UML-based Model-Driven Code Generation of Error Detection Mechanisms

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Presenter resume

- B.Sc. Computer Science (2016)
- M.Sc. Computer Science (2018)
- Since 2018: Research assistant and PhD student in the Software Engineering group of Osnabrück University
- PhD topic: Automatically generating source code for safety mechanisms from UML model representations
- Currently on the lookout for a co-advisor of my PhD thesis

Outline

- Introduction
- Overview
- Related Work
- MDD Code Generation for Error Detection
- Use Case
- Conclusion and Future Work

Introduction

Safety-critical applications

IEC

IEC 61508-3

Edition 2.0 2010-04

INTERNATIONAL STANDARD

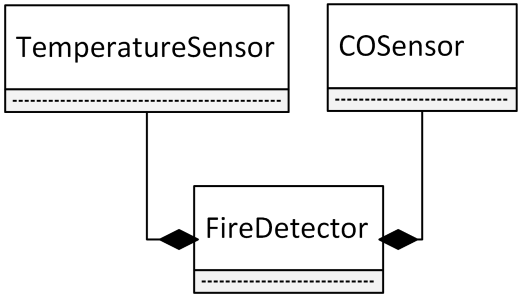
NORME INTERNATIONALE

BASIC SAFETY PUBLICATION
PUBLICATION FONDAMENTALE DE SÉCURITÉ

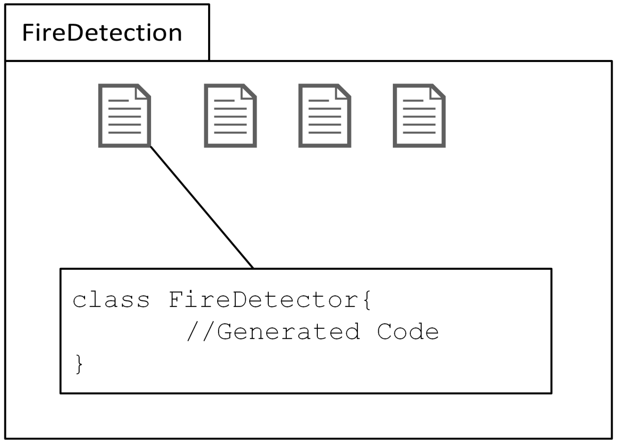
Functional safety of electrical/electronic/programmable electronic safety-related systems –
Part 3: Software requirements

Sécurité fonctionnelle des systèmes électriques/électroniques/électroniques programmables relatifs à la sécurité –
Partie 3: Exigences concernant les logiciels

Safety standards



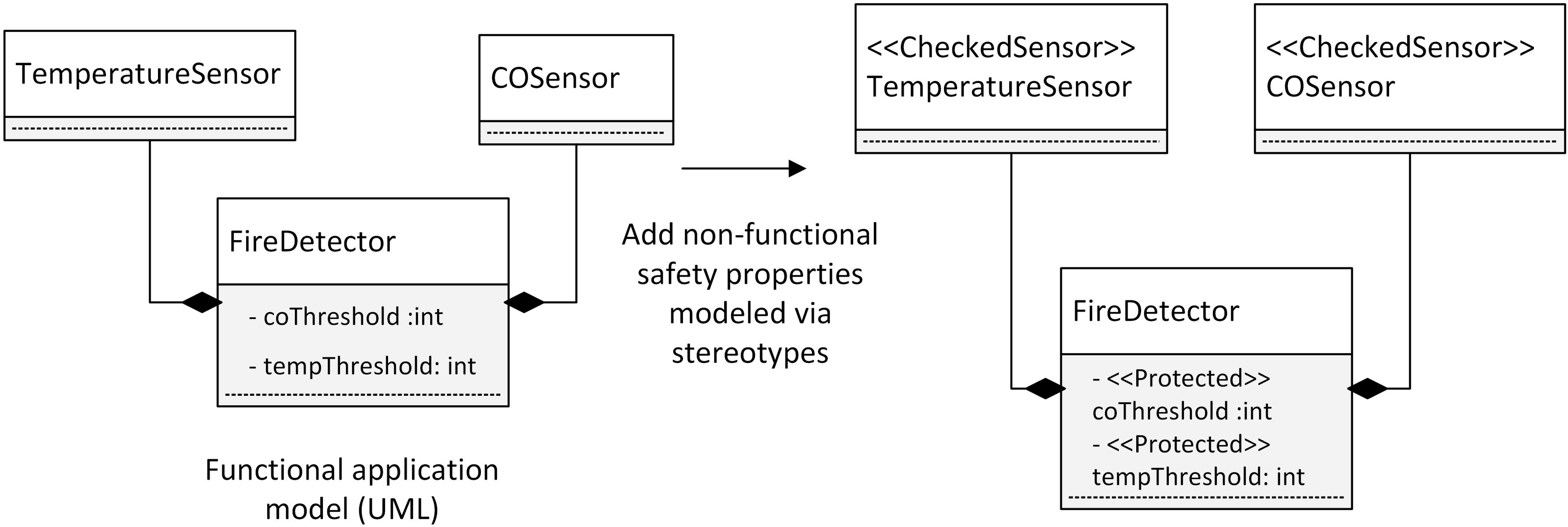
Modeling



```
class FireDetector{
        //Generated Code
}
```

Source code

Overview - I



TemperatureSensor

COSensor

FireDetector

- coThreshold :int
- tempThreshold: int

Add non-functional safety properties modeled via stereotypes

<<CheckedSensor>> TemperatureSensor

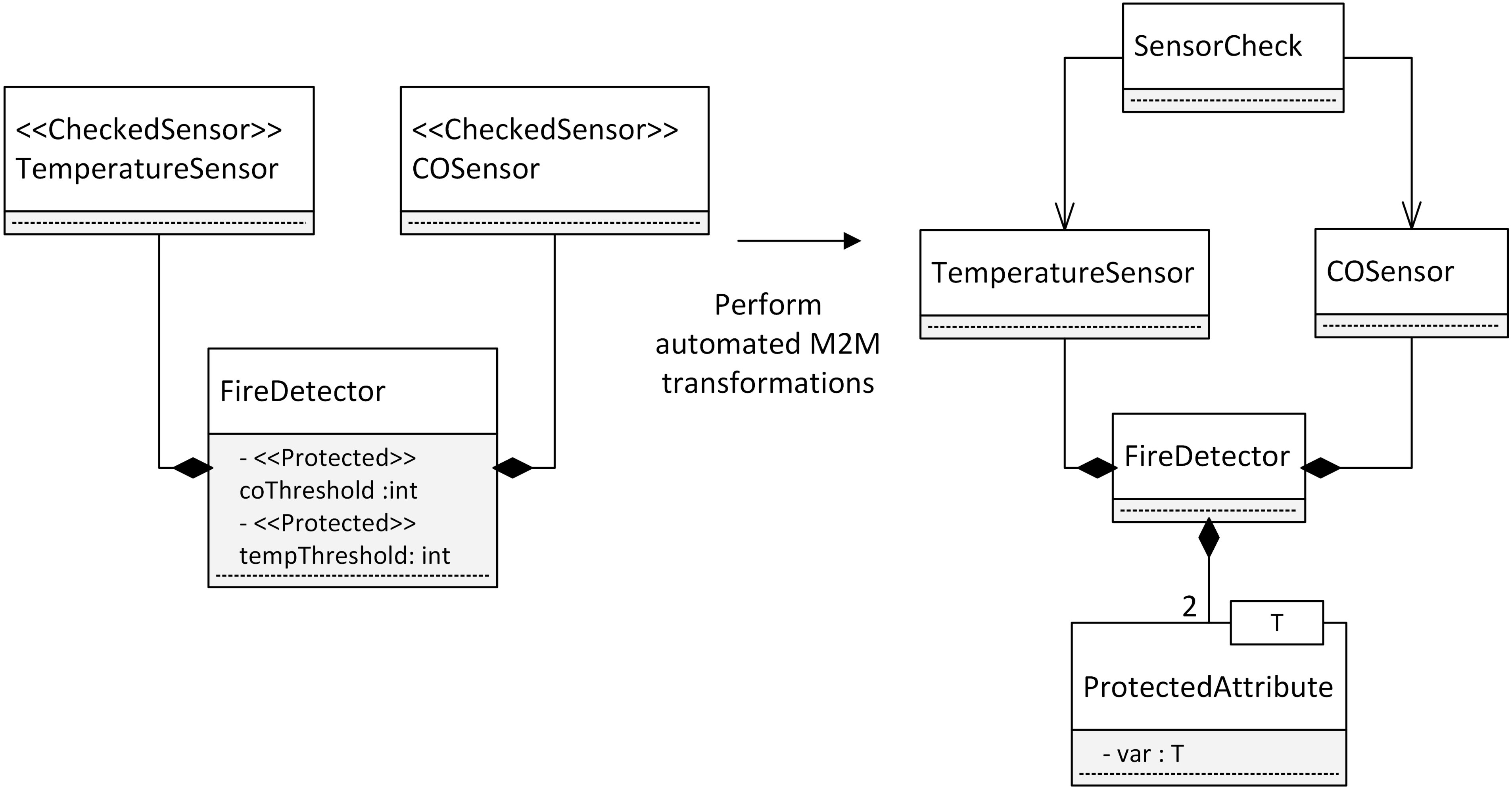
<<CheckedSensor>> COSensor

FireDetector

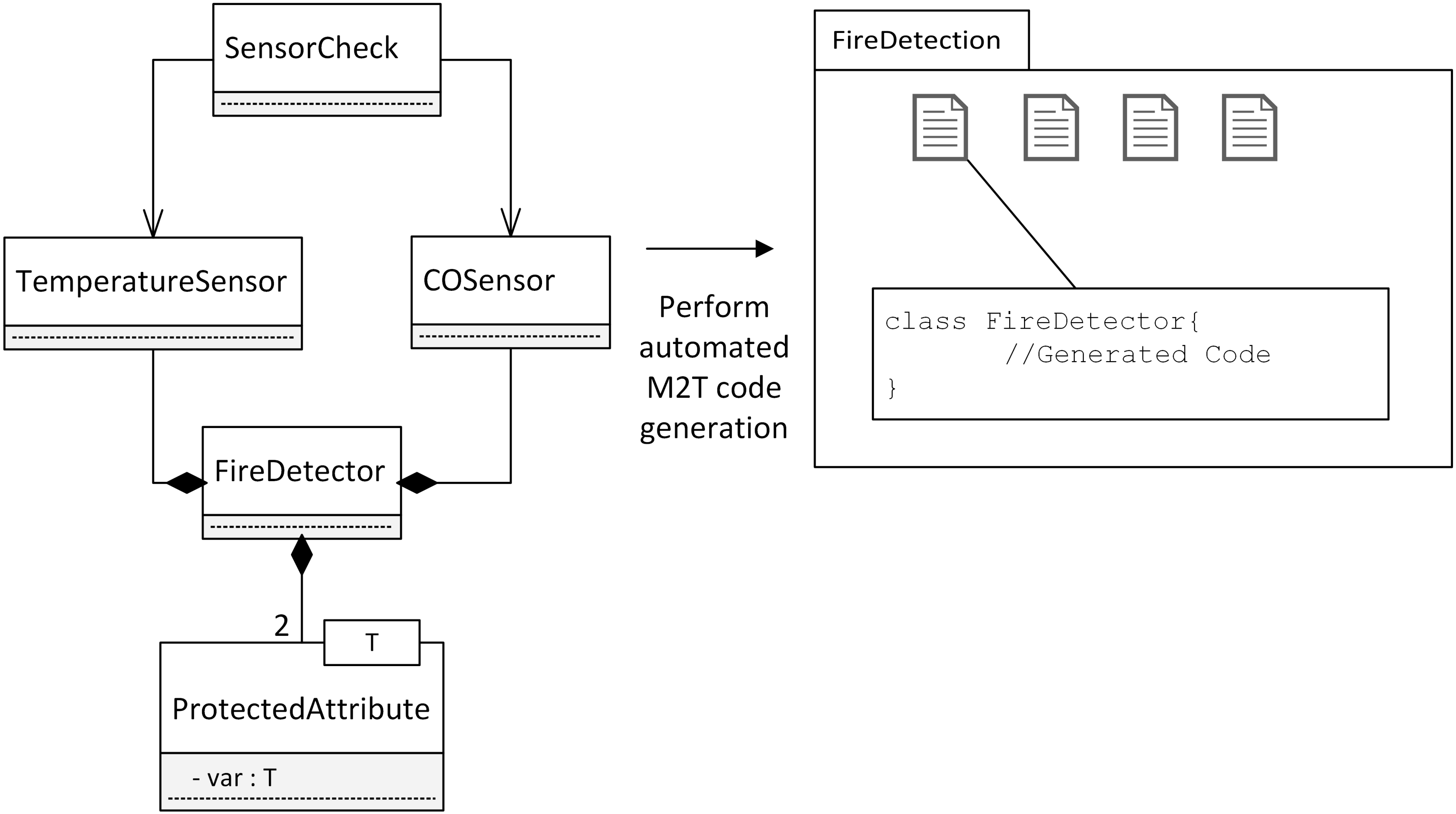
- <<Protected>> coThreshold :int
- <<Protected>> tempThreshold: int

Functional application model (UML)

Overview - II


<<CheckedSensor>>
TemperatureSensor
<<CheckedSensor>>
COSensor
FireDetector
- <<Protected>>
coThreshold :int
- <<Protected>>
tempThreshold: int
Perform
automated M2M
transformations
SensorCheck
TemperatureSensor
COSensor
FireDetector
2
T
ProtectedAttribute
- var : T

Overview - III



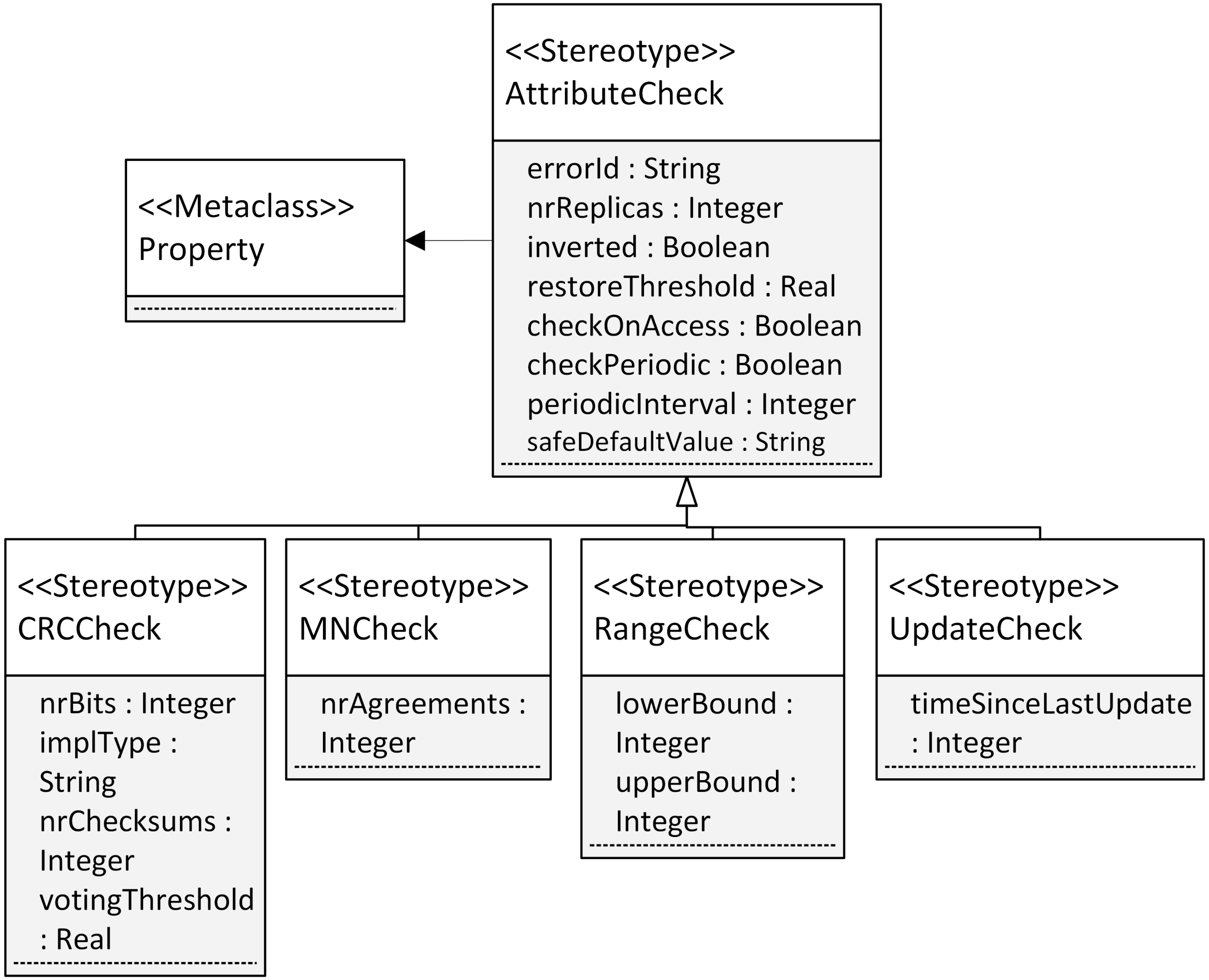
Perform automated M2T code generation

```
class FireDetector{
        //Generated Code
}
```

Related Work

- Basic UML → C++ MDD Tools (Rhapsody, 2020; Enterprise Architect, 2020)
- Advanced code generation for UML (Sunitha and Samuel, 2019)
- Modeling of embedded aspects (MARTE, 2008; Bernadi et al., 2011; SAFURE, 2017)
- MDD Generation of other safety mechanisms (Huning et al., 2019; Huning et al., 2020)
- Code generation for error detection (Trindade et al., 2014; Pezze and Wuttke, 2016)

UML Profile for error detection mechanisms



<<Metaclass>>
Property

<<Stereotype>>
AttributeCheck

errorId : String
nrReplicas : Integer
inverted : Boolean
restoreThreshold : Real
checkOnAccess : Boolean
checkPeriodic : Boolean
periodicInterval : Integer
safeDefaultValue : String

<<Stereotype>>
CRCCheck

nrBits : Integer
implType : String
nrChecksums : Integer
votingThreshold : Real

<<Stereotype>>
MNCheck

nrAgreements : Integer

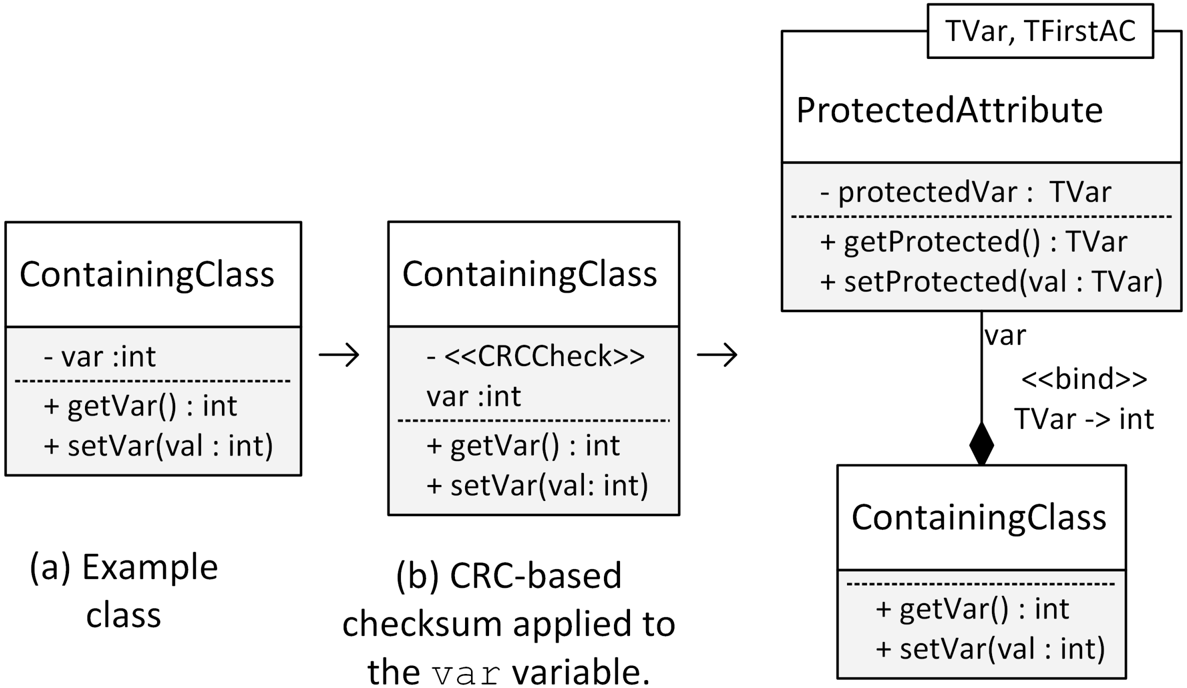
<<Stereotype>>
RangeCheck

lowerBound : Integer
upperBound : Integer

<<Stereotype>>
UpdateCheck

timeSinceLastUpdate : Integer

Basic concept for transparent generation



ContainingClass
- var :int
+ getVar() : int
+ setVar(val : int)

→

ContainingClass
- <<CRCCheck>> var :int
+ getVar() : int
+ setVar(val: int)

→

TVar, TFirstAC
ProtectedAttribute
- protectedVar : TVar
+ getProtected() : TVar
+ setProtected(val : TVar)

var
<<bind>>
TVar -> int

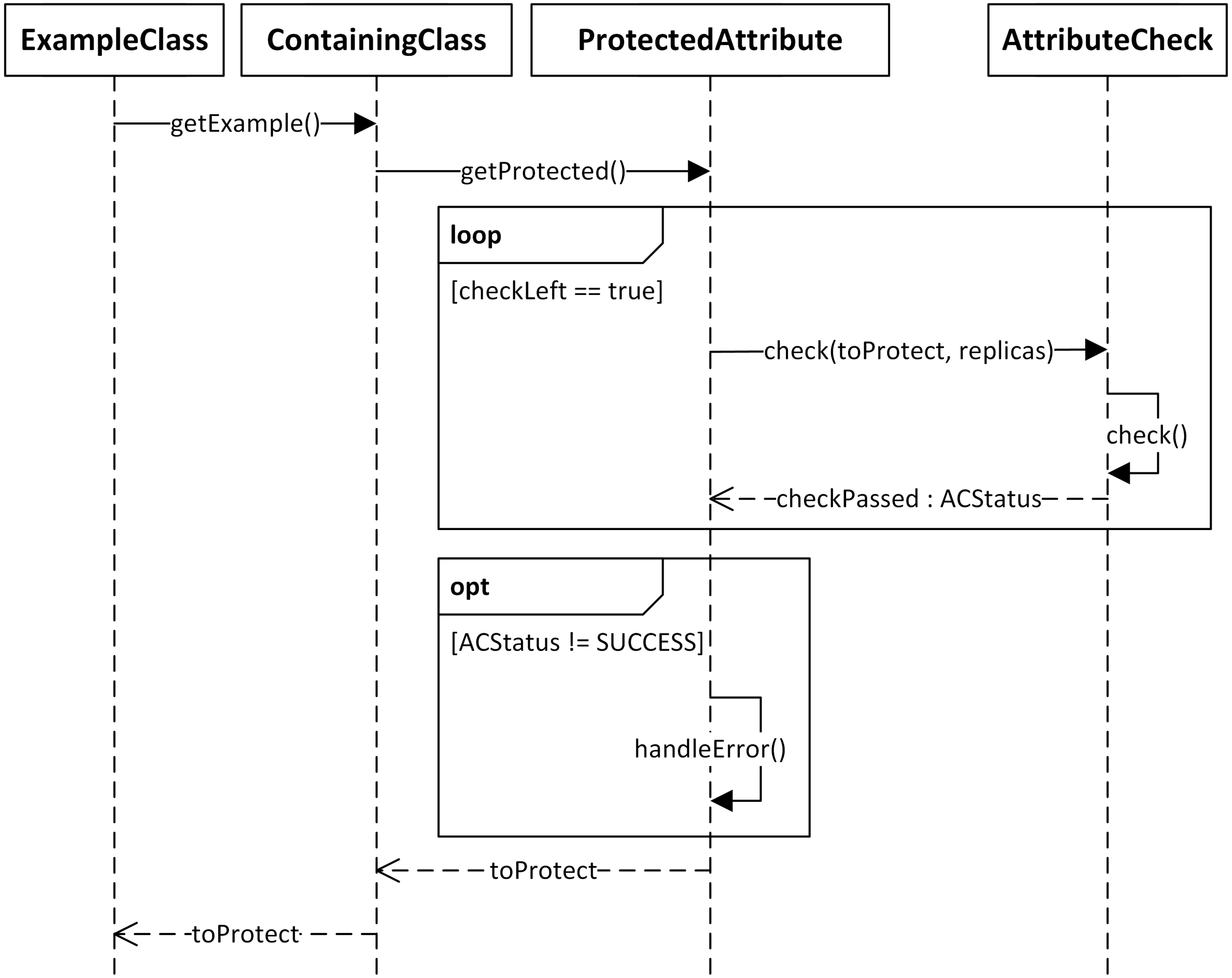
ContainingClass
+ getVar() : int
+ setVar(val : int)

(a) Example class

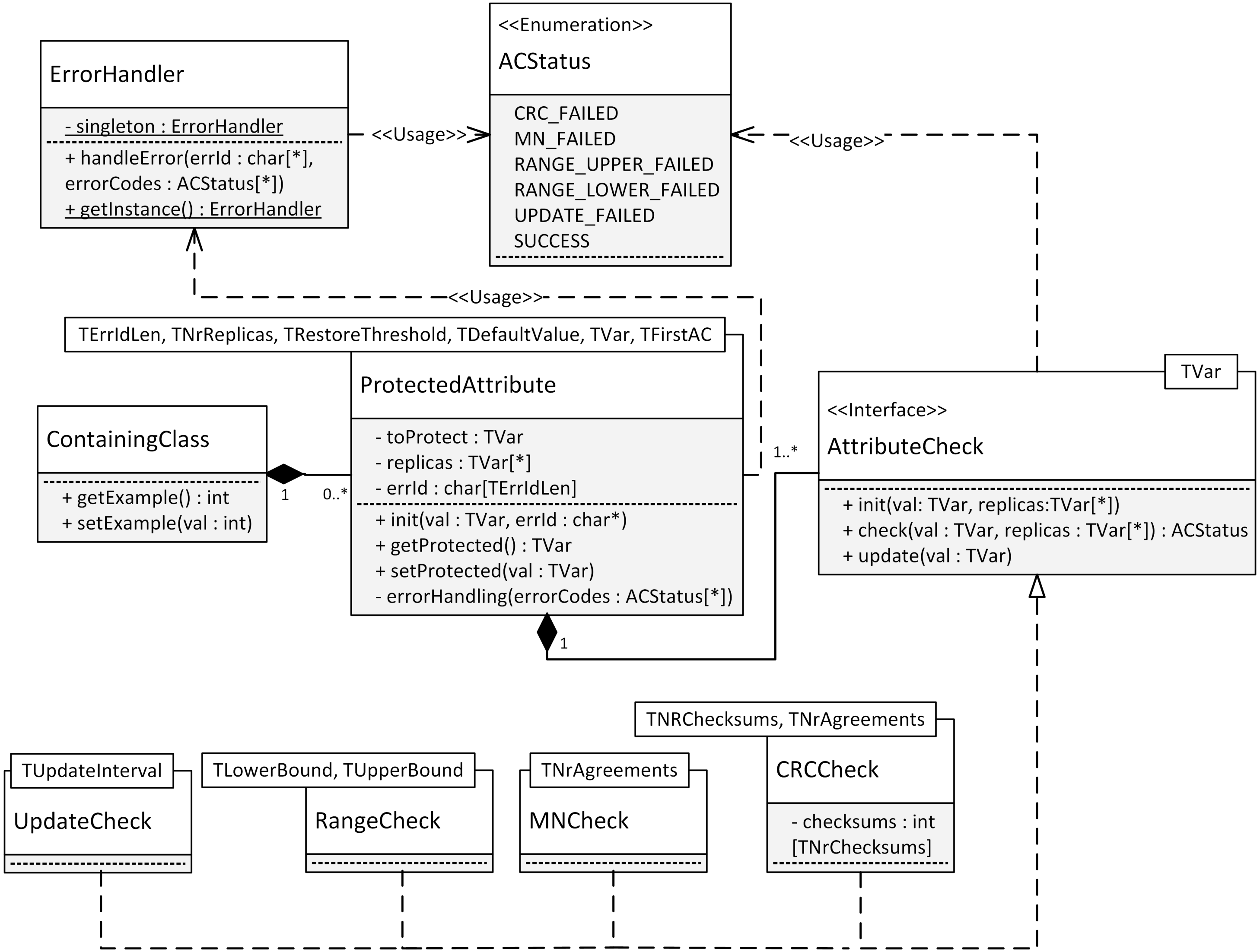
(b) CRC-based checksum applied to the `var` variable.

(c) Primitive `var` variable replaced by wrapper class (`ProtectedAttribute`) that contains a CRC-based error detection mechanism.

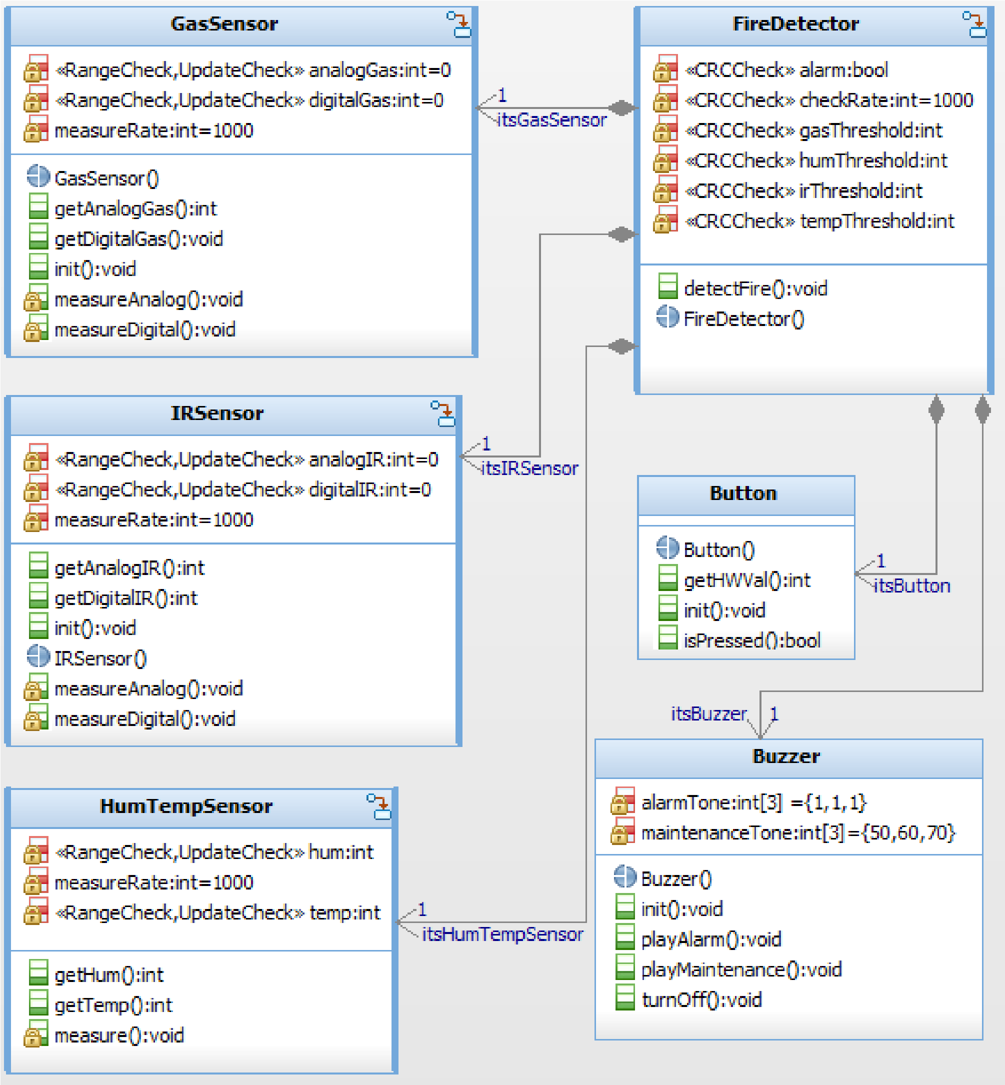
Runtime behavior



Software Architecture


ErrorHandler
- singleton : ErrorHandler
+ handleError(errId : char[*], errorCodes : ACStatus[*])
+ getInstance() : ErrorHandler
<<Usage>>
<<Enumeration>>
ACStatus
CRC_FAILED
MN_FAILED
RANGE_UPPER_FAILED
RANGE_LOWER_FAILED
UPDATE_FAILED
SUCCESS
<<Usage>>
<<Usage>>
TErrIdLen, TNrReplicas, TRestoreThreshold, TDefaultValue, TVar, TFirstAC
ProtectedAttribute
- toProtect : TVar
- replicas : TVar[*]
- errId : char[TErrIdLen]
+ init(val : TVar, errId : char*)
+ getProtected() : TVar
+ setProtected(val : TVar)
- errorHandling(errorCodes : ACStatus[*])
ContainingClass
+ getExample() : int
+ setExample(val : int)
1
0..*
1
1..*
TVar
<<Interface>>
AttributeCheck
+ init(val: TVar, replicas:TVar[*])
+ check(val : TVar, replicas : TVar[*]) : ACStatus
+ update(val : TVar)
TUpdateInterval
UpdateCheck
TLowerBound, TUpperBound
RangeCheck
TNrAgreements
MNCheck
TNRChecksums, TNrAgreements
CRCCheck
- checksums : int [TNrChecksums]

Use Case: Development of a Fire Detection System



GasSensor

«RangeCheck,UpdateCheck» analogGas:int=0
«RangeCheck,UpdateCheck» digitalGas:int=0
measureRate:int=1000

GasSensor()
getAnalogGas():int
getDigitalGas():void
init():void
measureAnalog():void
measureDigital():void

FireDetector

«CRCCheck» alarm:bool
«CRCCheck» checkRate:int=1000
«CRCCheck» gasThreshold:int
«CRCCheck» humThreshold:int
«CRCCheck» irThreshold:int
«CRCCheck» tempThreshold:int

detectFire():void
FireDetector()

IRSensor

«RangeCheck,UpdateCheck» analogIR:int=0
«RangeCheck,UpdateCheck» digitalIR:int=0
measureRate:int=1000

getAnalogIR():int
getDigitalIR():int
init():void
IRSensor()
measureAnalog():void
measureDigital():void

Button

Button()
getHWVal():int
init():void
isPressed():bool

HumTempSensor

«RangeCheck,UpdateCheck» hum:int
measureRate:int=1000
«RangeCheck,UpdateCheck» temp:int

getHum():int
getTemp():int
measure():void

Buzzer

alarmTone:int[3] ={1,1,1}
maintenanceTone:int[3]={50,60,70}

Buzzer()
init():void
playAlarm():void
playMaintenance():void
turnOff():void

Conclusion and Future Work

- Conclusion:
  - Specify error detection mechanism with UML stereotype
  - Source code for mechanism is generated automatically
  - Generation is transparent due to wrapper class
- Future Work:
  - Performance Evaluation
  - More safety mechanisms
  - Combination with safety assurance cases for certification
  - Apply concept to other non-functional properties

References

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Bernardi, S., Merseguer, J., and Petriu, D. (2011). A dependability profile within MARTE. Software and System Modeling, 10:313–336.

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Huning, L., Iyenghar, P., and Pulvermueller, E. (2020). A UML profile for automatic code generation of optimistic graceful degradation features at the application level. In Proceedings of the 8th International Conference on Model-Driven Engineering and Software Development, MODELSWARD, Valetta, Malta. INSTICC, SciTePress.

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