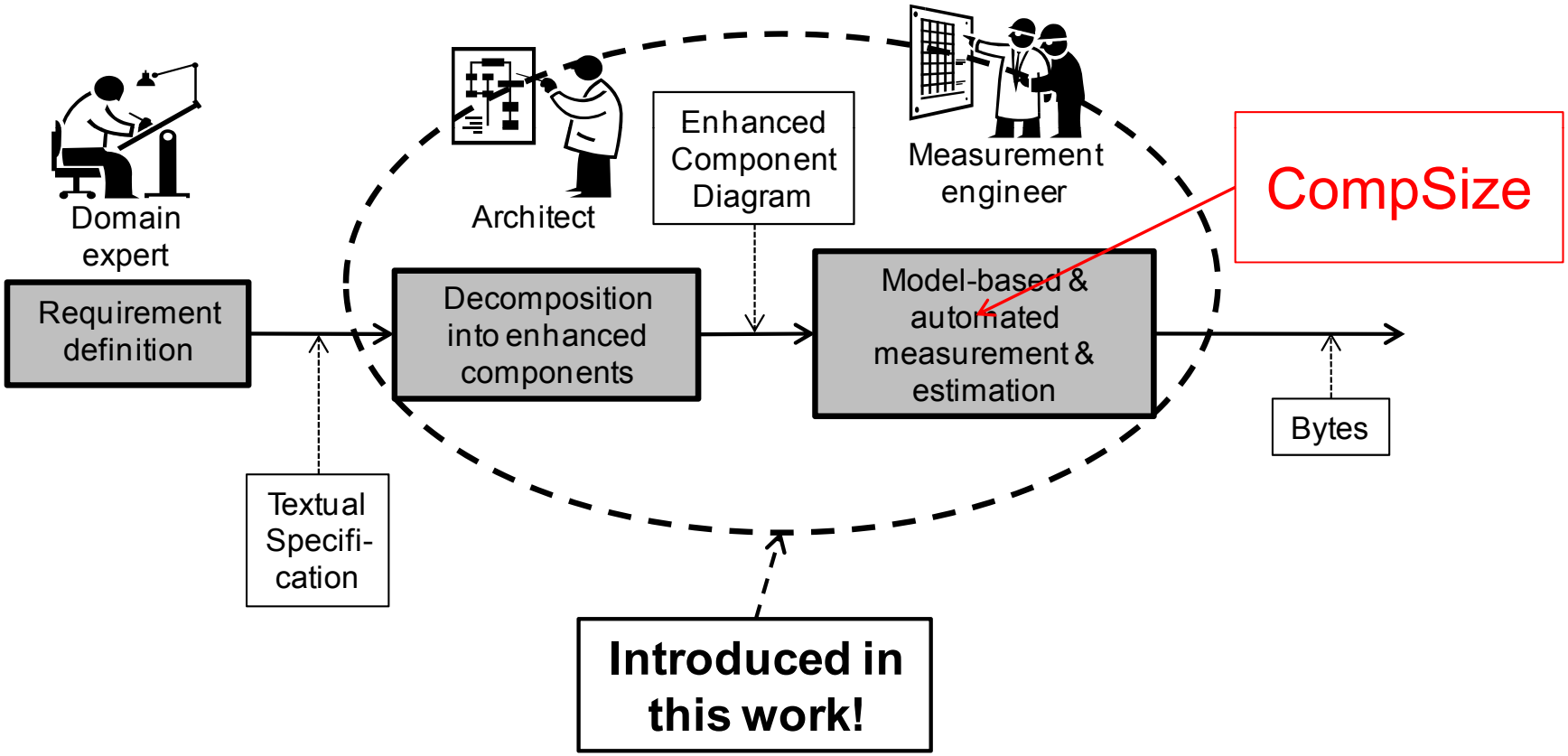
Requires 2,5 man years in effort for the complete application software in a car!

Problem

- RQ1: “How can UML support in modeling all information needed for automated estimation of Software Code Size?”
- RQ2: “How much manual effort can be saved by modeling all information needed for automated estimation of Software Code Size?”

Solution

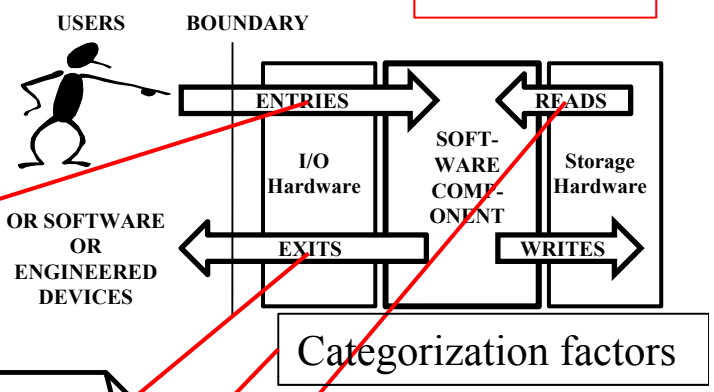
Proposed estimation approach



Evaluation

RQ1: “How can UML support in modeling all information needed for automated estimation of Software Code Size?”

CFP=7!



Categorization factors

5x

<<Interface>>
IInteriorLightStatus_rsp
<<Signal>>
InteriorLightStatus_rsp

<<use>>

<<Category>>
LGT_ControlTruckBedCargoLamp

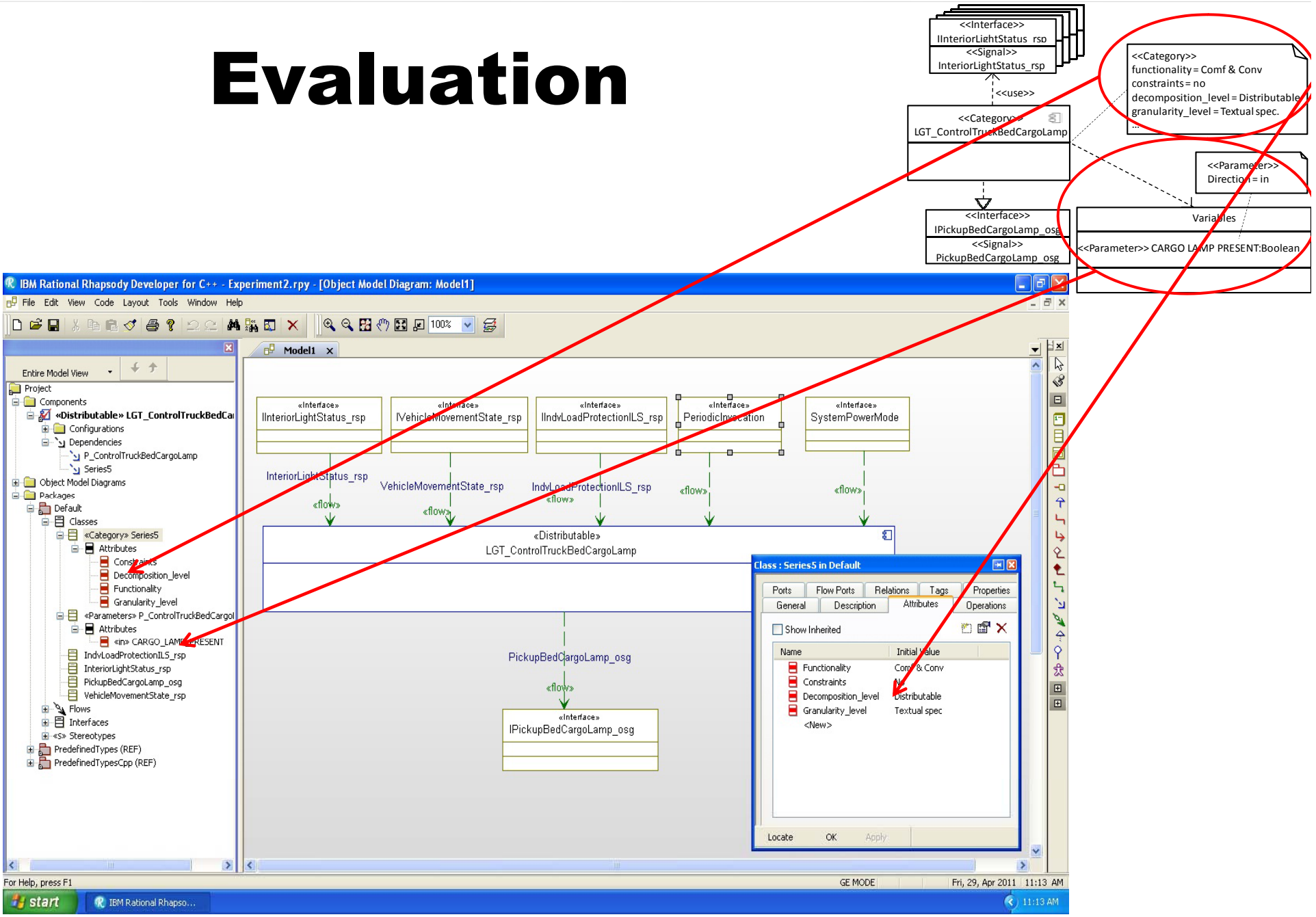
<<Category>>
functionality = Comf & Conv
constraints = no
decomposition_level = Distributable
granularity_level = Textual spec.
…

<<Parameter>>
Direction = in

<<Interface>>
IPickupBedCargoLamp_osg
<<Signal>>
PickupBedCargoLamp_osg

Variables
<<Parameter>> CARGO LAMP PRESENT:Boolean

Evaluation


<<Interface>>
IInteriorLightStatus_rsp
<<Signal>>
InteriorLightStatus_rsp
<<use>>
<<Category>>
LGT_ControlTruckBedCargoLamp
<<Interface>>
IPickupBedCargoLamp_osg
<<Signal>>
PickupBedCargoLamp_osg
<<Category>>
functionality = Comf & Conv
constraints = no
decomposition_level = Distributable
granularity_level = Textual spec.
<<Parameter>>
Direction = in
Variables
<<Parameter>> CARGO LAMP PRESENT:Boolean
IBM Rational Rhapsody Developer for C++ - Experiment2.rpy - [Object Model Diagram: Model1]
File Edit View Code Layout Tools Window Help
Entire Model View
Project
Components
«Distributable» LGT_ControlTruckBedCa
Configurations
Dependencies
P_ControlTruckBedCargoLamp
Series5
Object Model Diagrams
Packages
Default
Classes
«Category» Series5
Attributes
Constraints
Decomposition_level
Functionality
Granularity_level
«Parameters» P_ControlTruckBedCargoL
Attributes
«in» CARGO_LAMP_PRESENT
IndvLoadProtectionILS_rsp
InteriorLightStatus_rsp
PickupBedCargoLamp_osg
VehicleMovementState_rsp
Flows
Interfaces
«S» Stereotypes
PredefinedTypes (REF)
PredefinedTypesCpp (REF)
Model1
«Interface»
IInteriorLightStatus_rsp
«Interface»
IVehicleMovementState_rsp
«Interface»
IIndvLoadProtectionILS_rsp
«Interface»
PeriodicInvocation
«Interface»
SystemPowerMode
InteriorLightStatus_rsp
VehicleMovementState_rsp
IndvLoadProtectionILS_rsp
«flow»
«Distributable»
LGT_ControlTruckBedCargoLamp
PickupBedCargoLamp_osg
«Interface»
IPickupBedCargoLamp_osg
Class : Series5 in Default
Ports
Flow Ports
Relations
Tags
Properties
General
Description
Attributes
Operations
Show Inherited
Name
Initial Value
Functionality
Comf & Conv
Constraints
Decomposition_level
Distributable
Granularity_level
Textual spec
<New>
Locate
OK
Apply
For Help, press F1
GE MODE
Fri, 29, Apr 2011 11:13 AM
start
IBM Rational Rhapso...
11:13 AM

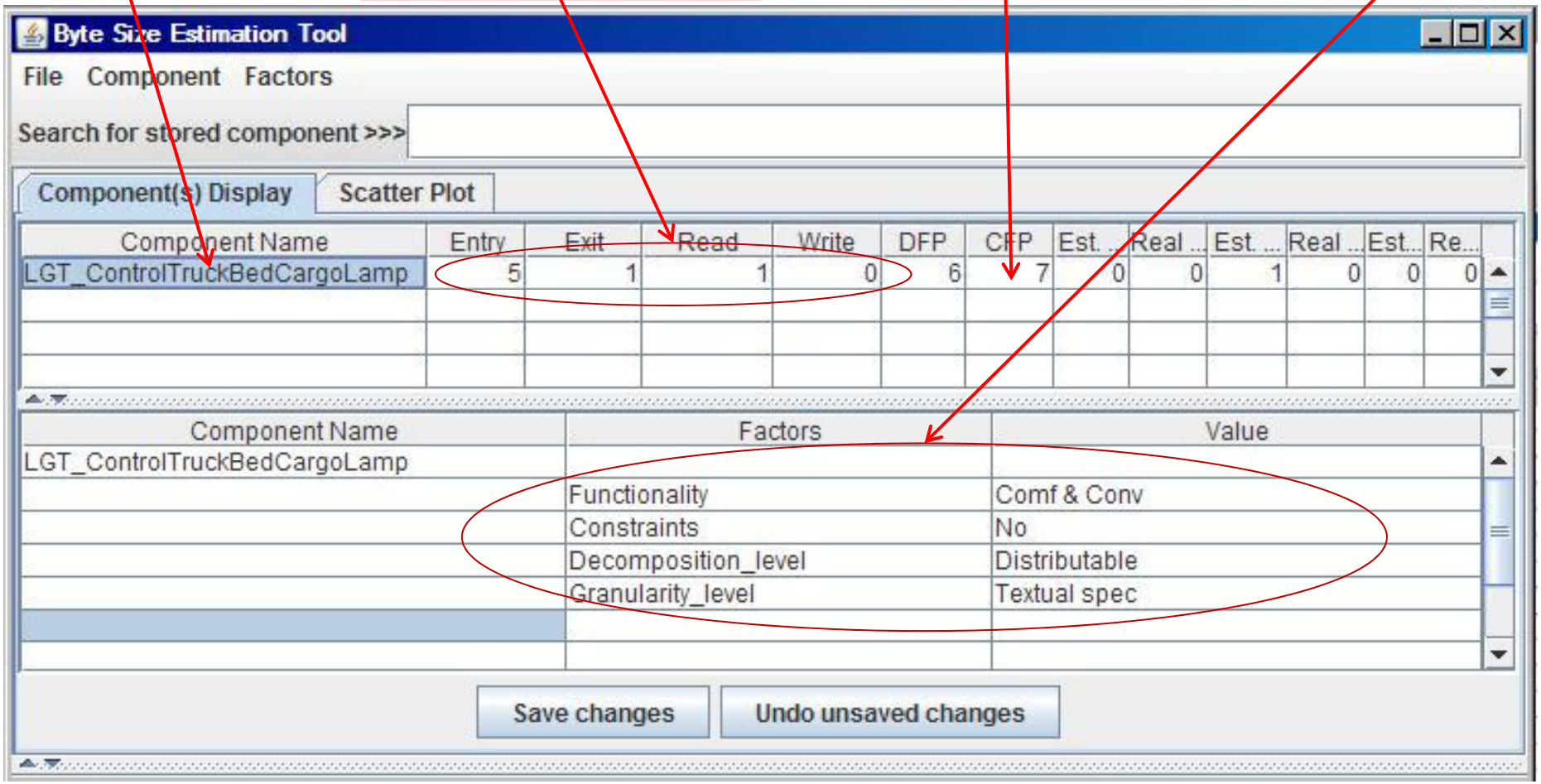
Evaluation

Component name

COSMIC data movement types

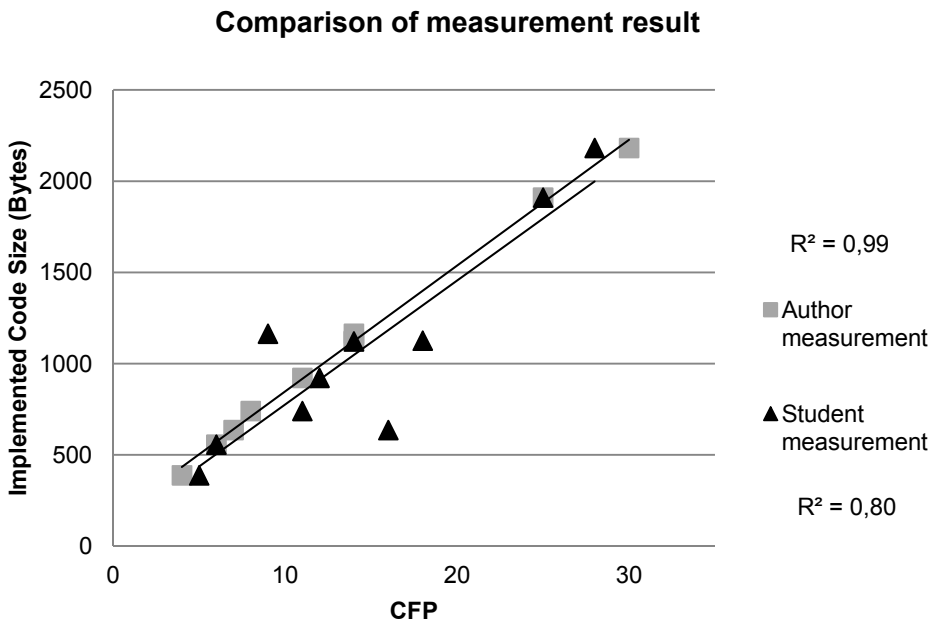
CFP

Categorizat-ion factors



Evaluation

RQ2: “How much manual effort can be saved by modeling all information needed for automated estimation of Software Code Size?”



Case study conducted by Master students

- Our manual estimations was replicated using the UML Profile
- 0,5 man years (instead of 2,5!) to estimate the size of the complete application software in a car

Results

- We have defined a UML Profile capturing the information needed for memory size estimation.
- We have developed a tool that can import the information captured in the UML Profile.
- Using the UML Profile requires 0,5 man years (instead of 2,5 man years!) to estimate the size of the complete application software in a car.

Backup

Textual Specification

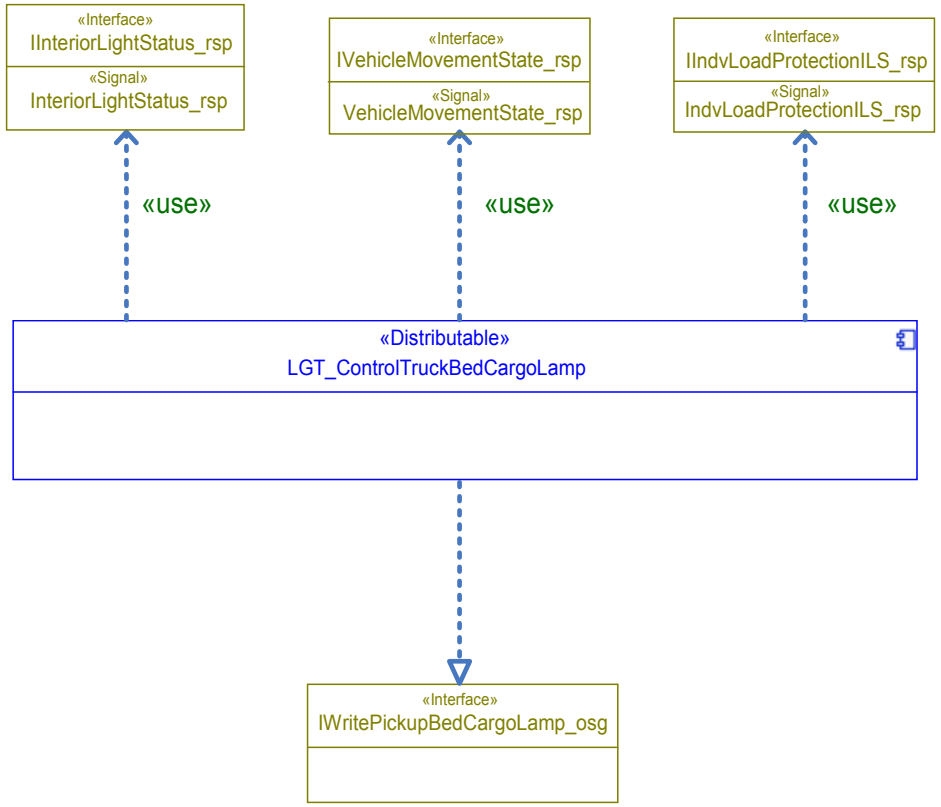
The feature **Shall** be enabled when the calibration CARGO LAMP PRESENT is set true. <END>

If the vehicle power mode is “OFF”, and the cargo lights are illuminated, the SYSTEM **Shall** keep the cargo lamps active as long as Inadvertent Load Control power is active. <END>

CUSTOMER “ACTION”	CUSTOMER PERCEIVABLE “OUTPUT”	MAXIMUM LATENCY “ACTION” to “OUTPUT”
INTERIOR ILLUMINATION Lamps Switch On and Vehicle Parked.	***Cargo Lamp Illuminates***	**100 ms**

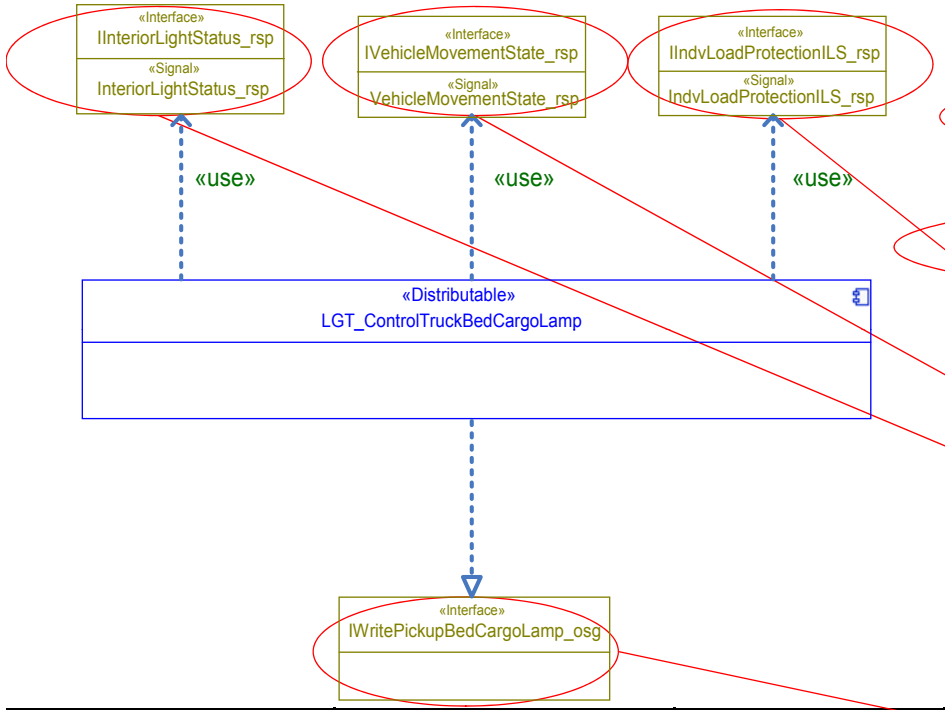
Back to Manual Estimation approach

Component Diagram



Back to Manual Estimation approach

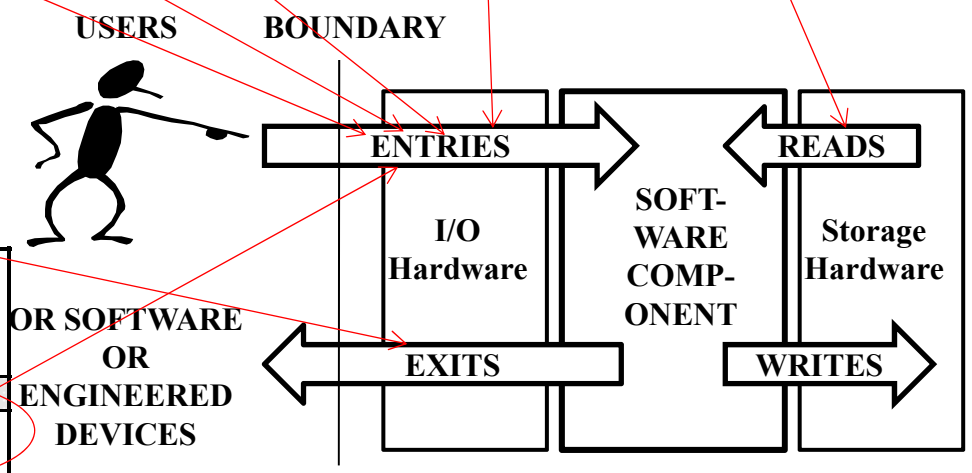
Functional Size Measurement



The feature **Shall** be enabled when the calibration CARGO LAMP PRESENT is set true. <END>

If the vehicle power mode is "OFF", and the cargo lights are illuminated, the SYSTEM **Shall** keep the cargo lamps active as long as Inadvertent Load Control power is active. <END>

CUSTOMER "ACTION"	CUSTOMER PERCEIVABLE "OUTPUT"	MAXIMUM LATENCY "ACTION" to "OUTPUT"
INTERIOR ILLUMINATION Lamps Switch On and Vehicle Parked.	***Cargo Lamp Illuminates***	**100 ms**

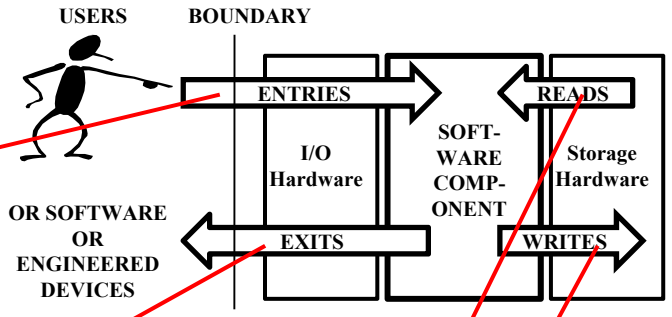


CFP=7!

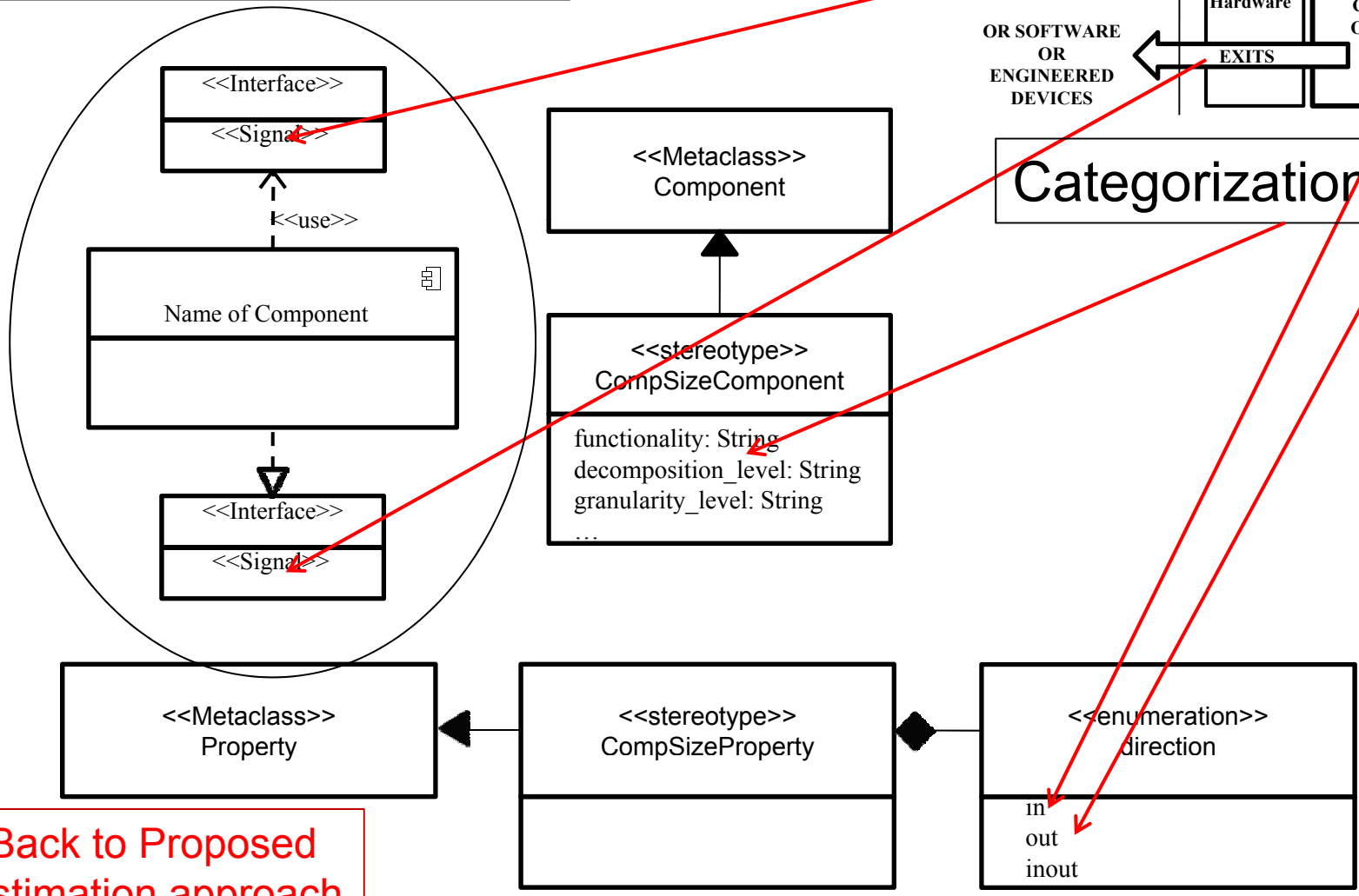
Back to Manual Estimation approach

UML Profile

Already in use at Saab

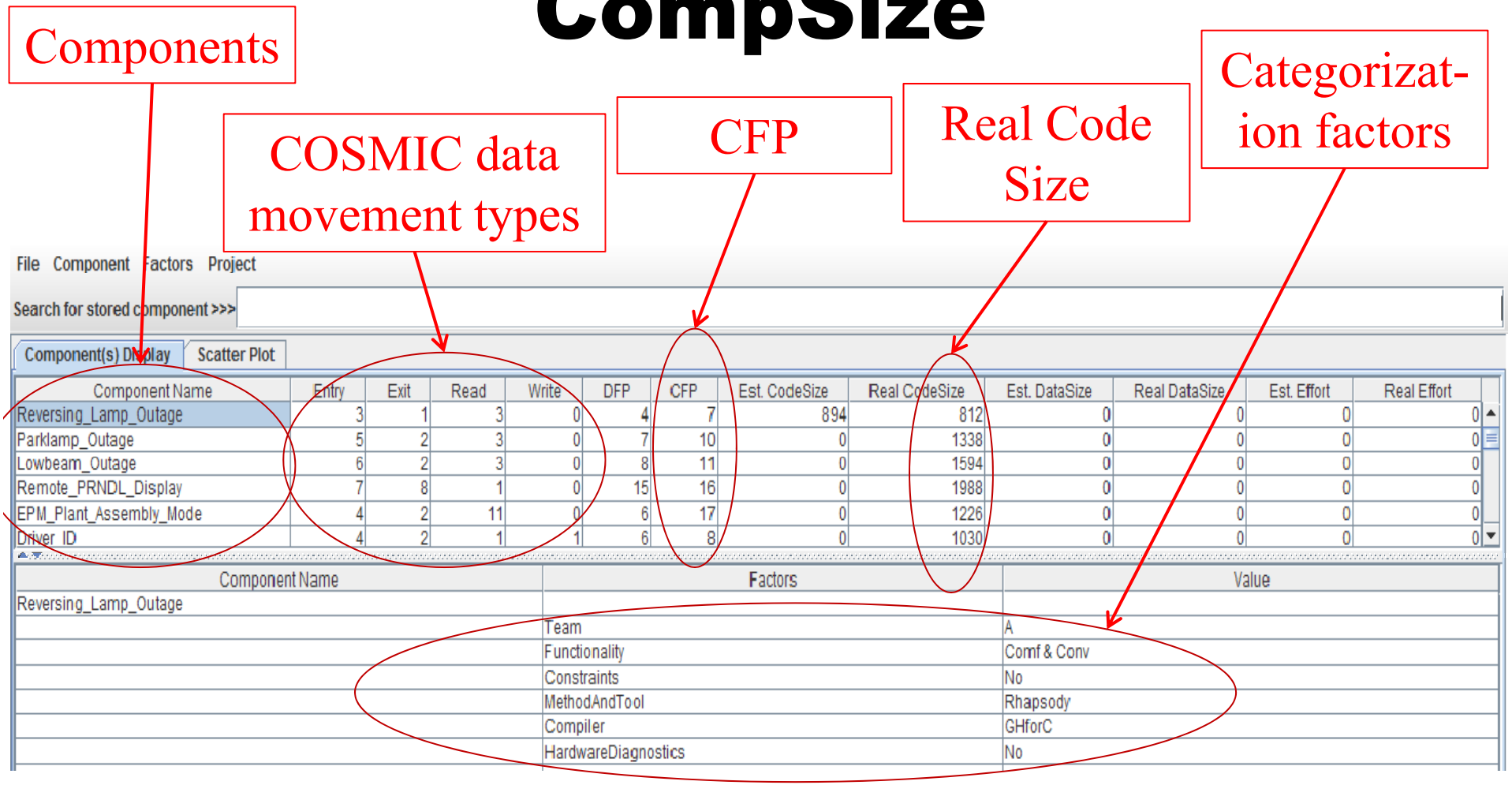


Categorization factors



Back to Proposed Estimation approach

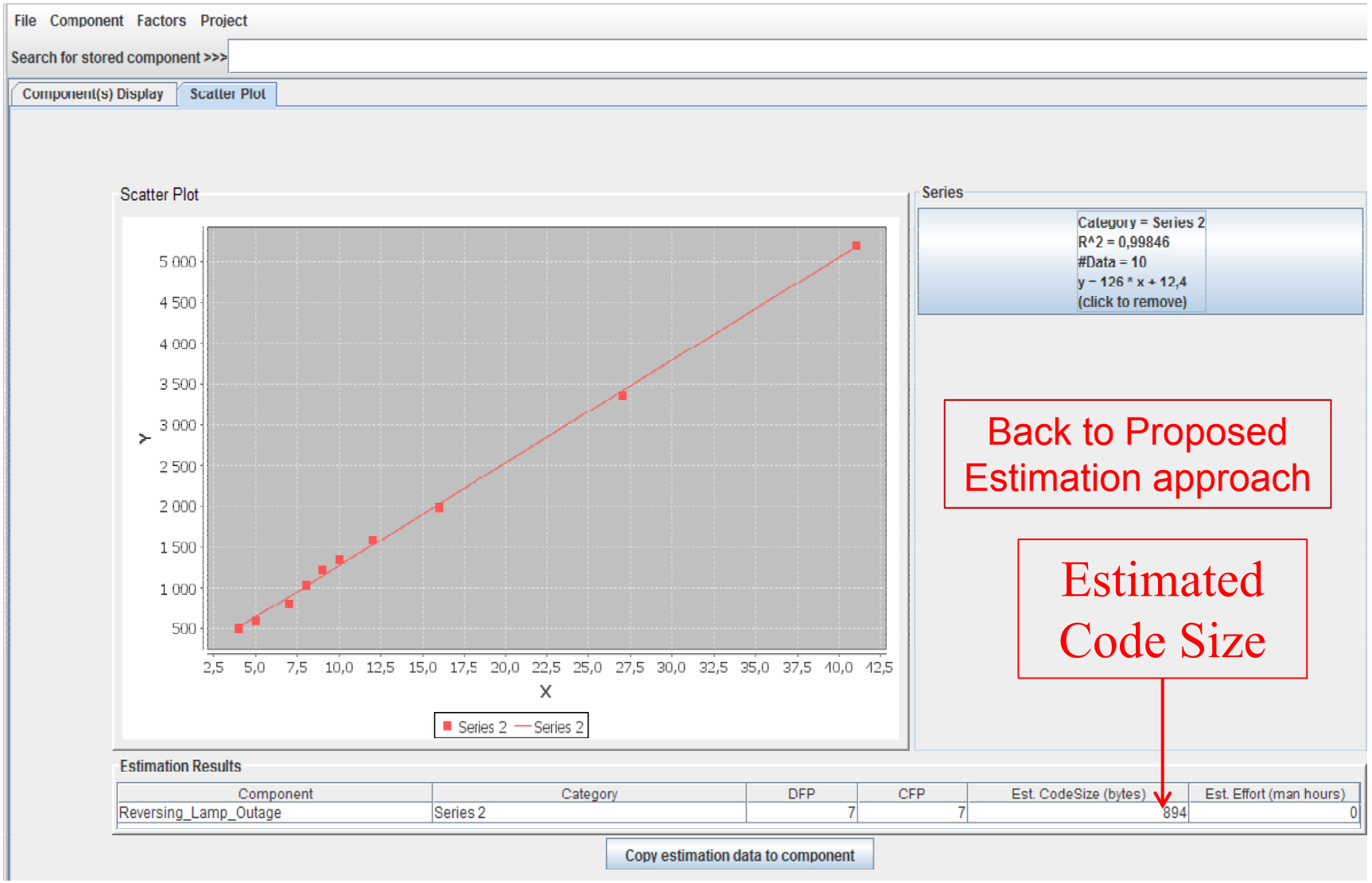
CompSize



Component Name	Entry	Exit	Read	Write	DFP	CFP	Est. CodeSize	Real CodeSize	Est. DataSize	Real DataSize	Est. Effort	Real Effort
Reversing_Lamp_Outage	3	1	3	0	4	7	894	812	0	0	0	0
Parklamp_Outage	5	2	3	0	7	10	0	1338	0	0	0	0
Lowbeam_Outage	6	2	3	0	8	11	0	1594	0	0	0	0
Remote_PRNDL_Display	7	8	1	0	15	16	0	1988	0	0	0	0
EPM_Plant_Assembly_Mode	4	2	11	0	6	17	0	1226	0	0	0	0
Driver_ID	4	2	1	1	6	8	0	1030	0	0	0	0

Component Name	Factors	Value
Reversing_Lamp_Outage		
	Team	A
	Functionality	Comf & Conv
	Constraints	No
	MethodAndTool	Rhapsody
	Compiler	GHforC
	HardwareDiagnostics	No

CompSize


File Component Factors Project
Search for stored component >>>
Component(s) Display
Scatter Plot
Scatter Plot
5 000
4 500
4 000
3 500
3 000
2 500
2 000
1 500
1 000
500
Y
2,5 5,0 7,5 10,0 12,5 15,0 17,5 20,0 22,5 25,0 27,5 30,0 32,5 35,0 37,5 40,0 42,5
X
Series 2 Series 2
Series
Category = Series 2
R^2 = 0,99846
#Data = 10
y = 126 * x + 12,4
(click to remove)
Back to Proposed Estimation approach
Estimated Code Size
Estimation Results
Component
Category
DFP
CFP
Est. CodeSize (bytes)
Est. Effort (man hours)
Reversing_Lamp_Outage
Series 2
7
7
894
0
Copy estimation data to component