Integration of Component-Based Frameworks with Sensor Modeling Languages for the Sensor Web

By

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Abstract

The goal of this thesis is to develop an easily modifiable sensor system. To achieve this goal SensorML (an XML based sensor language) is combined with Java Beans (a component model language). An important part of SensorML is its process model. Each sensor in the real world is depicted in SensorML by a process model, whereas the connections between the sensors are shown by a process chain. This thesis presents a translator that reads these documents and converts them to Java Beans. Through testing the Translator is proved more efficient than the convenient Object Oriented approach.

Keywords: Sensor languages, SensorML, IEEE1451, sensor web, component based framework, Java Beans, Unified Modeling Language.

The dedication of this thesis is split in four: First and foremost to my mother, father and brother who have always given me their best, second to my grandparents who have supported me, third to my country, Iran, with the hope that peace and prosperity would reign there, and last to anyone, in any country with any ethnicity and religion who never loses hope.

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List of Abbreviates

SensorML	Sensor Modelling language
DDL	Device Description Language
WASP	Wirelessly accessible sensor population
ECHONET	Energy conservation and home care network
IEEE	Institute of Electrical and Electronics Engineers
XML	Extensible Markup Language
UML	Unified Modelling Language
TEDS	Transducer Electronic Data Sheet
O&M	Observation and Measurement
TransducerML	Transducer Markup Language
SCT	SensorML/Component Translator
CBSE	Component Based Software Engineering

Chapter 1 Introduction and Outline

1.1. Motivating Scenario

One of the most important objectives of any software system is its modifiability. The systems targeted in this thesis are sensor systems. A sensor system is a collection of sensors. A sensor is an individual detector. The users of these sensor systems are developers. An important factor when implementing sensor systems is their ease of modification thus the objective of this thesis is to develop software for a sensor system that is easily modifiable.

As sensors become pervasive sensor languages have become a popular option to represent sensory data. Figure 1 shows an example of a typical sensor system. The sensor data is received through a Gateway and it can be read by the user and stored in a Data Base. As it will be shown in later chapters using sensor languages will result in an extensible and discoverable system also providing the user with ease of integrity of new software components.

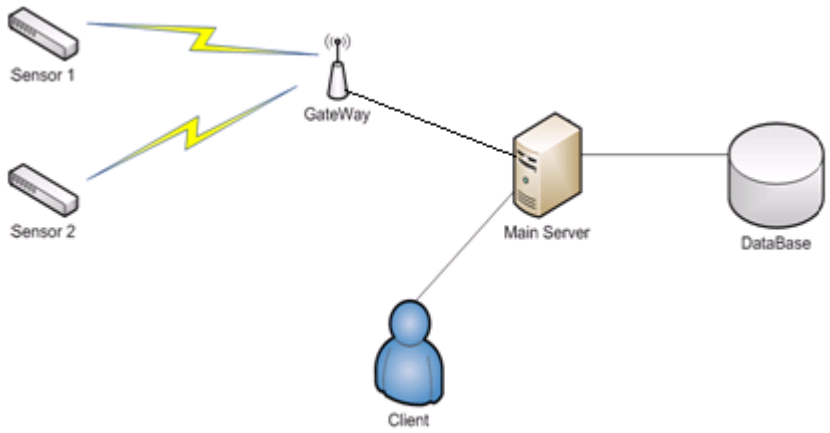

Figure 1. Typical sensor system

Many sensor languages have been developed to define a successful sensor system. Some of these languages are: IEEE1451 TEDS (Transducer Electronic Data Sheet)[1][2], SensorML [3][4][5], Device Kit [6], Device Description Language (DDL) [6], ECHONET (Energy Conservation and HOme care NETwork)[7].

All of the above sensor languages provide sensor data, but not all of them specify the process by which this sensor data is processed. One of the sensor languages that specifies a data processing model is SensorML and it is because of this data processing model that SensorML is selected as the sensor language in this thesis.

Even with a processing model SensorML is still not complete: just like XML, SensorML is nothing more than data representation (or in this case sensor data and process representation). The approach proposed converts SensorML into an executable application (in this case a Component-Based Framework).

Another problem in SensorML is its process model. The process model in SensorML can be seen as either a benefit or hindrance for the developer depending on how you look at it: it is a benefit when you consider the fact that other sensor languages like IEEE 1451 TEDS don't even have this process model part. It can also be considered as a hindrance considering the fact that SensorML just specifies the connections between process models without specifying the sequence in which these processes will be executed.

SensorML's lack of implementation and the lack of coordination between process models motivate the development of a translator to convert SensorML into Component Based Models. This translator will convert process models in SensorML, which specify sensors in the real world, to components and the connections in the process chain, which specifies the connections between the sensors, to events. The reason for the conversion of SensorML to Component Based Models is mainly to use the event handling capability in these models to answer SensorML's need for coordination. Java Beans [8] is selected as the Component Based Model. Java Beans is a Component-Based Model that is Java Based and abides by certain rules such as special naming patterns. The reason for this selection is that Java Beans uses Java, which will provide platform independence. Also Java Beans has a straight forward approach to deal with components and event handling.

1.2. Problem statement

Almost all sensor systems work in the same manner:

- A command is sent to sensors to gather data.
- Sensor data is captured by a middleware
- Sensor data is used by a software application.

- Sensor data is usually stored in some sort of data base for future use.

One of the greatest challenges when developing sensor system applications is to develop applications where changes can be implemented in them easily.

As the end users' comfort in using a software system is one of the goals of a successful product thus the objective of this thesis is to *develop a methodology or approach to simplify the software design of sensor systems based on leveraging the explicit descriptions of the sensors.*

Sensor Modeling Languages are used in order to develop sensor system that are easily modifiable. A translator is developed to automatically convert this sensor modeling language to components. These components, which replace the software application in the sensor systems, have the ability to insert sensor values in the data base.

1.3. Thesis Contributions

The main objectives of this research are as follows:

- To describe a sensor system using SensorML documents.
- To design and implement a translator to generate component based (Java Beans) code from the SensorML documents.
- To compare this approach with another functional sensor system in order to demonstrate that the developed system is better than the conventional Object Oriented (OO) approach in terms of measuring the impact of change in the sensor system.

The contributions of the research reported in this thesis can be summarized as follows:

- The design and implementation of the SensorML/Component Translator (SCT), which is used to convert SensorML documents into executable, code (Java Beans).
- Enhancements of the current sensor system implementation. These improvements include developing a sensor system that is easier to modify than the conventional Object Oriented approach. An enhancement of SensorML's process model by using component based frameworks. SensorML lacks proper coordination between process models; it specifies the process models' connections without mentioning anything about the time and sequence of these processes' execution. Component based languages' events are used to solve SensorML's coordination problem.

1.4. Structure of the Thesis

In this chapter, the motivating scenario for this research, the problem statement, and the thesis contributions were presented.

The remaining chapters of the thesis are as follows:

- Chapter 2: Gives the background information and related work. The first part of this chapter goes in depth about a few sensor languages stating their pros and cons and finally stating why SensorML was chosen as a suitable sensor language.The second part of this chapter talks about component based framework stating their qualities and introducing a few well known component based frameworks. The third part of this chapter talks about Component-based frameworks for sensors.
- Chapter 3: This chapter gives the design of the method implemented in the thesis.

- Chapter 4: This chapter presents the testing and analysis of the approach taken in this thesis with a substitute Object Oriented approach.
- Chapter 5: presents the comparison between the work done in this thesis and the related work presented in chapter 2.
- Chapter 6: Presents the conclusion.

Chapter 2 Background and Related Work

In this chapter an in depth study of sensor languages is presented first. In the second part of this chapter component based frameworks are analyzed. In the last part of this chapter a study is presented with the goal of obtaining a better understanding of component-based programming.

2.1 Sensor Modeling Languages:

Several sensor languages and standards have been proposed [1][2][3][4][5][6][7][9]. Here some of the most common standards in this area are presented.

Three of the most common sensor standards are IEEE 1451, SensorML and TransducerML [9]. They are used with a number of standard interfaces which have been developed by the OGC (Open Geospatial Consortium) namely: SOS (Sensor Observation Service) [4], SPS (Sensor Planning Service) [4], SCS (Sensor Collection Service) [4] and WNS (Web Notification Service) [4].

SensorML, TransducerML, O&M [10], SOS, SPS and WNS were developed by the OGC; IEEE1451 was developed by *NIST* (National Institute of Standards and Technology) to connect smart transducers to microprocessors and field networks. IEEE1451 defines devices as "*transducers*". Transducers can be seen as either actuators (which take an electrical signal and commit an action) or sensors (which produce a signal proportional to the input it receives).

The rest of the chapter is organized as follows. Section 1 gives an introduction to sensor languages: SensorML, IEEE1451, TransducerML, O&M, ECHONET, Device Kit and

DDL. A comparison between SensorML and IEEE1451 is provided in the second section followed by a study of component based frameworks in section three.

2.1.1. SensorML:

Sensor data processing is addressed by SensorML [3], [4], [5]. SensorML shows the sensor system with a *System* (or a *process chain).* The difference between a System and a process chain is that unlike process chains a System may have information beyond the sensors' connections and reference to the process models (the process models describe the sensors). Information like: the sensors' position, the calibration curve, response parameters, the sensors' locations in relation to the whole system, the sensor system's longitude, latitude, altitude and orientation, etc. In other words each System is a process chain but each process chain may or may not be a System. A System is at least composed of:

- References to the process models.
- Connections between process models.

A process chain is composed of sub parts called *process models*.

A process model itself describes the inputs and outputs and has a reference to a *process method* which consists of:

- A metadata or documentation part.
- A Schematron part showing the I/O constraints.
- A MathML part for the visualization of mathematical equations.
- A reference to a coding section.

Part of the SensorML description also captures static metadata information about the sensor like the sensor name, type, and manufacturer but the reason SensorML was chosen

was because of its process definition part. Figure 2 shows SensorML's process chain. The intention of this figure is to show SensorML's different components (the process chain, the process models, and the process methods), and the process models' connections inside the process chain (these connections are shown by the arrows in Figure 2).

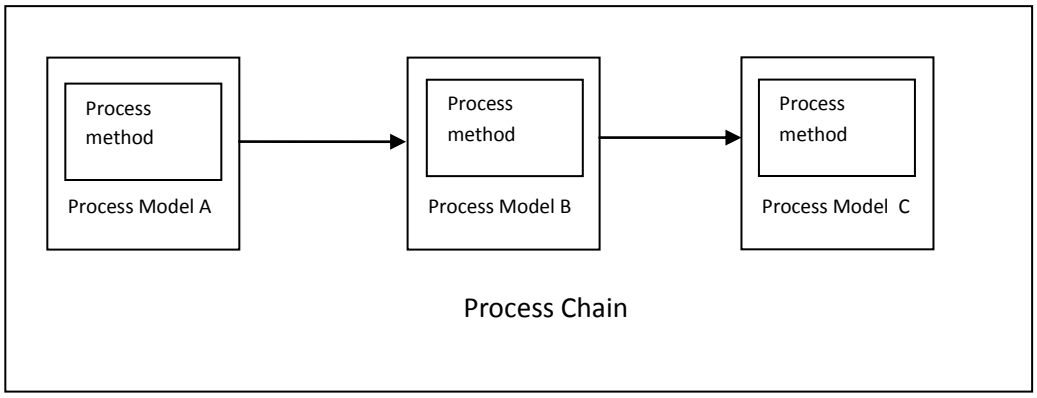

Figure 2. Process Chain in SensorML

Code 1 shows an example of a temperature sensor coded in SensorML. SensorML defines the *sml* XML namespace. This code shows the metadata for this sensor using the sml:Term tag and in this case it is trying to model an MTS 310 sensor board from Crossbow. The code also shows the sensor inputs (*sml:Inputs*) outputs (*sml:Outputs*) and a reference link to the process method given by the *sml:method* tag. This particular example has one input, "Temp1" and one output, "Temperature".

Code 2 shows an example of the process chain (the system as a whole). The sensor system is defined as a set of components that include references to SensorML sensor or devices, given by the *sml:component* reference, and links between these components (*sml:Link*). In this example the sensor system consists of only 1 component, the "Temp1" sensor and therefore the source and destination links point to the same component.

Code 3 shows the contents of the process method, "*Calibration.java*" file. This process method contains a method (*Temperature_Calibration()*) that will convert raw temperature data to calibrated, temperature data.

```
<sml:member>
<sml:Component>
<sml:identification>
<sml:IdentifierList>
<sml:identifier name="Manufacturer">
<sml:Term definition="urn:ogc:def:identifier:manufacturer">
  <sml:value>Crossbow</sml:value>
  </sml:Term>
  </sml:identifier>
  <sml:identifier name="Mote Type">
  <sml:Term definition="urn:ogc:def:identifier:moteType">
  <sml:value>Mica2</sml:value>
  </sml:Term>
  </sml:identifier>
  <sml:identifier name="Sensor Board">
  <sml:Term definition="urn:ogc:def:identifier:sensorBoard">
  <sml:value>MTS310</sml:value>
  </sml:Term>
  </sml:identifier>
  </sml:IdentifierList>
  </sml:identification>
  <sml:inputs>
  <sml:InputList>
  <sml:input name="Temp1">
  <swe:Quantity>
  <swe:uom code="" xlink:href="degreeF" />
  </swe:Quantity>
  </sml:input>
  </sml:InputList>
  </sml:inputs>
  <sml:method xlink:href="C:\\workspace\\tezFogh7_13\\Calibration.java" />
  </sml:Component>
  </sml:member>
  </sml:SensorML>
```

Code 1. SensorML document for Temperature sensor

```
<sml:member>
  <sml:System>
  <sml:classification>
  <sml:ClassifierList>
  <sml:classifier name="sensorType">
  <sml:Term definition="urn:ogc:def:identifier:sensorType">
  <sml:value>Temperature</sml:value>
  </sml:Term>
  </sml:classifier>
  </sml:ClassifierList>
  </sml:classification>
  <sml:components>
  <sml:ComponentList>
  <sml:component name="Temperature"
  xlink:href="C:\\SensorMLEditor\\workspace\\BR\\Temperature.xml" />
  </sml:ComponentList>
  </sml:components>
```

```
 <sml:connections>
 <sml:ConnectionList>
 <sml:connection>
 <sml:Link>
  <sml:source ref="Temperature\Temp1" />
  <sml:destination ref="Temperature\Temp1" />
  </sml:Link>
  </sml:connection>
  </sml:ConnectionList>
  </sml:connections>
  </sml:System>
  </sml:member>
  </sml:SensorML>
```

Code 2. SensorML document of a System (Process Chain) with a Temperature sensor

```
public class Calibration{
public void Temperature_Calibration(){
double out = 2.5 * ((double) Temp1 / 4096) * 100 * 2. - 273;
System.out.println("Calibrated Temperature is: " + out);
  }
}
```

Code 3. Process method Calibration.java

Figure 3 shows an example of a SensorML system with one, temperature sensor that has a single input and a single output.

Figure 4 shows an example of another sensor system with a wind chill and a temperature sensor. Wind chill has two inputs, temperature and wind speed. As can be seen from Figure 4 the output of the temperature sensor provides one of the inputs to the wind chill sensor.

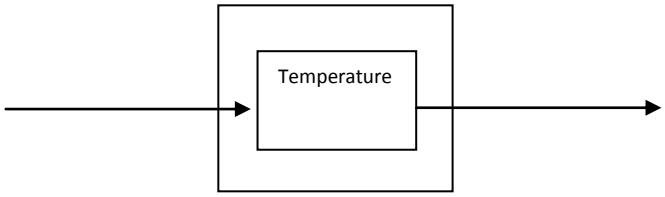

Figure 3. SensorML system with Temperature sensor

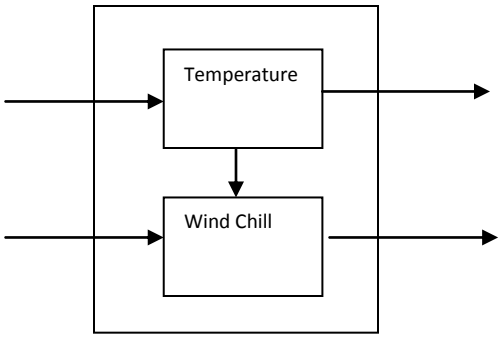

Figure 4. SensorML system with WindChill and Temperature sensors

2.1.2. IEEE 1451

A transducer is a superset of sensors and actuators. A smart transducer is a unit consisting of a transducer, a microcontroller, a converter and software used for signal conditioning, calibration and communication [1], [2].

NIST has developed a set of smart transducer interfaces which are known as IEEE1451. Figure 5 shows the structure of IEEE1451.

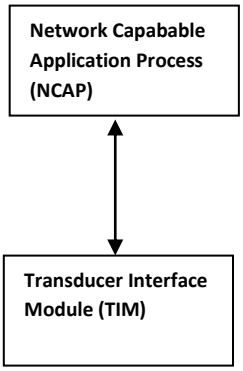

Figure 5.IEEE 1451 structure

The TIM (Transducer Interface Module) in Figure 5 consists of: transducers, Transducer Electronic Data Sheets (TEDS), analog to digital and digital to analog converters (A/D and D/A converter.)

The analog output of the transducers is converted to a digital form by the A/D converter. The digital result can be processed by a microprocessor; finally the obtained value can be passed in the network by a network communication protocol.
The TEDS (Transducer Electronic Datasheet) are used to store information about the transducer: from the manufacturer related information to calibration data. The TEDS have several advantages these include: sensor discovery, documentation, plug and play functionality.

The division of Figure 5 into two parts (NCAP and TIM) provides the advantage of modularity. For example, two manufacturers can focus on building the part they are interested in (as long as they abide by certain standards) [1].

2.1.2.1. IEEE1451 family of standards:

There are seven elements in the IEEE 1451 family of standards. These are:

- *IEEE1451.0:* This IEEE standard is used to read and write to the TEDS.
- *IEEE1451.1:* This element defines the format of information communicated across IEEE1451.1 is defined by three models: a data model that specifies the format of information communicated across IEEE1451.1 objects, an object model which is application part and two communication models defining the interface between the communication network and the application objects.
- *IEEE1451*.2: This standard was developed for peer to peer configurations; it describes an interface between the NCAP and the transducers.

- *IEEE1451*.3: This standard does the same work as the standard before only this time instead of peer to peer configuration this is done for multi-drop communication protocols.
- *IEEE1451.4:* This element standard was defined for analog transducers with analog and digital operating modes.
- *IEEE1451*.5: This standard was defined as an interface between NCAP and wireless transducers.
- *IEEE1451*.6: This standard uses CANOpen network interface and it defines an interface between the NCAP and the transducers.
- *IEEE1451.7:* This element defines an interface between transducers and RFID systems.

2.1.3. TransducerML:

Transducers are the super sets for sensors and actuators. When receiving a message from a transducer it is a stream of binary data; in this form it is impossible to tell what the data means. TransducerML gives some meaning to the stream of data received. How much of the data is used is dependent on what it is going to be done with the data. If for example the purpose is only to display data on the screen then it is enough to know the structure of the data but if the purpose is also to know what the sensor is measuring we also need to know the transducer's or sensor's characteristics.TML is part of the Sensor Web Enablement (SWE) and it is used with O&M and SensorML.

In TransducerML not only is the sensor data transmitted but also the sensor metadata is transmitted; this is used for searching, discovering, subscribing and processing. Figure 6

depicts the relationships characterized by TML.

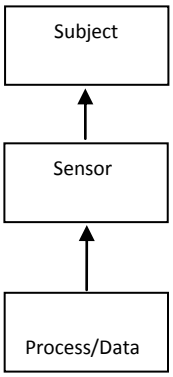

Figure 6. Relationship between TML components

TransducerML has several similarities to SensorML the main ones being that:

TransducerML's encoding is XML, and its design perspective is data oriented everything is seen as input, process and output. Howevere, unlike SensorML the basic components in TransducerML are *processes* and the composite components are *subjects*.

2.1.4. Observations and Measurement (O&M):

O&M document defines a set of ways to tie the values and the unit of measures together. This information is encoded in an XML format.

The basic information provided by Observation includes the time of the event (*timestamp)*; the value of a procedure such as instrument or simulation (*using*); the identification of phenomenon being sampled (*observable*); the association of other features that are related to the Observation (*relatedFeature*); the common related features that have fixed role such as Station or Specimen *(target)*; the quality indicators associated

with the Observation *(quality)*; the result of the Observation *(resultOf)*; location information *(location)* and the metadata description *(metadataProperty)*.

2.1.5. ECHONET (Energy Conservation and Home- care Network):

This standard originated in Japan with the purpose of monitoring energy consumption. It allows the integration of devices from multiple vendors. To get a device incorporated in the network the vendors must provide the same interface as specified in the ECHONET specification [6],[7].

The ECHONET device specification is a list of devices each shown as classes. The classes properties and methods are explained in plain English.

Having a device specification which is like a big dictionary is what makes ECHONET unscalable: if the device changes the specification and therefore the standard must change.

The objectives of ECHONET are that: data transmission should not require rewiring of the existing houses, it should be possible to use products from different vendors together in a single network, Plug and Plug should be provided, low cost connections with existing standards should be provided.

2.1.6. Device Kit:

The Device Kit enables the development of applications for devices when hardware-information is unknown. Device Kit uses eclipse to generate the component to interface with a hardware device [6].

The application interfaces with the Device Kit and the Device Kit interfaces with the hardware.

Device Kit uses the publish/subscribe service: an application subscribes to a service and it is notified when an event is published.

Device Kit makes use of DKML (Device Kit markup language) which is an xml file that contains information about the devices. There exists a DKML to java generator to convert between the DKML and java formats.

As it can be seen from the description of Device Kit; Device Kit is quite similar to the work performed in this thesis. The similarities are the following:

- Device Kit uses DKML, which is an XML file containing information about sensors, in this thesis SensorML is uses, which is an XML file containing information about the sensor data and processes.
- There is a generator that converts DKML to java. In this work a translator is developed that converts SensorML to Java Beans, which is Java language following a set of patterns.
- Publish/subscribe services are used in both Device Kit and the code generated by the translator in this thesis.

A big difference between SensorML and Device Kit is that in SensorML the hardware information is not unknown and it is embedded inside the process model where as Device Kit provides a platform for applications where hardware information is unknown.

2.1.7. DDL (Device Description Language):

DDL was first developed in the University of Florida. It assumes devices have no networking capabilities and they connect to applications via motes. Therefore, DDL only focuses on device to device interfaces [6].

In DDL a device consists of information on the *properties* (which provides information about the device such as the device's vendor, its purpose, etc), *internal mechanisms* (which are related to the operation of the device and hidden from the outside world), *interfaces* (which are links between internal mechanisms and the external world).

DDL classifies devices into: *sensors* (which provide users with inputs), *actuators* (which accept outputs from users), and *complex devices* (which do both of the aforementioned tasks.)

Sensor Services are subdivided into three parts:

1. Physical sensor service: a service which gets an input from a single source.
2. Basic Virtual Sensor service: a service that accepts input from multiple sources with the same unit.
3. Derived Virtual sensor service: a service that accepts input from multiple sources with different units.

Each DDL file descriptor contains information needed for the discovery of the device like the device name and its model; it also contains the description of the device's operations. Here, the inputs are known as *signals* and the outputs are known as *readings.*

The DDL schema will define constraints on the DDL document. This is enforced by the *DDL validity checker.*

The DDL element which is the root element of the DDL consists of a sensor, an actuator and a device. Each sensor consists of a description and an interface. The description part of the sensor has the descriptive information about the sensor, whereas the Interface part of the sensor consists of the signals and the readings.

2.1.8. Analysis of sensor modeling Languages:

Table 1 shows a comparison between all the senor modeling languages presented in Chapter 2.1.

As it can be seen in this table there are two big differences between SensorML and the other sensor modeling languages. These are:

- SensorML supports the processing of sensor data while the other senor modeling languages (except DDL) don't do this.
- The communication with SensorML is done through a DOM Parser. The way sensor data is read or written to TEDS is with a Maxim/Dallas Semiconductor DS9097U-S09 Universal 1-Wire COM Port Adapter. The software that communicates with the TEDS needs to know how to interpret the sequence of the binary code in order to read and write to the TEDS.

	Captures sensor information	**Protocol to communicate with the information model**	**Supports sensor discovery**	**Supports processing of sensor data**
SensorML	Yes	Uses DOM Parser	Yes	Yes
IEEE1451	Yes	Communication through hardware and software with the TEDS.	Yes	No
TransducerML	Yes	Uses DOM Parser	Yes	No
O&M	Yes	Uses DOM Parser	Yes	No
ECHONET	Yes	Device Specifiifaction	Yes	No
DeviceKit	Yes	Using a Generator to convert DKML to Java	Yes	No
DDL	Yes	DDL file descriptor	Yes	Yes

Table 1. Comparison between SensorML and IEEE1451

As was stated in Chapter 1 main goal of this work is to: convert sensor languages into executable, component based programs.

SensorML is selected as the sensor language because with the exception of DDL it is the only sensor modeling language that specifies the execution process of a sensor system. This is very important in determining the flow in component based design. SensorML is chosen instead of DDL because SensorML is a better known standard and because the connections in the process chain of SensorML are easily mapped into Component-Based Frameworks, which are the second part of this work.

2.2. Component based frameworks

Component Based Software Engineering (CBSE) [11],[12] was first introduced in the 1990s and is based upon building reusable software components. Java Beans is an example of a component based framework which is created using the Java language [8]. One of the qualities of Component-Based Frameworks which makes them especially interesting in this thesis is the event handling, which will be used to implement the connections between the processes.

Now several Component-Based Frameworks will be discussed.

2.2.1. Java Beans:

Java Beans are software components that abide by a certain number of rules such as special naming patterns.

Introspection (which is the ability to extract a Bean's properties, method and events), properties (which are the behaviors of Beans), Event handling (the capability of the Beans to communicate with each other), persistence (the ability to save and restore Beans' properties), methods (which are like normal Java methods) are the core Beans' concepts.

In this section some of the most important features of Java Beans that are exclusive to Java Beans like event handling, introspection and persistance are explained.

The connections in the process chain can be modeled in different manners: one of them is to provide a coordinator which will facilitate the communication between the process models; the other is by using events. In this design connection by means of events is used. Java Beans uses three classes when dealing with events: *PropertyChangeSupport* (which contains three methods: *add/removePropertyChangeListener* and *firePropertyChange*), *PropertyChangeEvent* (which contains three methods *getNewValue*, *getOldValue* and *getPropertyName*), *PropertyChangeListener* (which is an interface supplying one method, *propertyChange*.

Events are addressed in Java Beans by using bound properties. Bound properties are properties that transmit notifications when changes occur to event handlers.

A java bean that has bound properties must keep a list of propertyChangeListeners. As such the bean implements the propertyChangeListener interface. When we implement this interface we override the *propertyChange* method that specifies what should happen once the property changes.

The class PropertyChangeSupport implements methods that add and remove PropertyChangeListeners. Since adding and removing PropertyChangeListeners is needed the Bean will have a PropertyChangeSupport attribute.

The firePropertyChange method that is called within the *setter* method sends a PropertyChangeEvent (that lets us see the old and new value of the changed attribute and the name given to it) to Java classes which implement the PropertyChangeListener.

Introspection is the process by which properties, methods and events in a class are exposed. By following a set of basic conventions (such as each property has to have a set and get method and these set and get methods are composed of the name set or get plus the name of the property). Code 4 shows an example of introspection and its output for the Temperature sensor. The Temperature sensor has one input called *Temp1*.

A person might need to provide more descriptive information of the java bean. In this case they will use the *BeanInfo* class which involves more work but is sometimes necessary.

```
import java.beans.BeanInfo;
import java.beans.Introspector;
import java.beans.IntrospectionException;
import java.beans.PropertyDescriptor;

public class Temperature
{
    double Temp1;

    public double getTemp1()
    {
        return Temp1;
    }


 public void setTemp1( double x )
    {
        Temp1=x;
    }


}
```

Code 4. Example of a class (Temperature) that is going to be tested for introspection

```
import java.beans.BeanInfo;
import java.beans.IntrospectionException;
import java.beans.Introspector;
import java.beans.PropertyDescriptor;
```

```
public class Test {
       public static void main( String[] args )
     throws IntrospectionException
{
 BeanInfo info = Introspector.getBeanInfo( Temperature.class,
Object.class );
 for ( PropertyDescriptor pd : info.getPropertyDescriptors() )
     System.out.println( pd.getName() );
}
}
```

Code5. Example of testing Introspection for class Temperature

Persistence is the mechanism by which any bean can store its state. It gets converted in a data stream and saved; any program can retrieve this state by deseralizing it. It is also possible to serialize parts of the bean this is done by excluding the fields you don't want serialized by using the keyword *transient.*

2.2.2. Microsoft's Component Object Model (COM)

Microsoft's COM has an architecture as shown in Figure 7 [13]. In COM there exists a virtual pointer (*vpointer*), which points to a virtual table (the methods are in this table), each entry in the virtual table points to a method implementation.

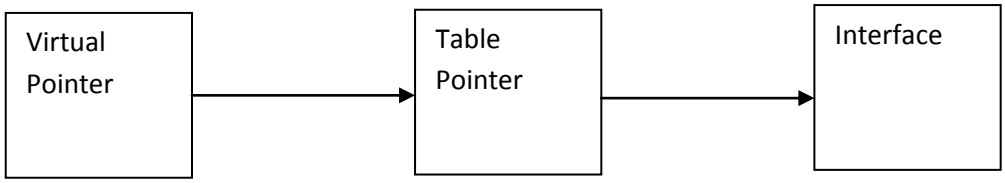

Figure 7. The structure of COM

The interface part of Figure 7 consists of 4 parts:

- *QueryInterface*: this is a pointer to other interfaces.

- *AddRef*: to assign memory. (interfaces are a pointer to a block of memory)
- *Release*: release memory.
- Other methods

COM has been implemented both across C and Java platform.

There are several problems with COM:

- COM was created because of MS Office product's need to interact with each other.
- When COM is used with Java it only supports a version of Java implemented in Microsoft Windows thus it undermines a very strong point in Java which is its ability to work across multiple platforms.
- From this thesis' point of view COM needs to be able to use XML format (for the SensorML documents) and at the moment COM doesn't seem able to do this.

2.3. Component-Based Modeling Framework for Sensors

In this section a discussion of the related work is presented. Specifically, we focus on the application of Component-Based Frameworks with sensor modeling languages. The work presented in this part is closely related to the approach taken in this thesis. A comparison of the work presented in this section and this thesis is presented in chapter 5.

2.3.1. Insense (A Component-Based Model and Language for Wireless Sensor Network Applications)

Insense is a component based language for wireless sensor networks developed by *Alan Dearle et. Al* [14][15]. Insense is an implementation of a component diagram. A component has an input channel and an output channel with which it can connect to other

components. The components' channels have primitive types. Insense is written using Java and it creates a C source code.

To define a component in Insense two things have to be defined: an interface and an implementation of that interface. In the interface the type of the input and output channel is defined. The implementation of the interface has three parts: the variables of the component, the constructor and the behavior of the component. The constructor is used to initialize the component; the behavior is the part of the component that runs until it is stopped by either the component itself or another component by using the keyword *stop*.

Four operations (send, receive, connect, and disconnect) can be performed on the channels. Each channel consists of two half channels each of which have five parts (a buffer for the type storage, *Ready* and *nd_received* for communication purposes, a binary semaphore called *mutex*, which provides mutual exclusion on the channel, a list of *connections* that are pointers to the half channel).

2.3.2. UM-RTCOM (A Component Framework for Wireless Sensor and Actor Networks)

UM-RTCOM [16][17][18] is presented in paper by Manuel Diaz et al. It consists of two parts: the code and the abstract model. The abstract model in UM-RTCOM lets perform real time analysis such as deadlock freedom. There are two main types of components in UM-RTCOM: primitive and generic. Primitive components are the base components and they are subdivided into active and passive components. Generic components in UM-RTCOM act as a container for other component whether they are primitive or generic.

The generic components consist of three parts: an interface part which specifies the provided and required interfaces, a part which includes the implementation part and a part that specifies the published and subscribed events.

In UM-RTCOM active components indicate the execution flow and they are used to interact with other components. Passive components do not specify any execution. They are rather used for mutual exclusion and they allow the use of shared resources in the system.

In UM-RTCOM there are three synchronization primitives: *wait (*which is used in active components and makes a component wait until an event occurs*), call (*which is used to call methods*) and raise (*which is used to trigger events*).* The three synchronization primitives are the only way to communicate with other components.

UM-RTCOM has three features which makes it suitable for use in real time environments. These are: *configuration slots (*which is the capability of manipulating certain parameters, this results in reusability of the software*), Real time constraints specification (*using this feature the user could specify the kind of real time aspect they are interested in; for example a user might be interested in completing a task by a certain deadline*), real time analysis.*

2.3.3. From a UML Platform Independent Component Model to Platform Specific Component Models

This work is done by Tewfik Ziadi et al [19]. In this paper Tewfik Ziadi et al. present a method for mapping UML to component based languages like Enterprise Java Beans (EJB) and Corba Component Model (CCM).

The three main parts of a component in this paper are:

- *Ports:* a port defines a set of interfaces that are provided or required by the component. “The basic type of port is the operation port”. The operation port defines a method which is either provided or required by the component.
- *Parts:* A part is a sub component.
- *Connectors:* There are two types of connectors: delegation and assembly. The delegation connector exists between the component and the sub component. The assembly connector exists between the ports (required and provided).

To map the UML model to EJB each component is mapped to a bean (for each bean there exist an interface part and an implementation part.

CCM is composed of three parts:

- Attributes
- Provided and required ports
- Published and received events

To map the UML model to CCM each component in UML is mapped to a component in CCM. Each provided and required port in UML is mapped into CCM interfaces.

2.3.4. V3Studio: A Component-Based Architecture Modeling Language

In this paper Diego Alonso et al describe a new meta-model for component based architecture- V3studio [20]. This meta-model consists of three views: a structural view, and two behavioral views.

V3studio provides a platform independent and easy meta-model which is also easy to integrate with other meta-models.

V3studio can be seen as rather constrained form of UML. V3studio defines three models: one for the component view, one for the state machine and one for the activity diagram. These models are implemented used the graphical model framework (GMF). In order to depict component behaviors in V3studio two diagrams are used: state diagrams and activity diagrams. State diagrams show what happens when an event occurs in a system, whereas activity diagrams describe the data flow. In V3studio a state diagram is defined for the system and for each state an activity diagram should be defined. Components can communicate with each other via portlinks.

There are two types of components in V3studio: simple components and complex components. Complex components contain simple ones and their relationship inside them.

2.3.5. Building component software with COM and Eiffel

This approach uses Microsoft's Component Object Model (COM) standard with an object oriented model (Eiffel) [13]. COM is a standard to deal with components. In COM there exists a virtual pointer (*vpointer*) and the vpointer points to a virtual table where the methods are and each entry in the virtual table points to a method implementation. The virtual tables and pointer can be comparable to the process models which contain references to the process method where the code is stored.

In COM one vpointer corresponds to one interface hence there is no multiple inheritance capability in COM. There is a super interface for all COM components called the *IUnknown* this is a clear difference with the work shown in this thesis because as explained before interfaces are a level of abstraction which is not provided in this work.

IUnknown has three methods: *QueryInterface, AddRef, Release. AddRef* and *Release* are to keep count of the total references to a component. QueryInterface is to access another interface.

COM has an Interface Definition Language (IDL), it consists of three parts: a part specifying that this is a COM declaration, another part showing a unique identifier, and the third part is the IUnknown interface. Besides the COM IDL there exists COM classes which implement the interfaces.

COM provides the ability of dealing with distributed components by using Remote Process Calls (RPC). COM lets component execute in both multi thread and not thread aware systems. Type libraries enable the discovery of interfaces. Using type libraries a person can find out about the interfaces, interfaces' methods and data type.

2.3.6. A Java Component Model for evolving software systems

The Java Component Model (JCM) [21] is another generic component development environment.

A component model in JCM consists of three parts:

- A specification model: defines the services provided and required by the component
- The implementation model: defines the implementation
- And the connector model: defines the connection between the components.

Overall generic component-based development environments like UM-RTCOM and JCM require a significant amount of customization in order to take advantage of sensor specification languages like SensorML.

Chapter 3 A Component based design for sensor web

In this chapter a comprehensive design overview of SCT (SensorML/Component Translator) is given, this section is followed by a section on how to set up and implement changes to the sensor system in this thesis, and another section on how to interact with the components created by SCT.

3.1. Overall view

In a typical sensor system the Main Server (MS) sends a data acquisition command and the sensors send data to the MS; the data gets stored in a DB. If a client needs to read the data from the DB it will send a request to the MS and the MS will read the data from the DB.

3.2. Translator design

This section provides the translator design using class, sequence and activity diagrams.

3.2.1. main_class

This class is the main class where the rest of the classes are executed from.

This class has the following attributes:

- *dpch*: this attribute is of type *DOMParser_pch* which store variables related to the process chain such as a reference to the process models and the connection between the process models.
- *d*: this attribute is of type *DOMParser* which store variables related to the process models such as the input and output and the type of the input and output and a reference to a source code outside SensorML. (This part denotes the process method).

Figure 8 shows the class diagram of the translator. As this figure shows the main_class is the class that calls all other classes so it has a connection to all other classes. DOMParser uses the instance of DOMParser_pch (the process chain) created in main_class; createsBean uses the instance of DOMParser (the process model) created in main_class.

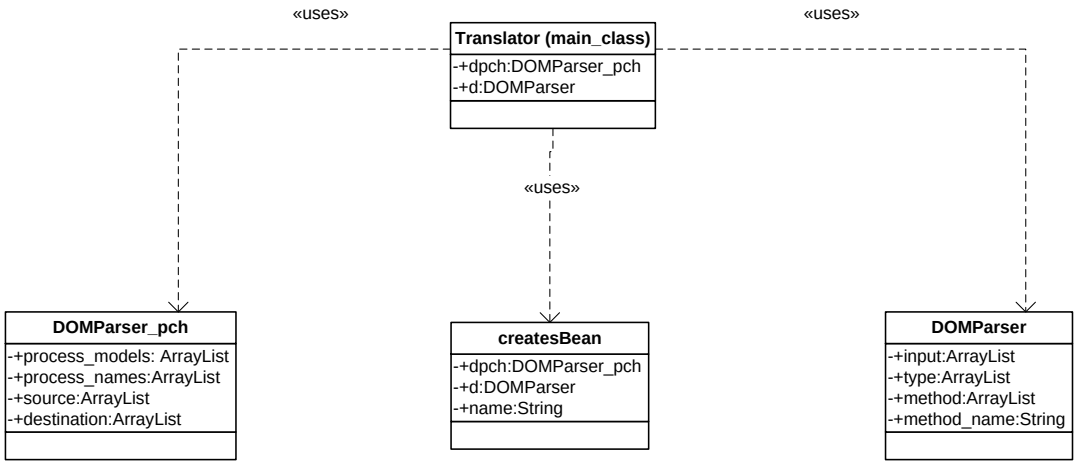

Figure 8. Class diagram of Translator

3.2.2. DOMParser_pch

This class reads the process chain of the SensorML document and it stores some of the information provided in the process chain document in ArrayLists.

Five kinds of information are stored:

1. *Process_models:* this is the location where the process models are saved.
2. *Process_names:* this is the name of the process models.
3. *Source:* this option is used to specify what component is the source in a connection.

4. *Destination:* this option is used to specify what component is the destination in a connection.

Figure 9 shows the activity diagram of this class. As it can be seen this diagram after having parsed the SensorML document DOMParser_pch stores information about the process models' location, source and destination.

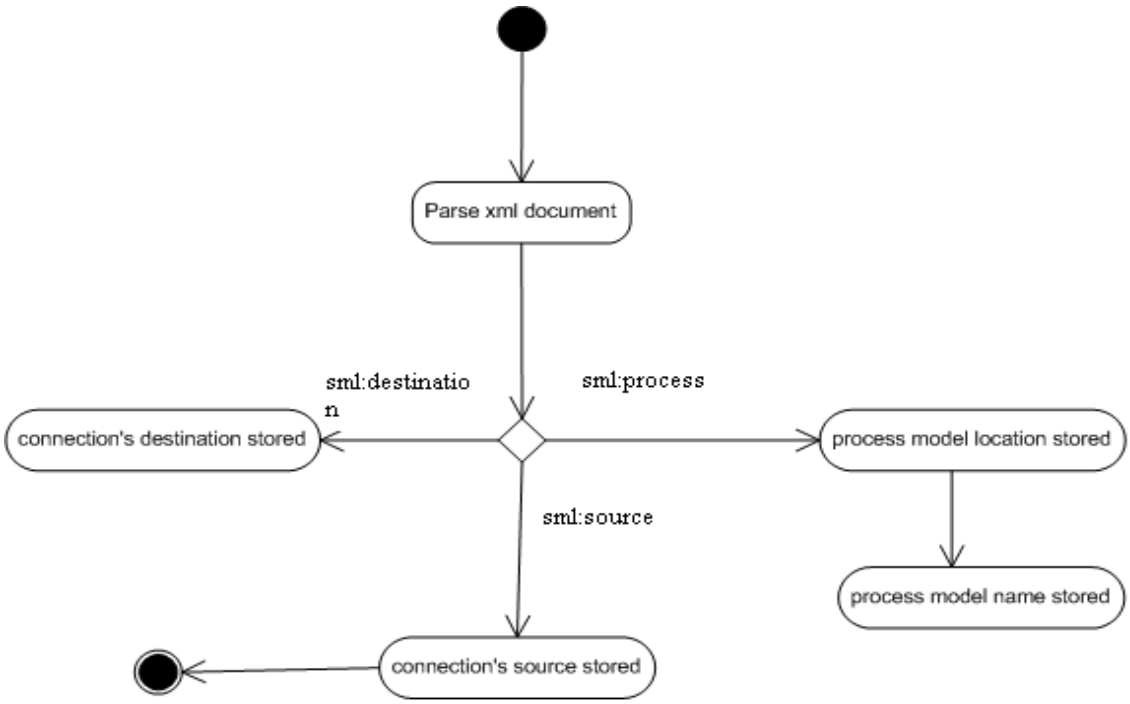

Figure 9. DOMParser_pch's Activity diagram

3.2.3. DOMParser

This class reads the process models of the SensorML document and it stores some of the information provided in the process models documents in ArrayLists. Five kinds of information are stored:

1. *Input:* this is the name of the input values to the process models.
2. *Type:* this is the unit of measure of the input values
3. *Method:* this is the location the method in the process model is stored.
4. *Method_name:* this is the name of the method.
5. Metadata information like: the sensor's manufacturer, the sensor Board, the sensor type, and the model number.

Figure 10 shows the activity diagram of this class. As it can be seen this class after having parsed the SensorML document this class stores the information about the process model's inputs, types and a reference to a java source code where the process method is.

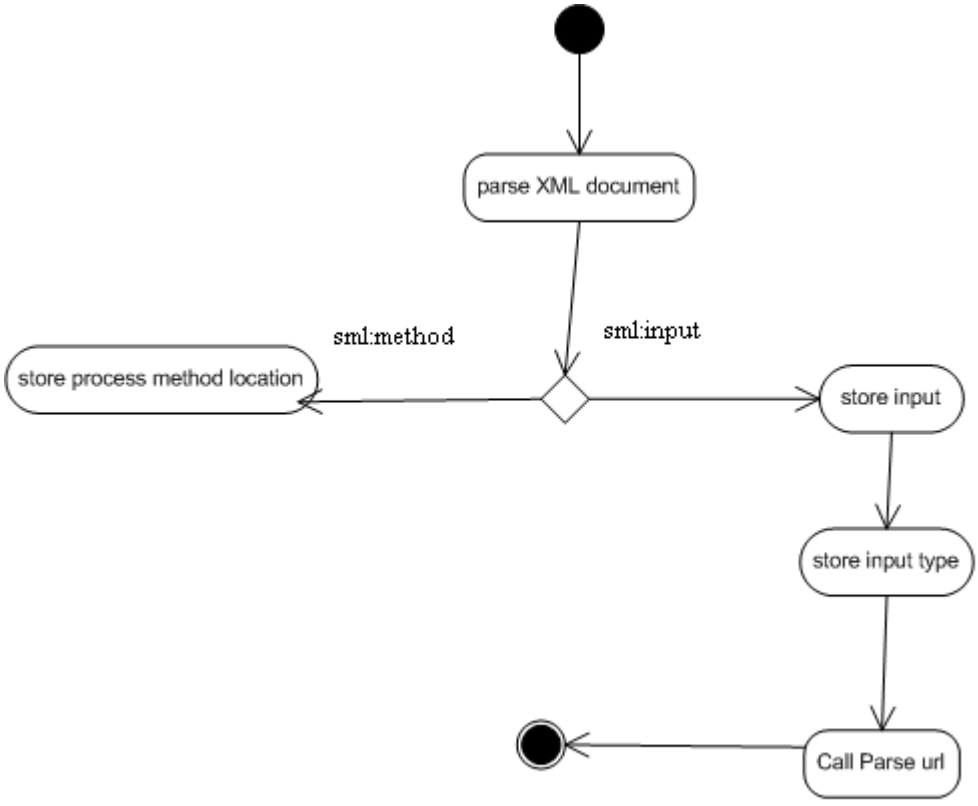

Figure 10. DOMParser's Activity Diagram

3.2.4. createsBean

The class createsBean maps the SensorML documents into Java Beans, so this class is the class that does the translation.

There are two kinds of Beans:

- *Normal Beans*: which are the equivalents of process models.
- *A connector Bean*: which is the equivalent of a process chain.

Each process model (sensor) gets converted to a normal Java Bean; so a normal Bean contains information about the sensor's inputs and outputs, the inside process of a sensor and the metadata of a sensor (like the mote type, the sensor type, the sensor board and the manufacturer). The process method contains information such as the calibration formula

and it is mapped to part of the Bean; the process chain shows the connection between the components and is mapped into events.

The connections in the process chain can be modeled in different manners: one of them is to provide a coordinator which will facilitate the communication between the process models. The other is by using events.

Normal Beans can communicate in two different ways: one way would be to connect the Normal Beans together without the use of a third component. Another way (which is the way done in this thesis) is to use a third component to connect these Beans together. The reason this approach was taken was because of its similarity to SensorML architecture: process models could be mapped into Beans and the process chain could be mapped into the connector Bean.

An event is an action that when it happens it triggers a change of state. Classes that are interested in events register for events using an event listener and when that event occurs they are notified that an event has occurred. The way Java Beans deals with this is by using the class `PropertyChangeSupport`. Any class that wants to receive events registers to `PropertyChangeListener`. The listeners will be invoked only when there is a call to the `firePropertyChange. FirePropertyChange` is called inside each setter operation and it stores the old and new value of that attribute and the given name of that attribute.

Table 2 shows the mappings between SensorML and Java Beans.

SensorML	**Java Beans**
Process method	Part of the Bean
Process model	A Bean
Process Chain	Events

Table 2. Mapping SensorML to Java Beans

This class creates a component. This class is in fact the translator which is between the SensorML file and the components.

This class needs three kinds of information to function:

1. *dpch:* this is an instance of the DOMParser_pch and provides the information of the process chain.
2. *d:* this is an instance of the DOMParser and provides the information of the process model.
3. *name:* this is the process models or the components name.

Figure 11 shows the sequence diagram of this class. In this diagram *out* and *file* are the *FileWriter* and the *FileReader*; the FileWriter is used to create the output files, which will be the Beans, the FileReader will be used to read the process method. StringTokenizer is used in the process chain to separate the name of the component from the component's attribute name. For example in code 6 StringTokenizer will separate Temperature from Temp1.

```
StringTokenizer stt = new StringTokenizer("Temperature/Temp1", "/");
```

Code 6. Example of StringTokenizer usage

The following things happen:

- First this class writes to the output file the attributes and their types.
- The constructor of this class is generated and it subscribes for any events that may occur using *propertyChangeListener*.
- The process method is read from a java source code using the reference in the process model. Then the *propertyChange* operation is created within the file; this operation is used to trigger any other events by setting the values of attributes.

- The setter and getter method are next created for each attribute. The set attribute is the process by which the events are initialized. Inside the set operation a call to the *firePropertyChange* method of the *propertyChangeSupport* class is made.
- In the firePropertyChange method a reference is passed to the old and new values of the attribute which is being set plus the desired name of the attribute.

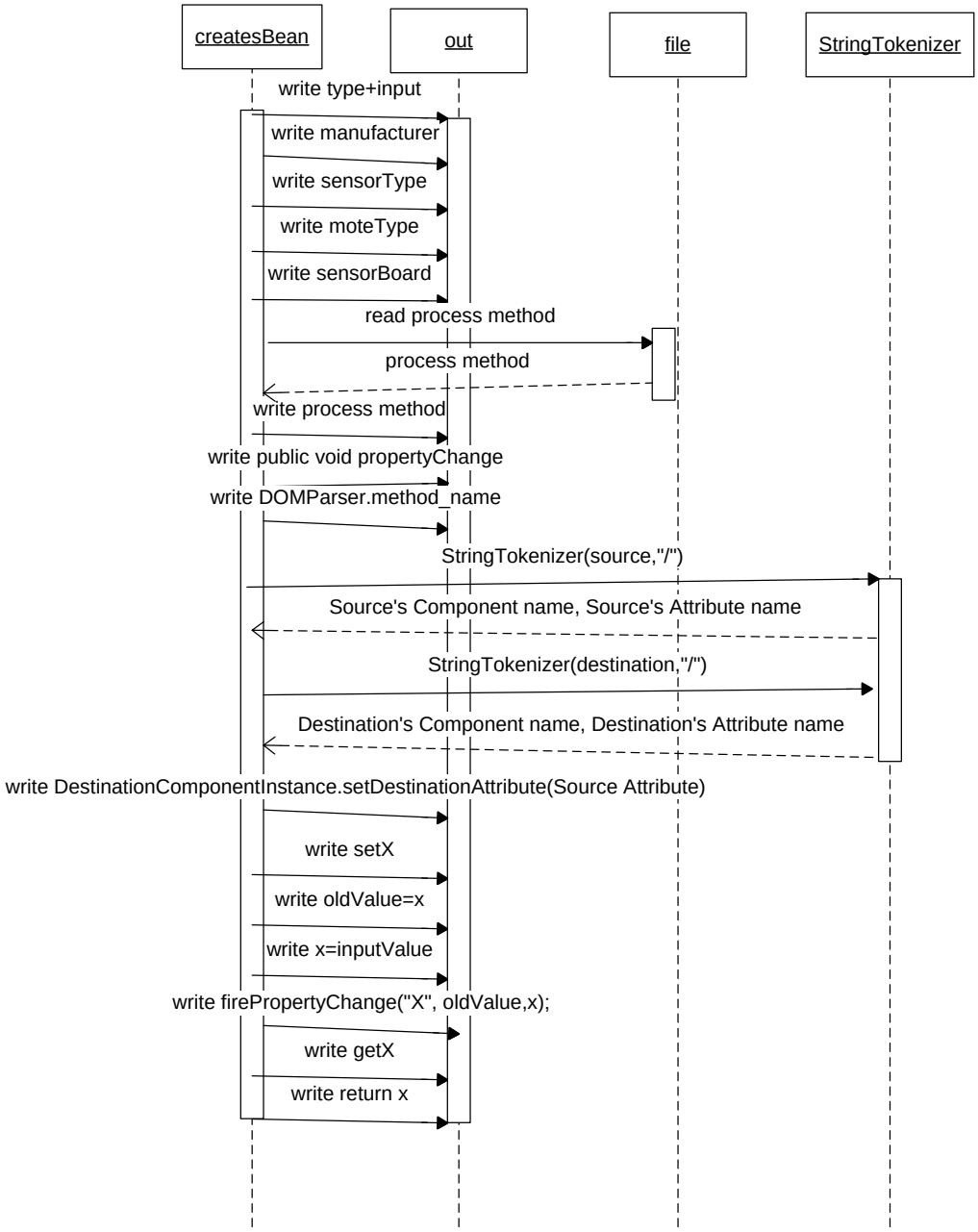

Figure 11. createsBean's Sequence Diagram

3.3. Setting up and Making Changes to the SCT sensor system

Figure 12 shows the relationship between the components created by the class createsBean: *WindChill, Temperature, and connector*. WindChill has two inputs: *Windspeed* and *Temp1* and it has two setter and getter methods to set and get the value of these inputs. The component Temperature has one input called *Temp1* and one setter and getter method.

Each Bean (except the connector Bean) has a run method which is the process method in SensorML.

Each Bean has a propertyChange method. This method is called when an event is fired. In the normal Beans this method only calls the run() method. In the connector Bean this method is used to connect Beans together.

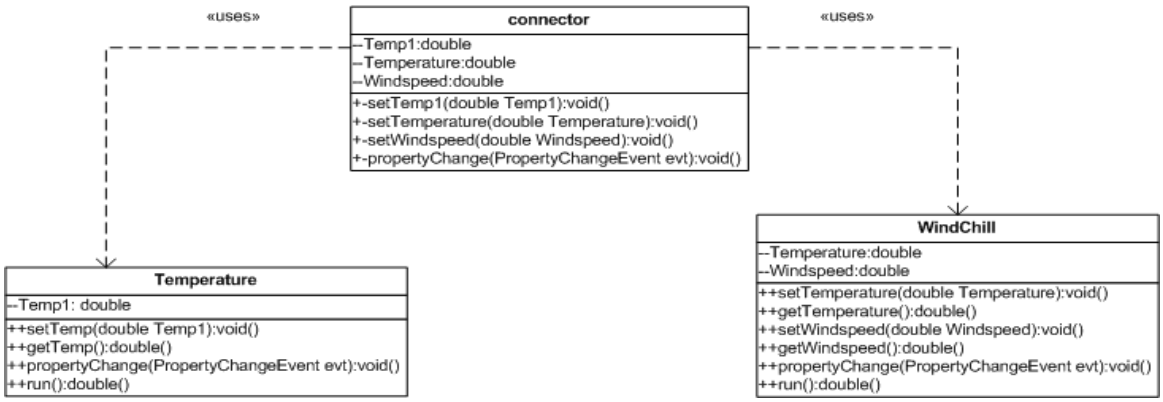

Figure 12. Example of the relationship between the created components

In the next sub-sections examples of creating and changing SensorML documents for Temperature and WindChill and the process chain, which connects Temperature and WindChill together, are provided.

3.3.1. Creating and Modifying SensorML documents and executing SCT

In this part a process model called Temperature and a process chain called SysBR will be created.

First a new project should be created as a place for saving all the process models and the process chain.

Select the project to create a new *sensorMLInstance*. An XML and a RNG file should be generated. All changes are made inside the RNG file. Upon each saving SensorMLEditor will change the contents of the XML file itself. Any changes to the XML file outside the editor may cause inconsistency and are thus discouraged. Figure 13 shows how to create a new SensorML instance.

To create a process model a person should click on sensorML element inside Temperature.rng and select from the drop down box the *sml.Component* member. Figure 14 shows the process of adding the sml.Component element. The inputs, identifier, and the method of the process model should be added to this element. To add the inputs a person has to add the *inputList* element and then add the input to the inputList. Figure 15 shows how to enter the values for an input. The identifier specifies the metadata part. Figure 16 shows how to enter the values for an identifier, the Manufacturer. The method element specifies the file path for the process method. Figure 17 shows how to enter the process method's path.

To generate a system (process chain) a new sensorMLInstance should be created and *sml.System* must be selected as the SensorML member. A *ConnectionList* must be added

as the System's element, and then connections must be added to the connection List. The connections have a source and destination part. The source is the component from where the attribute is coming and the destination is the component that is receiving the attribute. The source and destination for a sensor system with a Temperature sensor is:

Source=Temperature/Temp1

Destination=Temperature/Temp1

Figure 19 shows the screen shot of a process chain called SysBR.rng.

After having specified the requirements of SCT the Beans will be generated in a separate project. It is enough to run this project and obtain the desired results.

Code 7 and Code 8 show the code for Temperature. xml and SysBR.xml respectively.

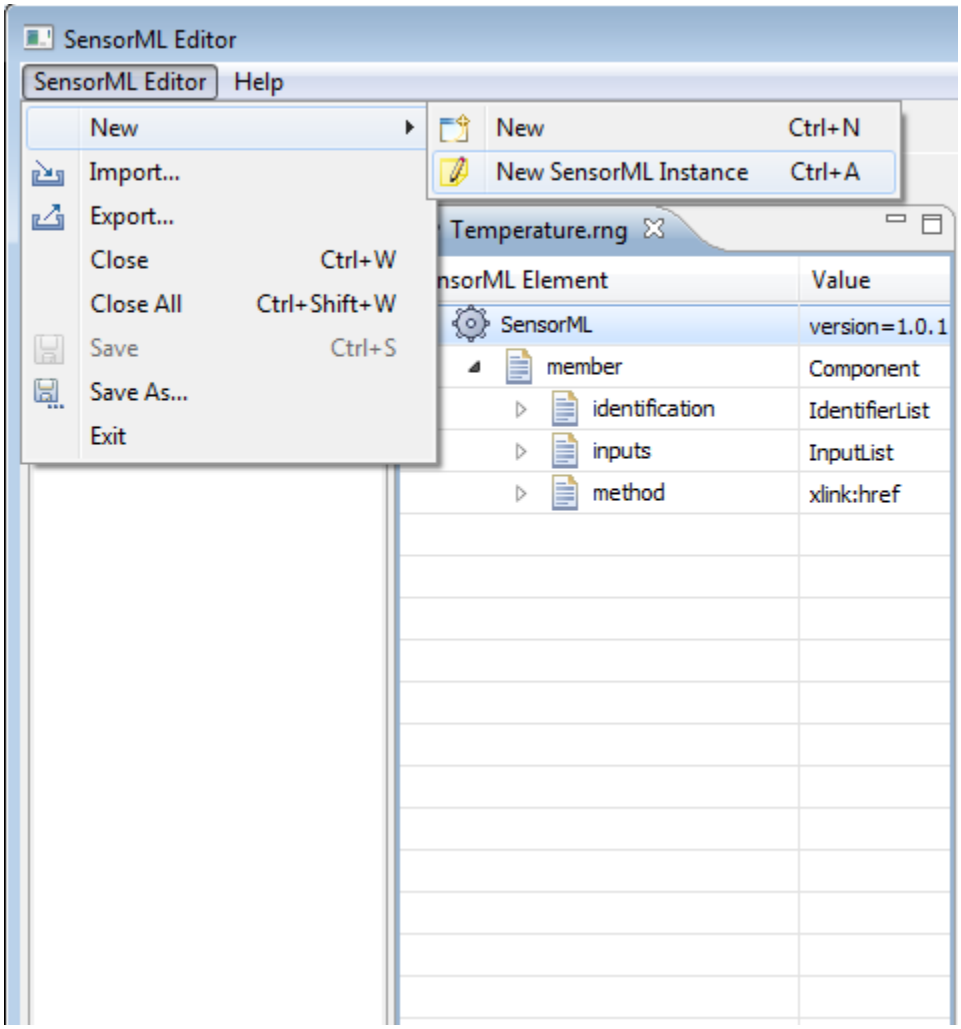

Figure 13. Creating a new SensorML instance

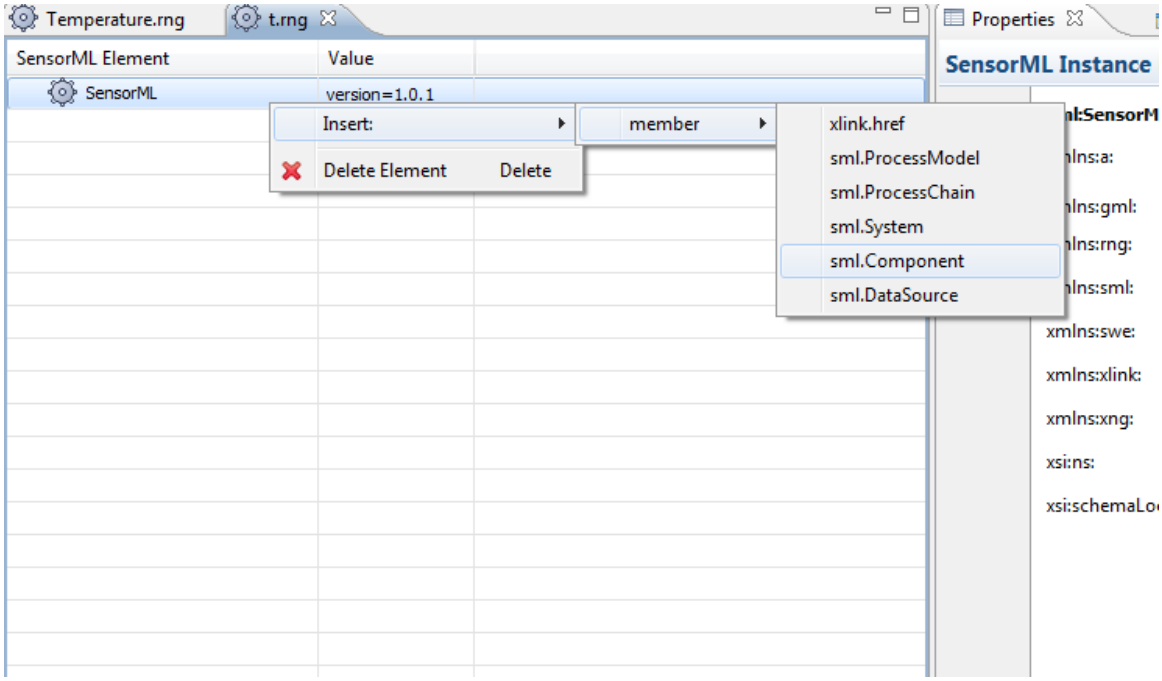

Figure 14. Inserting a member in Temperature

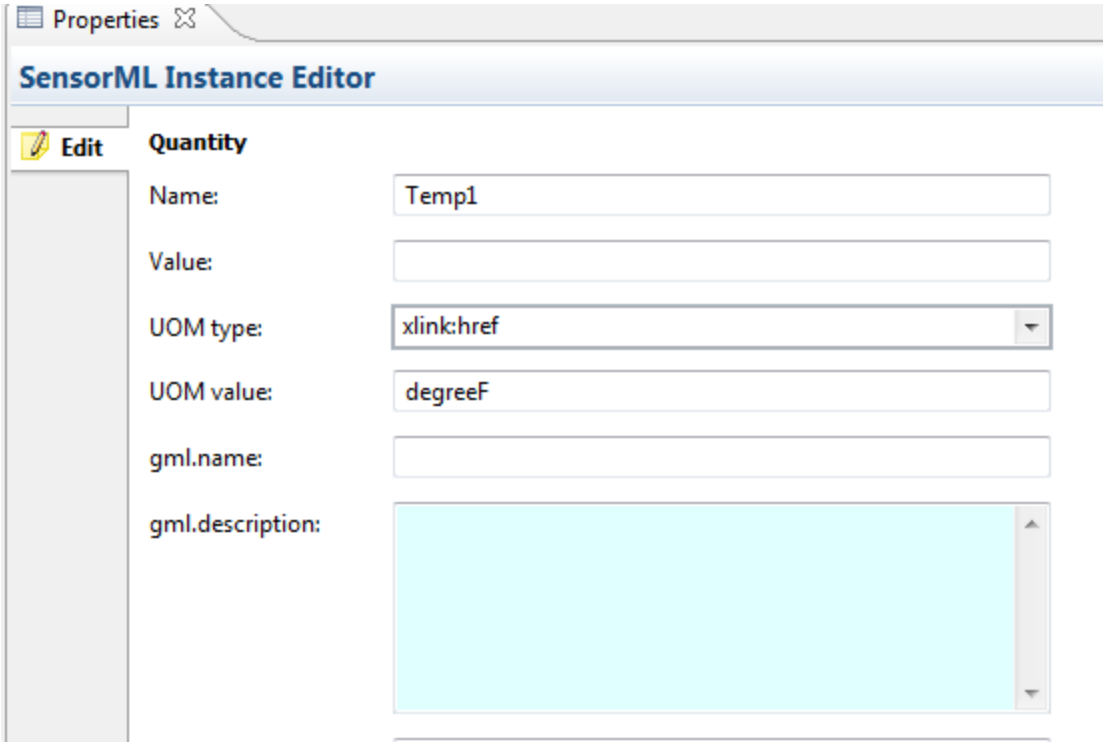

Figure 15. Setting the input name and uom

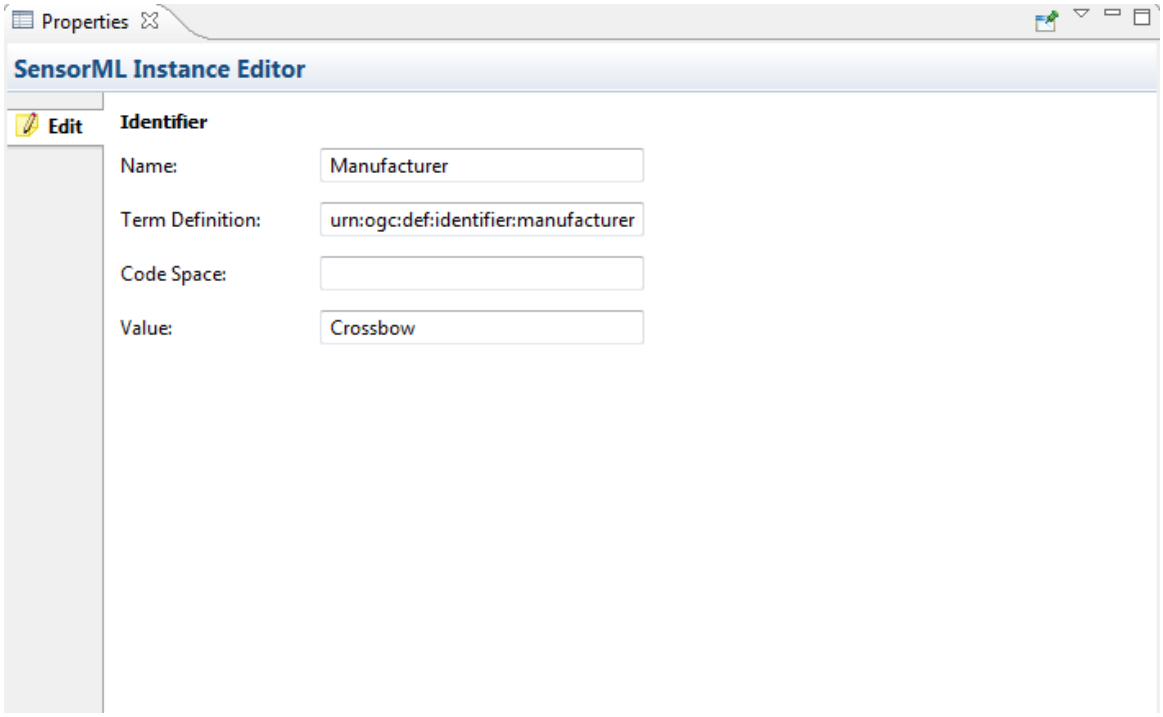

Figure 16. Inserting a new Identifier

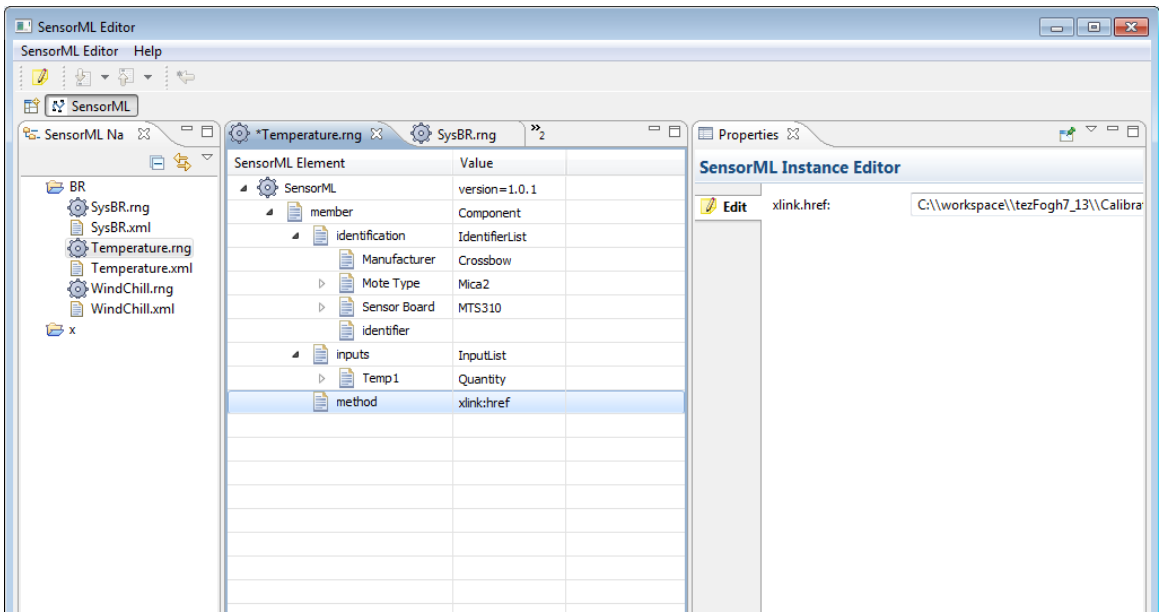

Figure 17. Temperature.rng

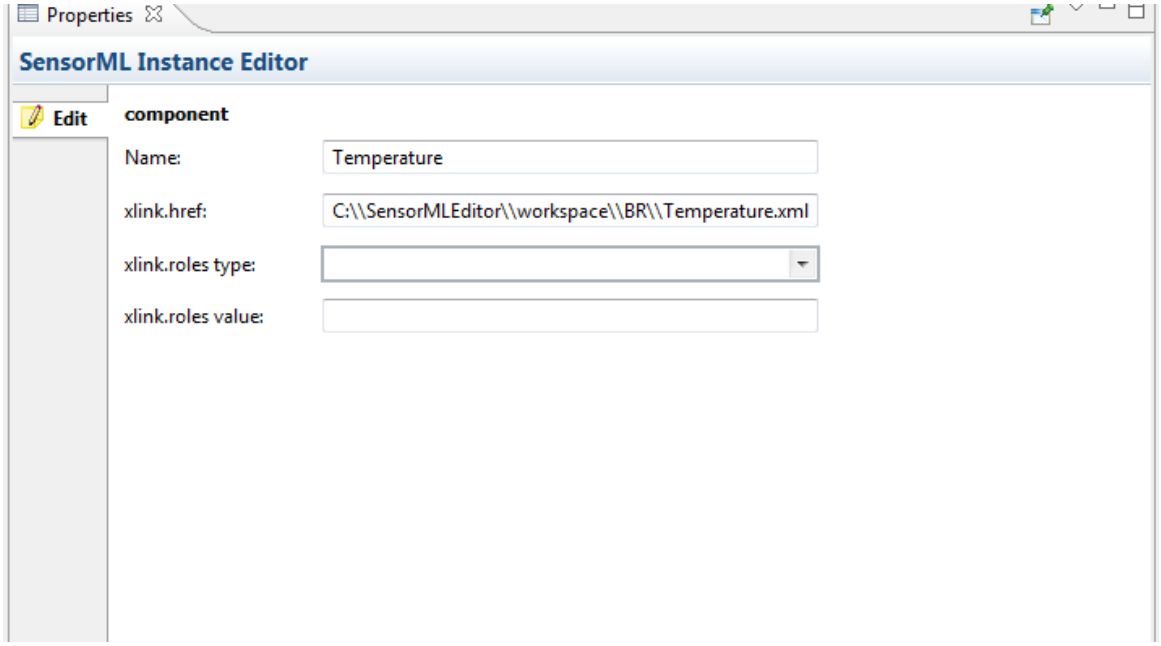

Figure 18. Inserting Components in a System

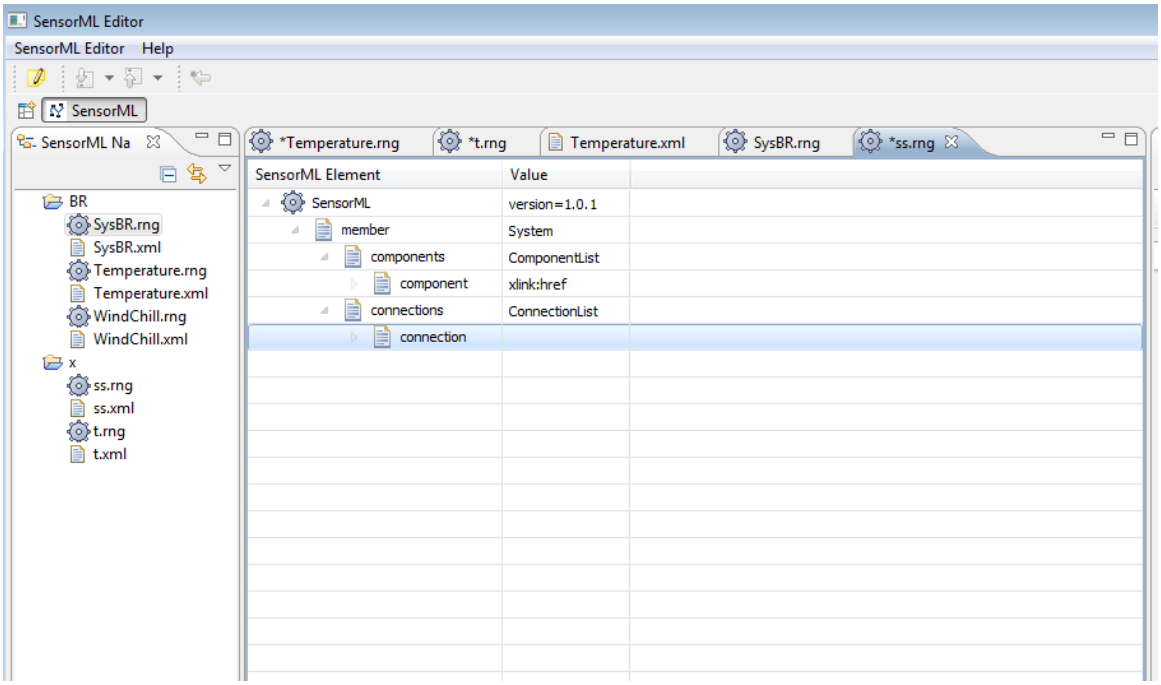

Figure 19. SysBR

```
<?xml version="1.0" encoding="UTF-8"?>
<sml:SensorML rng:version="1.0.1"
xmlns:a="http://relaxng.org/ns/compatibility/annotations/1.0"
xmlns:gml="http://www.opengis.net/gml"
xmlns:rng="http://relaxng.org/ns/structure/1.0"
xmlns:sml="http://www.opengis.net/sensorML/1.0.1"
```

```
xmlns:swe="http://www.opengis.net/swe/1.0.1"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xng="http://xng.org/1.0">
   <sml:member>
      <sml:Component>
         <sml:identification>
            <sml:IdentifierList>
               <sml:identifier name="Manufacturer">
                  <sml:Term
definition="urn:ogc:def:identifier:manufacturer">
                     <sml:value>Crossbow</sml:value>
                  </sml:Term>
               </sml:identifier>
               <sml:identifier name="Mote Type">
                  <sml:Term
definition="urn:ogc:def:identifier:moteType">
                     <sml:value>Mica2</sml:value>
                  </sml:Term>
               </sml:identifier>
               <sml:identifier name="Sensor Board">
                  <sml:Term
definition="urn:ogc:def:identifier:sensorBoard">
                     <sml:value>MTS310</sml:value>
                  </sml:Term>
               </sml:identifier>
            </sml:IdentifierList>
         </sml:identification>
         <sml:inputs>
            <sml:InputList>
               <sml:input name="Temp1">
                  <swe:Quantity>
                     <swe:uom code="" xlink:href="degreeF"/>
                  </swe:Quantity>
               </sml:input>
            </sml:InputList>
         </sml:inputs>
         <sml:method xlink:href="C:\\methods\\Calibration.java"/>
      </sml:Component>
   </sml:member>
</sml:SensorML>
```

Code 7. Temperature.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<sml:SensorML rng:version="1.0.1"
xmlns:a="http://relaxng.org/ns/compatibility/annotations/1.0"
xmlns:gml="http://www.opengis.net/gml"
xmlns:rng="http://relaxng.org/ns/structure/1.0"
xmlns:sml="http://www.opengis.net/sensorML/1.0.1"
```

```
xmlns:swe="http://www.opengis.net/swe/1.0.1"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xng="http://xng.org/1.0">
   <sml:member>
      <sml:System>
         <sml:classification>
            <sml:ClassifierList>
               <sml:classifier name="sensorType">
                  <sml:Term
definition="urn:ogc:def:identifier:sensorType">
                     <sml:value>Temperature</sml:value>
                  </sml:Term>
               </sml:classifier>
            </sml:ClassifierList>
         </sml:classification>
         <sml:position xlink:href="">
            <swe:Position>
               <swe:state>
                  <swe:Vector/>
                  <swe:SquareMatrix>
                     <swe:elementCount/>
                     <swe:elementType name=""/>
                  </swe:SquareMatrix>
               </swe:state>
            </swe:Position>
         </sml:position>
         <sml:components>
            <sml:ComponentList>
               <sml:component name="Temperature"
xlink:href="C:\\SensorMLEditor\\workspace\\BR\\Temperature.xml"/>
               <sml:component name="WindChill"
xlink:href="C:\\SensorMLEditor\\workspace\\BR\\WindChill.xml"/>
            </sml:ComponentList>
         </sml:components>
         <sml:positions>
            <sml:PositionList/>
         </sml:positions>
         <sml:connections>
            <sml:ConnectionList>
               <sml:connection>
                  <sml:Link>
                     <sml:source ref="Temperature/Temp1"/>
                     <sml:destination ref="Temperature/Temp1"/>
                  </sml:Link>
               </sml:connection>
               <sml:connection>
                  <sml:Link>
                     <sml:source ref="WindChill/Windspeed"/>
                     <sml:destination ref="WindChill/Windspeed"/>
                  </sml:Link>
               </sml:connection>
               <sml:connection>
```

```
                    <sml:Link>
                       <sml:source ref="Temperature/Temp1"/>
                       <sml:destination ref="WindChill/Temp1"/>
                    </sml:Link>
                 </sml:connection>
              </sml:ConnectionList>
           </sml:connections>
        </sml:System>
     </sml:member>
</sml:SensorML>
```

Code 8. SysBR.xml

3.3.2. Adding a new sensor (WindChill) to the system

In order to add a new sensor to the system two things must be done:

- A new process model must be created
- The process chain (system) must change

Suppose a new sensor called WindChill wants to be added to the system. In this case the process model for WindChill must be created in the same way the process model for Temperature was created. The only difference is that WindChill has two inputs instead of one input.

The process chain should be changed to reflect the new connections in the sensor system. If, for example, the old temperature sensor in the system is connected to the temperature sensor in WindChill this new connection should be depicted as follows:

Source=Temperature/Temp1

Destination=WindChill/Temp1

Where the first element is the component's name and the second element is the attributes name.

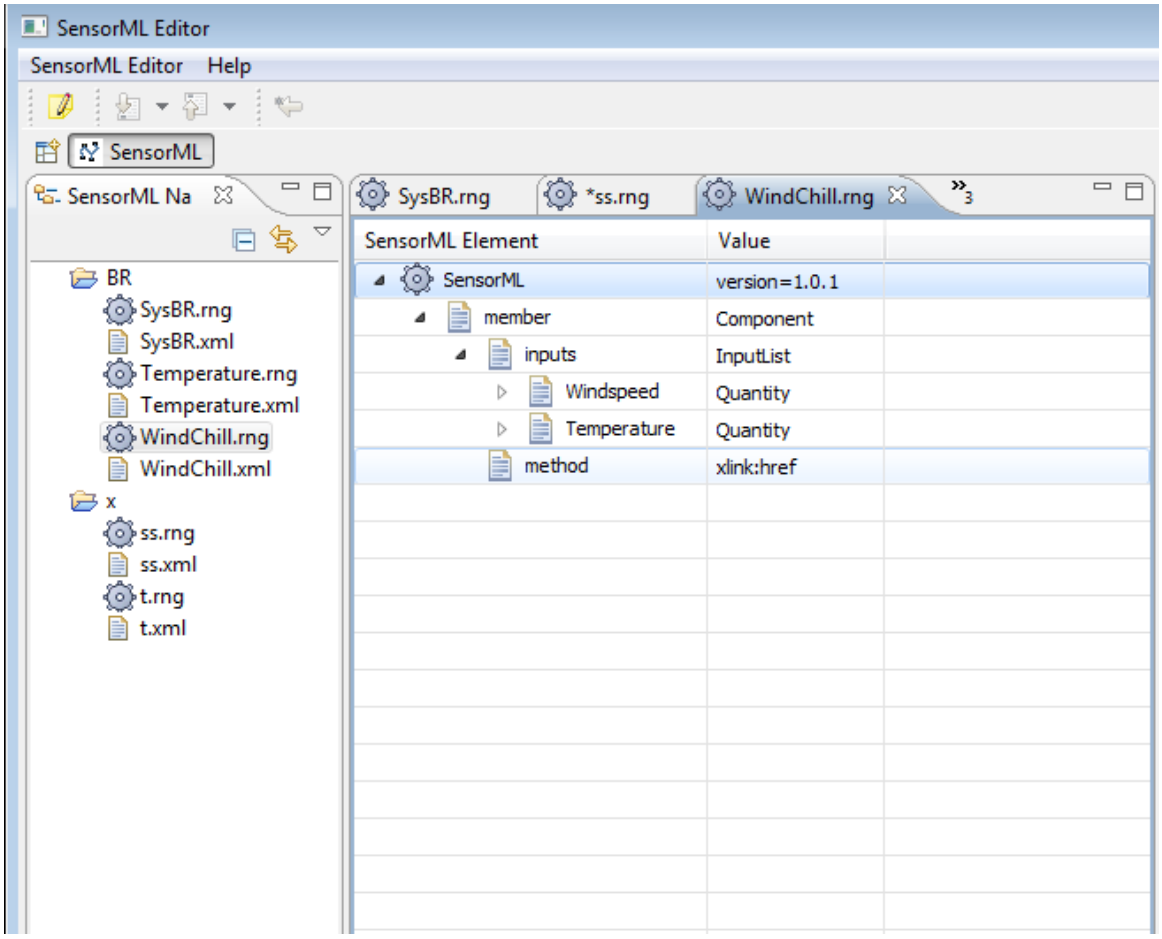

Figure 20. WindChill Component

Code 9 shows the code for WindChill.xml, whereas code 10 is the parts of SysBR.xml that have changed.

```
<?xml version="1.0" encoding="UTF-8"?>
<sml:SensorML rng:version="1.0.1"
xmlns:a="http://relaxng.org/ns/compatibility/annotations/1.0"
xmlns:gml="http://www.opengis.net/gml"
xmlns:rng="http://relaxng.org/ns/structure/1.0"
xmlns:sml="http://www.opengis.net/sensorML/1.0.1"
xmlns:swe="http://www.opengis.net/swe/1.0.1"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xng="http://xng.org/1.0">
   <sml:member>
      <sml:Component>
         <sml:inputs>
            <sml:InputList>
               <sml:input name="Windspeed">
                  <swe:Quantity>
                     <swe:uom code="" xlink:href="perMeter"/>
                  </swe:Quantity>
               </sml:input>
```

```
                <sml:input name="Temp1">
                   <swe:Quantity>
                      <swe:uom code="" xlink:href="degreeF"/>
                   </swe:Quantity>
                </sml:input>
             </sml:InputList>
          </sml:inputs>
          <sml:method xlink:href="C:\\methods\\WindChill.java"/>
       </sml:Component>
    </sml:member>
 </sml:SensorML>
```

Code 9. WindChill .xml

```
<sml:connections>
 <sml:ConnectionList>
 <sml:connection>
 <sml:Link>
  <sml:source ref=”Temperature\Temp1” />
  <sml:destination ref=”Temperature\Temp1” />
  </sml:Link>
  </sml:connection>
<sml:connection>
 <sml:Link>
  <sml:source ref=”WindChill\Windspeed” />
  <sml:destination ref=”WindChill\Windspeed” />
  </sml:Link>
  </sml:connection>
<sml:connection>
 <sml:Link>
  <sml:source ref=”Temperature\Temp1” />
  <sml:destination ref=”WindChill\Temperature” />
  </sml:Link>
  </sml:connection>
  </sml:ConnectionList>
  </sml:connections>
```

Code 10. Changed parts of SysBR.xml

Code 11 shows the Java Beans Code Created for Temperature. Code 12 shows the Java Beans Code created for WindChill.

```
//***********************************
//Temperature Bean
//***********************************
import com.mysql.jdbc.Statement;
import java.sql.*;
import java.beans.PropertyChangeSupport;
import java.beans.PropertyChangeListener;
import java.beans.PropertyChangeEvent;
import java.io.Serializable;
import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStream;
```

```
import java.io.InputStreamReader;
import java.beans.*;
public class Temperature implements PropertyChangeListener,
Serializable{
 public static WindChill b0=new WindChill();
double Temp1;
String manufacturer="Crossbow";
String getManufacturer(){return manufacturer;}
String sensorBoard="MTS310";
String getSensorBoard(){return sensorBoard;}
String sensorType="null";
String getSensorType(){return sensorType;}
String moteType="Mica2";
String getMoteType(){return moteType;}
private PropertyChangeSupport pcs = new PropertyChangeSupport(this);
boolean flag0=false;
public Temperature(){
pcs.addPropertyChangeListener(this);
}
public void run(){
            Temp1 = 2.5 * ((double) Temp1 / 4096) * 100 * 2. - 273;
            System.out.println("Calibrated Temperature is: " + Temp1);
      }
public void propertyChange(PropertyChangeEvent evt) {
run();
b0.setTemp1(Temp1);}
public void  setTemp1(double    in){
if (!flag0)
flag0=true;
double old=Temp1;
Temp1=in;
pcs.firePropertyChange("Temp1", old,Temp1);
}

public double getTemp1(){return Temp1;}
}}
```

Code 11. Code Created for Temperature Bean

```
//************************************
//WindChill Bean
//************************************
import com.mysql.jdbc.Statement;
import java.sql.*;
import java.beans.PropertyChangeSupport;
import java.beans.PropertyChangeListener;
import java.beans.PropertyChangeEvent;
import java.io.Serializable;
import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStream;
```

```
import java.io.InputStreamReader;
import java.beans.*;
public class WindChill implements PropertyChangeListener, Serializable{
double Windspeed;
double Temp1;
String manufacturer=”null”;
String getManufacturer(){return manufacturer;}
String sensorBoard=”null”;
String getSensorBoard(){return sensorBoard;}
String sensorType=”null”;
String getSensorType(){return sensorType;}
String moteType=”null”;
String getMoteType(){return moteType;}
private PropertyChangeSupport pcs = new PropertyChangeSupport(this);
53oolean flag0=false;
53oolean flag1=false;
public WindChill(){
pcs.addPropertyChangeListener(this);
}
public void run(){
      double out = 35.74 + 0.6215 * Temp1 – 35.75* Math.pow(Windspeed,
0.16) + 0.4275 * Temp1* Math.pow(Windspeed, 0.16);
      System.out.println(“Wind Chill is: “ + out);
}
public void propertyChange(PropertyChangeEvent evt) {
run();

}
public void  setWindspeed(double    in){
if (!flag0)
flag0=true;
double old=Windspeed;
Windspeed=in;
pcs.firePropertyChange(“Windspeed”, old,Windspeed);
}
public void  setTemp1(double    in){
if (!flag1)
flag1=true;
double old=Temp1;
Temp1=in;
pcs.firePropertyChange(“Temp1”, old,Temp1);
}

public double getWindspeed(){return Windspeed;}
public double getTemp1(){return Temp1;}
}
```

Code 12. Code created for WindChill Bean

3.4. Using the Components created by SCT

One of the best examples of the usage of components creates by SCT is to use the components generated by SCT to create outputs that will be stored in a Data Base and later on use these data as the sensor history to draw graphs, etc.

Figure 21 and 22 show the tables for the WindChill and Temperature sensors respectively. Code 13 and 14 shows the SQL code for creating tables for these components. The primary key helps differentiate each table entry from each other. The foreign key helps preserve the database consistency. Here, Temp1 in WindChill is dependent on Temp1 in Temperature; if Temp1 in Temperature gets deleted this will affect Temp1 in WindChill.

These tables are created by the SCT component's users. These users will use the outputs (and maybe the inputs of the sensors in their table). A suggestion of the fields that should be included in the tables are:

- An auto-incrementing, unique primary key.
- The output of the sensor
- The inputs of the sensor (some of which might reference other tables. For example the field Temp1 in the WindChill table will have to reference the field Temperature in the table Temperature.)

id	WindChill	Temp1	Windspeed

Figure 21. WindChill Table

Id	Temperature	Temp1

Figure 22. Temperature Table

```
CREATE TABLE Temperature
(
Id int NOT NULL AUTO_INCREMENT,
Temperature double,
Temp1 double,
PRIMARY KEY (Id)
)
```

Code 13. SQL command for creating a Temperature table

```
CREATE TABLE WindChill
(
Id int NOT NULL AUTO_INCREMENT,
WindChill double,
Temp1 double,
Windspeed double,
PRIMARY KEY (Id),
Foreign Key (Temp1) references Temperature(Temp1)ON DELETE CASCADE
)
```

Code 14. SQL command for creating a Temperature table

A developer can access the output of a component by making an instance of a component and then accessing the *out* attribute of this component. Code 15 shows an example of this. In this code the output of temperature is accessed and printed out on the console.

```
import java.sql.Connection;
import java.sql.DriverManager;
import java.sql.SQLException;
import java.sql.Statement;
public class MyBean {

      public static void main(String[] args) {
          Temperature b1 = new Temperature();
            b1.setTemp1(11);
            System.out.println("The result of Temperature is: "+
b1.out);
      }
}
```

Code 15. Accessing the output of a component

Code 16 shows how to insert the output value to the database. This code inserts the output value of the Temperature sensor into the Temperature table.

Figure 23 shows the contents of the Temperature table. The last row shows the result for code 15.

```
import java.sql.*;

public class CreateMySqlTable {

      public static void main(String[] args) {
            System.out.println("Creating a Mysql Table to Store
Java Types!");
            Connection con = null;
            String url = "jdbc:mysql://localhost:3306/";
            String db = "mydb";
            String driver = "com.mysql.jdbc.Driver";
            String user = "root";
            String pass = "root";
            try {
                  Class.forName(driver).newInstance();
                  con = DriverManager.getConnection(url + db, user,
pass);
                  try {
                        Statement st = con.createStatement();

                        Temperature b0 = new Temperature();
                        b0.setTemp1(11);
                        st.executeUpdate("INSERT INTO
Temperature(Temperature) VALUES ( "
                                    + b0.out + ")");

                        con.close();
                  } catch (SQLException s) {
                        System.out.println(s.getMessage());
                  }
            } catch (Exception e) {
                  e.printStackTrace();
            }
      }
}
```

Code 16. Inserting a new value inside the database

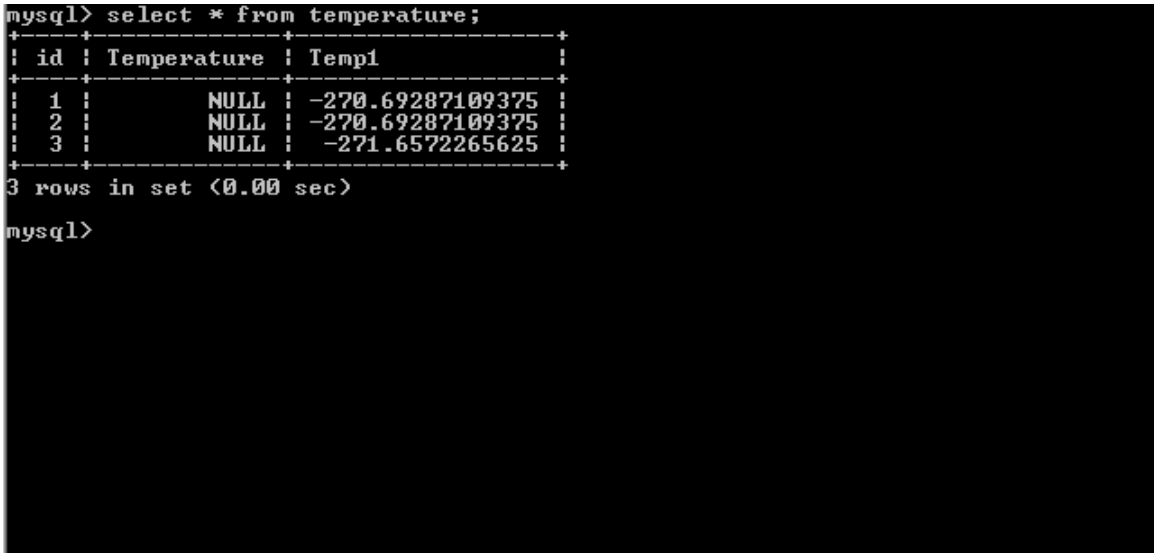

Figure 23. SQL snapshot of Temperature Table

Chapter 4 Testing and Validation

In this section an analysis of the SensorML / Component translator is performed by comparing it to an existing Java-based middleware sensor system called SensIV that was also developed at the same laboratory.

4.1. The SensIV system

The SensIV system is a sensor network that measures the temperature in a field using a set of temperature sensors consisting of a set of wireless sensors forwarding their data to a Java-based middleware platform.

Figure 24 shows the structure of the SensIV message. Each of the fields in this message with the exception of the readings field (which has 4* 2 Bytes) has a Bytes size. The important fields to add new sensors are: kiwi and mango hence only these two fields would be explained. Kiwi specifies the settings i.e.: Normal, Discovery, etc. Mango specifies the sensor boards for example MDA300. The combination of these two fields gives us all our possibilities.

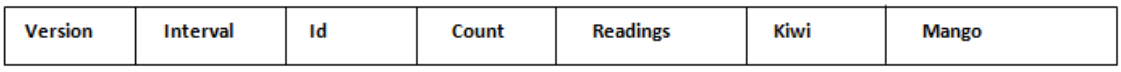

Figure 24.SensIV message structure

The SensIV middleware application is written in Java and is characteristic of a classical OO program. The design of SensIV is based on the proper interpretation of the incoming message from the sensor network, the type of sensor that sent the message. The details of the encoding of this information in the SensIV message are not relevant to this thesis.

The SensIV application is composed of many classes. Here, only five classes which are relevant to the work that is being carried out are included. These classes are: DemoMotes, FruitSalad, Lizard, DataConvert, Constants, MTS300, MTS310, MDA300. DemoMotes is the main executing class of SensIV; DemoMotes calls FruitSalad with the readings it has received from the middleware and the specific kiwi (that specifies the sensor settings) and the Mango (which specifies the sensor boards); FruitSalad calls Lizard using the getindex method with kiwi and mango parameters. The Mango links Kiwis to their corresponding data position arrays (arrays that provide the index locations for all the data for any specified kiwi).

The core classes that represent the sensors in SensIV are based on the type of sensor boards in the sensor network. In this case these are the Crossbow MTS300, MTS310, and MDA300 sensor boards. These classes are in effect comparable to the process models in SensorML except that in SensIV each sensor board type has only a single instance of the sensor board class, while when SensorML is used each sensor has a SensorML file describing it resulting in a Java bean for each sensor in the system.

Figure 25 shows the class diagram of SensIV.

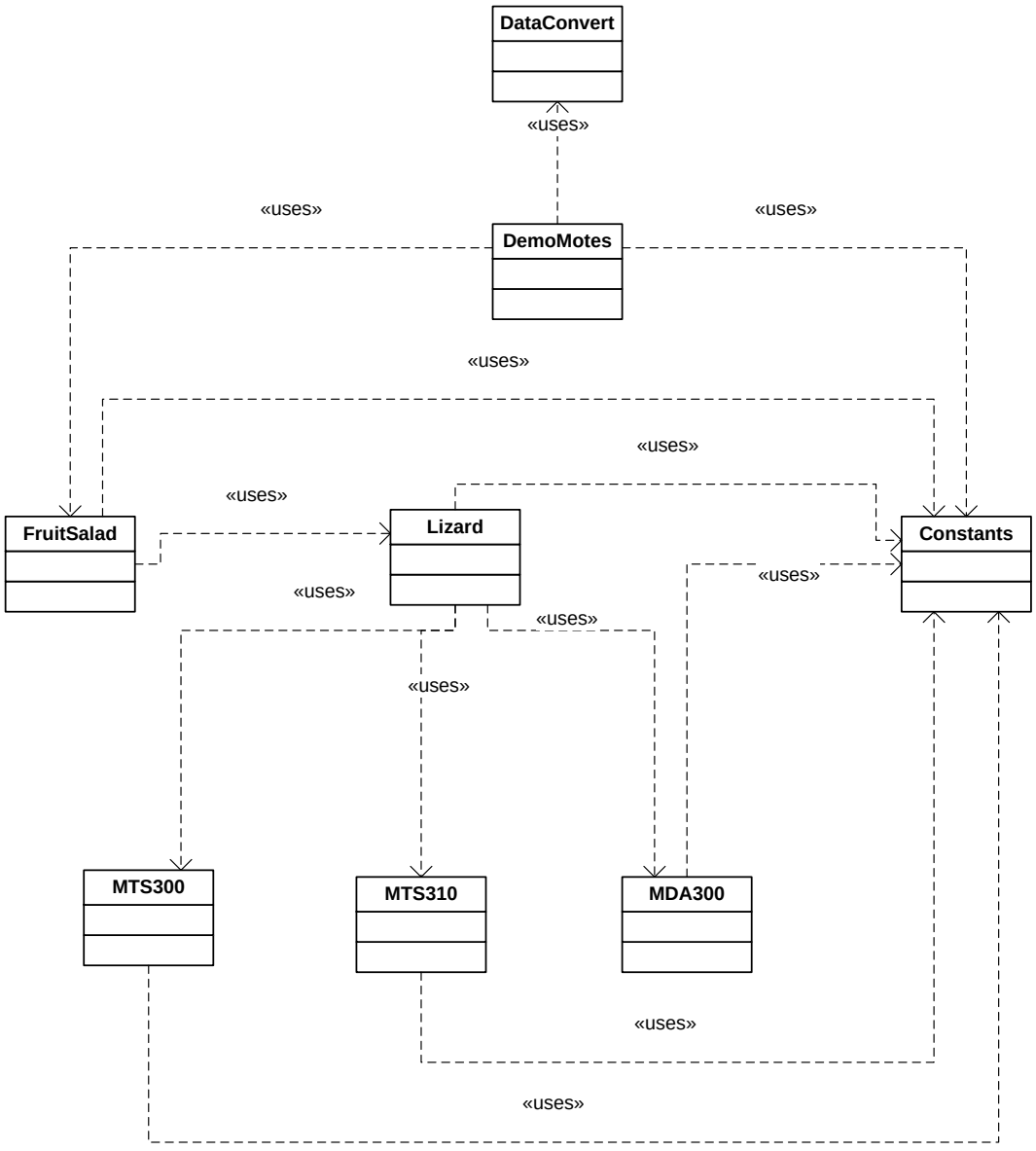

Figure 25. SensIV's class diagram

The purpose of this analysis is to learn if there is an improvement over SensIV in using the SensorML / Component translator in terms of:

1. User's effort in changing the sensor system.
2. Lines of code written.
3. Correctness of SensIV and the SCT.
4. Cohesion and Coupling of SensIV and of the SCT.

For the first metric a survey is handed out to the users and they are asked to fill it in. For the second metric changes are made to the system and the result of the system executions are presented. Two scenarios are considered. For each scenario the total lines of code that have to be added by the user to change the sensor system are counted. For SensIV the lines of code have to be typed in by the user in each of the classes that will be changing, whereas for SCT the user implements the changes by using the SensorMLEditor. The two scenarios are:

1. Scenario one: When there are multiple instances of a single sensor type (for example multiple instances of a Temperature sensor.)
2. Scenario two: When there are multiple instances of multiple sensor types (for example multiple instances of a Temperature and Humidity sensor.)

The third metric *"testing the correctness"* means testing SensIV and the translator in different scenarios and making sure they both work correctly (in an error free manner producing the correct results) The third metric uses two different scenario: one scenario with two instances of one kind of sensor for both systems and one scenario with two different kind of sensors for both systems.

The fourth metric cohesion is measured with an eclipse plug-in called *Metrics 1.3.6* [22].

4.2. User's effort in changing the sensor system

For this analysis several graduate and undergraduate students, and professors with software engineering background were asked to modify SensIV code as well as to use the SensorML / Component translator.

A two hour session was held and instructions were handed to these software developers. The software developers had different initial levels of knowledge about SensIV and the SensorML / Component translator but all of them were developers with a fundamental knowledge of Java and of XML. Before the software developers performed the code change exercise their development environment was set up with the appropriate files. Code development was performed on the Eclipse IDE.

The software developers where then guided in how to add a new sensor using both the SensorML / Component translator and then the SensIV system. After they all succeeded doing this they proceeded to fill in a survey about their experience of using both systems. The following questions were asked about each approach.

1. Time spent learning how to work with system
2. Correctness of code (did errors occur and did the system work as you were expecting it to work).
3. Ease of use (on a scale from 1–5).
4. Wealth of information captured by the system on the sensor (on a scale from 1–5).
5. Additional comments.

Also the developers were categorized as follows:

- Software developers who had knowledge of SensIV but no knowledge of the SensorML / Component translator.
- Software developers who were not acquainted with any of the 2 sensor systems and they were using both for the first time.
- Software developers with knowledge of both SensIV and the SensorML / Component translator.

The results of the survey are captured in the following sub-sections.

4.2.1. Results for software engineers who had knowledge of SensIV but no knowledge of the SCT

There were 2 developers who fell into this category. The first developer thought that learning SensIV was very time consuming, this user mentioned there were some errors when changes were implemented, from the point of view of ease of use this user mentioned that SensIV was quite difficult to get acquainted with, for wealth of information this user misunderstood the question so the user's answer is omitted in this section. About SCT this developer was of the idea that the only thing that confused him from a learning point of view was setting the paths, this user mentioned that the code of SCT was correct, from the point of view of ease of use this user pointed out that from a configuration point's of view SCT was still not completely easy to use for non experts, here again the user misunderstood the question about wealth of information and thus the answer is omitted from this section.

The second developer in this category commented that it took him an hour to learn to work with SensIV, he wrote a few lines of code which he said were necessary for

changing the system when a new sensor was added. In his opinion the system did work but it was difficult to modify it. For ease of use and wealth of information provided this user did not comment anything. For SCT this developer estimated that it had taken him about 30 minutes to learn how to work with the system. This user commented that SCT worked as expected. However, this user misunderstood the question on ease of use so this answer is not written in this section; for the wealth of information provided this user mentioned that SCT provided the users with the manufacturers' name, mote type, sensor type and sensor board, which he considered important information.

4.2.2. Results for software engineers who had no knowledge of SensIV or the SCT

The users in this category were engineers capable of working with eclipse and with an understanding of Java and XML. There were 2 developers in this category.

The first developer estimated the time needed for learning to work with the SensIV system one or two days, this developer said there were no errors in the code but from the ease of use point of view if everything was to be done by hand there were too many files to change. This user ranked the ease of use of SensIV 2/5. In the wealth of information provided part this user mentioned that he didn't saw much information provided and he ranked SensIV 1/5 in this part. This user estimated the time spent for learning SCT to be about 30 minutes, he didn't find any errors in the code, and he ranked the ease of use 3.85/5. In the wealth of information part this user ranked SCT 3/5. In his additional comments this user mentioned that SCT still required eclipse and this user was not so comfortable with this matter.

The second developer said it took about 40 minutes to have an understanding of what was happening in SensIV but even then everything was still confusing, this user said the

code executed correctly, from the point of view of ease of use this user ranked SensIV 3/5, from the point of view of wealth of information provided he ranked SensIV 4/5 but he mentioned information that was not provided by SensIV so this answer can be disqualified, for SCT this user commented that it took 45 minutes to learn to use the system, the only thing this user was concerned in from the stand point of correctness was the fact that when a person minimized the SensorMLEditor it closed down automatically or key combinations like CTRL+A didn't work in the editor. The second developer was impressed with the ease of use of the SensorML / Component translator, to quote "*I am impressed with the amount of effort put in and it seems to be a really good system making the developers life easy*". This developer gave 4/5 for ease of use of the SensorML / Component translator and 5/5 for the amount of information the system

4.2.3. Results for software engineers who had knowledge of both SensIV and the SCT.

There was only one developer that filled in the survey from this category. This developer was acquainted with both SensorML and SensIV systems as he had worked closely with both systems from the beginning.

This developer said it had taken them an hour to learn to work with SensIV, they said the code had been correct, they ranked the ease of use of SensIV 3/5 and the wealth of information provided by SensIV 1/5. About SCT this user estimated the learning time to be about an hour, and the code to be correct. They ranked SCT 4/5 for ease of use and 3.5/5 for wealth of information provided. This developer commented that understanding SensorML was easier than SensIV but here again there were configuration errors.

Table 3 shows a summary of the survey taken by the software developers.

Person No.	Cat.	Q1. SCT	Q1. SensIV	Q3. SCT	Q3. SensIV	Q4. SensIV	Q4. SCT
1	1	1	-	4	-	2	-
2	1	0.5	1	3	-	-	3
3	2	0.5	36	3.85	2	3	1
4	2	0.75	0.66	4	3	5	4
5	3	1	1	4	3	3.5	1
Ave	-	0.75	9.665	3.77	2.67	3.37	2.25

Table 3.Result of the software developers' survey

4.3. Evaluating the amount of code written.

It is important to note that in the components generated by SCT from all the lines of code automatically generated only 2.86% lines comes from the process method and is therefore not automatically generated.

For the second metric two scenarios are considered. These scenarios were tested by the developer of SCT:

1. Multiple instances of a single sensor type (for example multiple instances of a Temperature sensor.)
2. When there are multiple instances of multiple sensor types (for example multiple instances of a Temperature and Humidity sensor.)

4.3.1. Multiple instances of one kind of sensor

In the SensIV application, when a new instance of the same sensor is added no new code has to be written since the classes are not sensor specific but type specific.

In the case of the SensorML / Component translator 10 new lines have to be added. These lines are added using an editor. So in this case the ratio of the lines of code written in SensIV to the lines of code written in SCT is equal to 0 so in this case SensIV is better.

4.3.2. Multiple instances and multiple types of sensors

In the SensIV system we need to add totally 32 lines of code to capture the new sensor type. In the SensorML / Component translator the amount of new coding would be 14. So in this case the ratio of the lines of code written in SensIV to the lines of code written in SCT is equal to 2 so in this case SensIV is better.

4.4. Measuring the correctness

In this part the components were tested using simulated data and gave the same result as SensIV.

4.5.Cohesion and Coupling

4.5.1. Cohesion

Cohesion is defined as how strongly related to each other the functionalities of software modules are. Coupling is defined as the knowledge each class has of other classes.

In this thesis the *Cohesion in Methods* test of the Eclipse *Metrics 1.3.6* plugin was used to measure the coupling in both the SensIV code and the code generated by the SensorML / Component Translator.

The lack of cohesiveness in this plug-in is measured using an algorithm called Henderson-Sellers. The formula used in this method is:

M(A)-M/1-M

Where M(A) is the average number of methods that access all attributes, M is the total number of methods, and A is the number of attributes.

This formula shows that the more the methods access the attributes in a class the higher the cohesiveness. The measure of cohesion is not well applicable to Java Beans because access of classes is limited to getter and setter methods and there is a getter and setter value for each attribute. This formula will lead to a value which is very close to one. For example for a Java Bean where:

A=5, M(A)=2, M=10

The lack of cohesiveness in this case is equal to 8/9. In the case of SensIV code the cohesion factor is about 0.785. In the case of the code generated by the SensorML / Component Translator the cohesion factor is about 0.332.

Additions of new sensor types to both systems had little impact on the cohesiveness of the code. In both cases the values for lack of cohesion remained nearly the same.

4.5.2. Coupling

To compare the coupling of the components generated by SCT to SensIV a measure called Method Invocation Coupling (MIC) is used. MIC is defined as the number of classes that are coupled to a certain class [23]. The formula for MIC is:

$$MIC=nMIC/(N-1)$$

Where nMIC= number of classes that use a particular class
N=total number of classes

As an example when there are two components generated by SCT. (For example WindChill and Temperature components).

MIC (Temperature)=1/3=33%
MIC(WindChill)=1/3=33%
MIC(connectorBean)=1/3=33%

MIC(Execution class)=0

So the average MIC for the components generated by SCT where there are two components is 8.25%.

For SensIV where there are two sensors the MIC for each class is:

MIC(DemoMotes)=0
MIC(FruitSalad)=1/7
MIC(Lizard)=1/7
MIC(MTS300)=3/7
MIC(MTS310)=3/7
MIC(MDA300)=3/7
MIC(Constant)=6/7
MIC(DataConvert)=1/7

So the average MIC for SensIV=32.14%

As it can be seen the coupling for SensIV is four times more than the coupling for the components generated by SCT.

4.6. Analysing the results

From the four metrics the following are the most important ones:

1. A software developer's effort in changing the sensor system.
2. The amount of code written.
3. The cohesion and coupling of the code.

The Analysis of the results will be done for these three metrics. In term of the first metric, ease of use and the effort required by the developers, the developers seemed to prefer working with SensorML rather than directly with code as in the SensIV system. Fundamentally the concept of leveraging a resource specification language to facilitate software development leads to simpler code development.

In terms of the amount of code written the SensIV system did not require any new code when sensors of the same type are added to the network. This design feature in SensIV is at the expense of classifying sensors of the same type as equivalent such that there is no individual Object associated with each sensor. But when new sensor types where added to the system SCT outperformed SensIV in terms of the Lines of code written.

In terms of the third metric SensIV had a higher cohesion than the components generated by SCT but it also provided a higher coupling than the components generated by SCT. Table 4 summarizes the result of these three metrics.

	Users' opinion	Lines of Code written	Cohesion and Coupling
SensIV	9.67, 2.67, 2.25	Better for Multiple instances of a single sensor type	Cohesion=0.785, Coupling=32%
SCT	0.75, 3.77, 3.37	Better for Multiple instances of Multiple sensor types	Cohesion=0.332, Coupling=8%

Table 4. Results of the Testings

There might have been several threats to the validity of these tests of which the following are listed:

- In the survey SensorML and SCT was explained first this might have made attendants tired when explanation of SensIV was reached and as a result they might have paid less attention and might have made more errors.

- Nearly all the attendants were using SCT from scratch while 3/5 attendants were already familiar with SensIV this might have had the negative affect that changing an already existing sensor system might have been harder than becoming familiar with another sensor system from scratch.

Chapter 5 Comparison

In this Chapter SCT is compared with the approaches presented in section 2.2. The goal is to understand the similarities and differences between SCT and these approaches.

5.1. Insense

In this section the similarities and discrepancies between Insense [14][15] and the SensorML / Component translator (SCT), are examined.

There are several resemblances between Insense and SCT these include:

- Both Systems generate components.
- Both systems have input and output channels, which have to be compatible with the input or output channel of the component they are connecting to.
- Both systems create code for execution. SCT creates Java Beans from SensorML, whereas Insense creates C code from Java.
- Both systems provide mutual exculsion in the codes they create. SCT does this by using events: each component registers for events and waits for event notifications while Insense uses a semaphore for this purpose. In general both systems provide means by which components can communicate with each other.

Even though there are a lot of similarities between both systems a few differences also exist between them:

- Insense has an interface part and this is the means by which components communicate with each other, whereas SCT uses *getter* and *setter* methods for component communication.

- Another difference between Insense and SCT is that in the code generated by Insense there is a part called the behavior part, which runs until some component tells it to stop. The components generated by the SCT are controlled by events, they start when an event occurs and end when the code for servicing the event ends.
- In Insense there are four operations on the input and output channels of a component: send, receive, disconnect and connect; SCT doesn't directly support this.

5.2. UM-RTCOM

There are some differences between UM-RTCOM [16][17][18] and SCT. These are:

- There are two kinds of components in UM-RTCOM: active and passive. Active components are the ones specifying the execution flow while the passive ones are used for mutual exclusion on shared resources.

  The components generated by SCT do both jobs of active and passive components in one. Mutual exclusion is ensured by using event handling and the executing component is always the component triggered by the event.

- There are two main types of components in UM-RTCOM: primitive and generic. Generic components are composed of other components. Whereas in SCT each process model is mapped to one and only one component so in this work there are just primitive components. UM-RTCOM is a framework for real time systems and as such it is not targeted to sensor systems but could be used to develop sensor specific components.

  SensorML could be mapped into UM-RTCOM but with some difficulty since it is a generic component design tool that supports real-time analysis.

- Another difference is that the component in UM-RTCOM consists of an interface part which specifies the provided and required interfaces. These interfaces are the means by which components communicate, whereas components created by SCT communicate via getter and setter methods.
- The abstract model in UM-RTCOM let us perform real time analysis such as deadlock freedom while the abstract model in this thesis (SensorML) lets us specify the connections and the inputs and outputs to the components.
- In UM-RTCOM the only way components can communicate is by explicitly using synchronization primitives (*wait, raise, call*) in SCT this is done implicitly by using events.

There are several similarities between UM-RTCOM and SCT. These include:

- Both the components in UM-RTCOM and the components generated by SCT have an implementation part, which is the execution part of the components.
- Both systems have parts that use events.

5.3. UML Platform Independent Component Model to Platform Specific Component Models

The similarities between this approach [19] and SCT are:

- The approach presented maps UML to component based languages like Enterprise Java Beans (EJB) or Corba Component Model (CCM). The work done in this thesis converts SensorML to Java Beans. As it can be seen both approaches are very similar: both approaches convert a modeling language to a component based language.

- Both approaches create components and have some method by which components can communicate. In this approach components can communicate by using *Ports*, which are interfaces, while in the components generated by SCT components communicate by using setter and getter methods.
- In this approach in order to connect components to each other *connectors* are used. The connectors that are comparable to the connections between the components created by SCT are called *assembly connectors.* The assembly connector exists between the ports (required and provided.)

The differences between the two systems are:

- One of the main differences between the two systems is that UML is a general modeling language while SensorML is a modeling language specific to sensors.
- Another difference between the two systems is that in this approach one of the composing parts of a component is *parts*, which are subcomponents. In the components generated by SCT there is nothing comparable to parts.
- One of the types of connectors that does not exist in the components in this thesis is the *delegation connector*. The delegation connector is used to connect components and sub components together.
- To map the UML model to EJB each component is mapped to a bean (for each bean there exists an interface part and an implementation part) this is very similar to the work carried out in this thesis were every process model is mapped into a component or a Bean but with the difference that in this thesis the SensorML model gets mapped into Beans that *only* have the implementation part.

5.4. V3studio

The discrepancies between V3studio [20] and SCT are:

- V3studio provides a more graphical form of representation than SensorML and SCT. V3studio defines three models: one for the component view, one for the state machine and one for the activity diagram. These models are implemented used the graphical model framework (GMF).
- In V3studio there exists a component type called the *complex components* that does not exist in the components generated by SCT.
- In V3studio component communication is done via interfaces while in the components generated by SCT this is done via getter and setter methods.
- In V3studio communication parts are called *ports.* A communication part that doesn't exist in the components created by SCT, and which is used to connect complex components together, is called the *assembly port.*
- In the behavioral model of V3studio there are vertexes that have no equivalent in the components created by SCT and are called *pseudo states,* which are not real states but they can mark the initial or final states of the state diagram.
- The second part of behavioral diagrams is transitions. One kind of transition that has no equivalent in this work are internal transitions, which are a loop in the same state.

The similarities between V3studio and the work done in this thesis are:

- V3studio resembles SensorML in the sense that in comparison to UML it is a more constrained language. V3studio can be considered as a meta-model that describes a subset of UML and as such it is UML compliant and vice versa.

- The state diagram in V3studio is comparable to a process chain that describes what components are connected to each other hence specifying the different states a component will be in when it would be translated.
- The activity diagram in V3studio specifies the flow of data and is comparable to the components generated by SCT.
- The component type that exists in both V3studio and the components generated by SCT are simple components.
- Both approaches provide means by which components can communicate. The ports which are comparable to the communication part in the components generated by SCT are called *Delegation portlinks.*
- Another similarity between the two systems is that in both systems the means by which components communicate has to have compatible types.
- In the behavioral model of V3stdudio there are two components: *vertexes* and transitions. The vertexes that are equivalent to the different stages of a component life are called states.
- External transitions are a kind of transitions that do have an equivalent in this work. External transitions are comparable to events, which change the state in which a component is in.

5.5. COM and Eiffel

Some of the differences between the two methods include:

- A difference between Java Beans and COM [13] is that in Java Beans there is no actual use of pointers; Java Beans uses Components, which are called Beans, and the connections between these components is depicted with events.
- Another difference between the components in COM and the components generated by SCT is that all components in COM inherit from a component called *IUnknown.* The components in this thesis don't inherit from anything hence they are simple components.
- IUnknown has a method called *QueryInterface.* QueryInterface is used to access another interface and it can be compared to getter and setter methods.
- COM has its own Interface Definition Language (IDL) and with that IDL it defines the interface by which the components will interact.
- Another difference is that COM can also work with distributed systems. In order to work with distributed systems COM uses Remote Process Call (RPC). In the work done in this thesis RPCs are not taken into consideration.

Some of the resemblances between the two approaches are:

- In COM there exists a virtual pointer (*vpointer*) and the vpointer points to a virtual table where the methods are and each entry in the virtual table points to a method implementation. This is very similar to the referencing used in SensorML. In SensorML each process chain references to a process model and the process model references the process method. The process chain in SensorML can be

compared to the vpointer, the process model to the virtual table and the method implementation to the process method.

- Another similarity between the work done in this thesis and [12] is that in both approaches the component model (the component model in [12] is COM and the component model in this thesis is Java Beans) are not being used alone. Java Beans is being used with a translator and COM is being used with an Object Oriented (OO) language called *Eiffel*.
- Both COM and the work done in this thesis have an implementation part. In the case of COM this implementation part are the classes that implement the interfaces; in the case of the work done in this thesis these are the Java Beans generated by SCT.
- COM lets component execute in both multi thread and not thread aware systems that is why COM introduces a new concept called apartments. Each apartment belongs to a single process but each process can have multiple apartments. Each apartment can be either single or multi threaded. In the work done in this thesis threads are not directly dealt with but if you consider that when a component is waiting for events to happen other components can be executed this could be comparable to what threads do.
- In COM Type libraries, which are used to discover the type of interfaces, are comparable to introspection in Java Beans.

5.6. JCM

The similarities between JCM [21] and the work done in this thesis are:

- Both the component models in JCM and this thesis consist of connector models. In this thesis the connections between the components is depicted with events.
- Both models provide an implementation part for the components.
- Both designs provide loosely coupling of Java classes. In JCM the components interact via interfaces, whereas in this thesis the components interact via getter and setter methods.

Some of the disparities between the two systems include:

- The component model in JCM consists one part that the component model in this thesis lacks; this part is called the specification model which provides interfaces via which the components connect to each other. In the component model in this thesis this is done with getter and setter methods.
- Regardless of whether Java RMI is used or another form of RMI is chosen the components created by SCT use Java Beans, which is a more constrained form of Java.

Chapter 6 Conclusion and Future Work

6.1. Summary and Conclusion

In this thesis a translator was designed and implemented to convert sensor languages to component based frameworks. This was done with the purpose of enhancing the existing design and implementation of sensor systems.

A variety of sensor languages were introduced. The two most common ones being: SensorML and IEEE1451. SensorML was selected as the sensor language in this work because it specified the execution process of a sensor system and this was very important in determining the flow in component based design.

It was decided that Java Beans would be the most suitable component based framework in this work because of its popularity between programmers and because of it being platform independent.

The translator's design involved reading the process chain, process models and process methods information from the SensorML document using a DOM parser and then create a component (a Bean- components in Java Beans are Beans), then create the connections between the Beans and then execute the Beans.

In the last chapter the SCT was compared against an existing sensor system (SensIV) to learn if the objectives of the work (the enhancement of sensor systems in terms of ease of use when changes occurred to sensor system) were fulfilled. The results showed that when changes were introduced in the system the SCT was easier to work with than SensIV: the SCT required less learning and it was easier to edit as all a user had to do was to change SensorML documents in the SensorMLEditor whereas SensIV, even for the

people who had worked with it, was harder to work with and a change in SensIV could mean adding new bugs to the system and editing SensIV is harder as the users have to go to the source code and put their modifications there.

6.2. Future works

In this work the SensorML to Java Beans mapping was done. We propose a new design for future works: A SensorML to UML mapping.

The benefits of mapping SensorML to UML are the following:

1. UML is a general modeling language and it is not language dependent and as such it can be mapped to many programming languages.
2. Other meta-models might exist for this purpose but UML is the best known meta-model hence there are many tools supporting UML.

The way the translation between SensorML and UML can be done is via XMI. XMI (The XML Metadata Interchange) is a standard for interchanging metadata via XML. XMI is mostly considered as an interchange format for UML. It is enough to create a translator that changes SensorML into an XMI format then importing the XMI file into a UML editor; the translation could be done by the UML Editor to any supported programming language.

Another modification that might be constructive is to modify the SensorML language. At the moment SensorML allows the construction of one (sensor) System (or process chain). Sensor networks consist of several correlated sensor systems. An amendment to the SensorML architecture is suggested where more than one process chains can be added and connected to each other.

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Appendices

Appendix A

The software developed for this thesis utilized the following software and libraries.

Software used:

1. Eclipse IDE version 3.4.2 for trouble shooting and execution of the translator at www.eclipse.org

2. Net Beans IDE version 6.8 for trouble shooting and execution of the translator at http://netbeans.org

3. SensorML editor as the development environment for the SensorML documents at http://vast.uah.edu/index.php?option=com_content&view=article&id=149&Itemid=103

Libraries used:

The most important libraries used in this work are

1. j*ava.beans.PropertyChangeSupport*: Contains three methods: *add/removePropertyChangeListener* and *firePropertyChange*. It implements methods that add and remove *PropertyChangeListeners*.

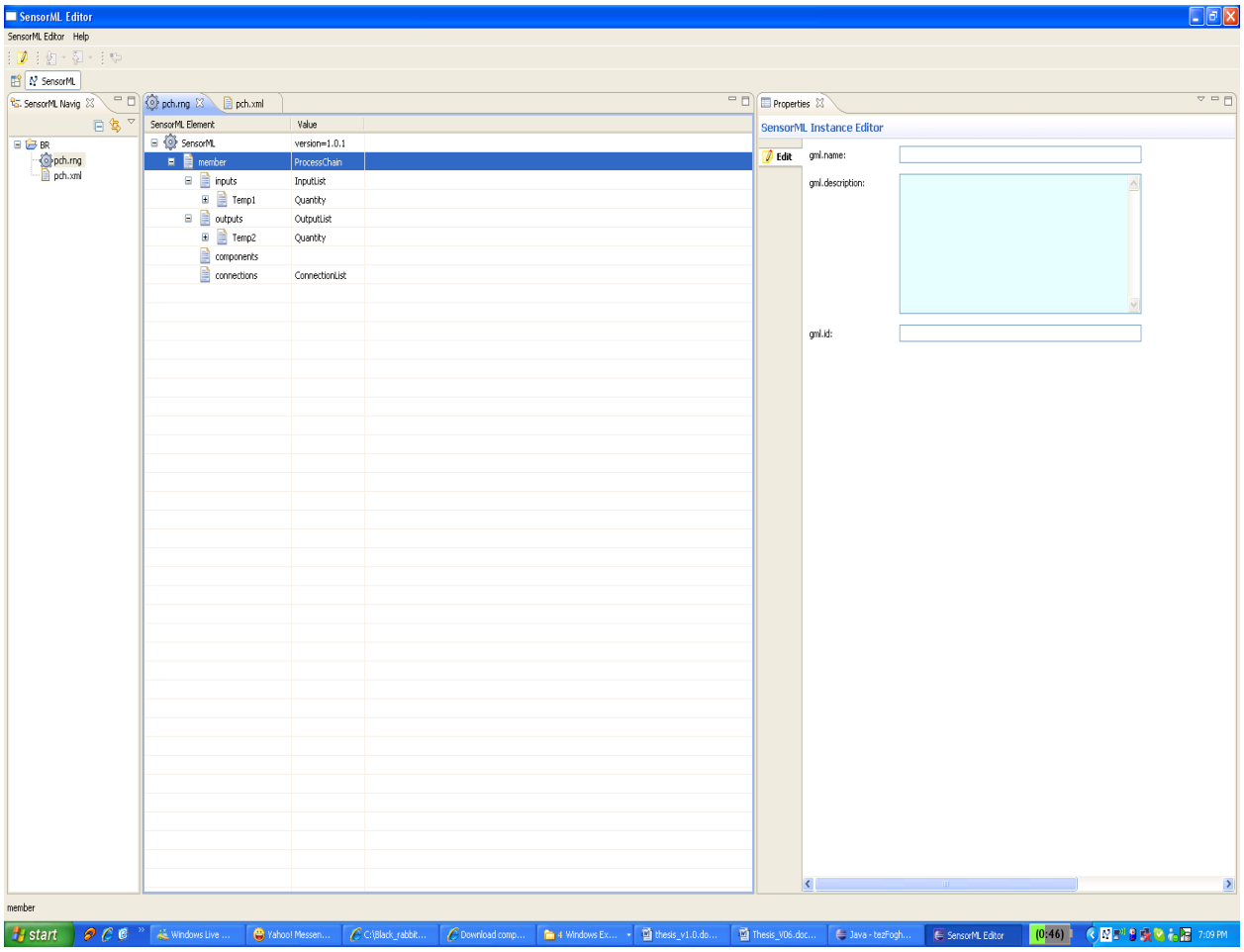
2. *java.beans.PropertyChangeListener*: This is an interface supplying one method, *propertyChange*. A java bean that has bound properties must keep a list of *propertyChangeListeners*. As such the bean implements the *propertyChangeListener* interface.

3. *java.beans.PropertyChangeEvent*: Contains three methods *getNewValue*, *getOldValue* and *getPropertyName*.

4. *javax.xml.parsers.DocumentBuilderFactory:* It provides the user with a DOM tree.

Appendix B

Following is the screen shot of an example of SensorML document (process chain) document made with the SensorML editor:



Appendix C

Following are the translator's source code:

```
//*****************************************
//main_class CLASS
//JOB: Main executing class
//*****************************************

import java.io.BufferedReader;
import java.io.BufferedWriter;
import java.io.FileOutputStream;
import java.io.FileWriter;
import java.io.IOException;
import java.io.InputStream;
import java.io.InputStreamReader;
import java.io.PrintStream;
import java.io.PrintWriter;
import java.util.ArrayList;
import java.util.logging.Level;
import java.util.logging.Logger;
import java.util.Scanner;

import javax.swing.JFrame;
import javax.swing.JOptionPane;

public class main_class {
	static long start, end, total;
	static int count1 = 0;

	public static void main(String[] args) {
		start = System.currentTimeMillis();
		/*
		 * try { // TODO Auto-generated method stub new readURL(); }
catch
		 * (IOException ex) {
		 *
Logger.getLogger(main_class.class.getName()).log(Level.SEVERE, null,
		 * ex); }
		 */

		ArrayList input_class = new ArrayList<String>();
		String s = "";
		int count = 1;
		// System.out.println("Enter path to the process chain: ");
		Scanner in = new Scanner(System.in);
		// String filename = in.nextLine();
		System.out
				.println("Enter path to where you want your
files to be created(use two backslashes to seperate directories) : ");
		in = new Scanner(System.in);
		String filePath = in.nextLine();
```

```
            System.out.println("Enter path to SensorML's Editor
workspace");
            String sensorMLWorkspace = in.nextLine();

            System.out.println("Enter name of your process chain");
            in = new Scanner(System.in);
            String pch_name = in.nextLine();

            DOMParser_pch dpch = new DOMParser_pch(sensorMLWorkspace +
pch_name);
            DOMParser d = null;
            int size = dpch.process_models.size();

            for (int i = 0; i < size; i++) {

      System.out.println(dpch.process_models.get(i).toString());
                  d = new
DOMParser(dpch.process_models.get(i).toString(), "url.xml");
                  Integer Count = new Integer(count);
                  String fname = dpch.process_names.get(i).toString();
                  createsBean mb = new createsBean(dpch, fname,
filePath, d);
                  count++;
                  count1++;
            }

      }
}
```

Main_class (Execution class) source code

```
//*******************************************
//CREATES BEAN CLASS
//JOB: creating Java Beans
//*******************************************
import java.io.*;
import java.util.ArrayList;
import java.util.StringTokenizer;
import java.util.logging.Level;
import java.util.logging.Logger;
import java.sql.*;

/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */
/**
 *
 * @author 100378007
 */
public class createsBean {
      String inputDB = "";
      String BeanName;
      int count_bean = 0;
      int count = 0;
      int count2 = 0;
      // String pk="";
      // static String dests = "";
```

```
      // static String dest_var = "";
      static ArrayList dests = new ArrayList<String>();
      static ArrayList dest_var = new ArrayList<String>();

            public createsBean(DOMParser_pch dpch, String name, String
filePath,
                  DOMParser d) {
            FileWriter fstream;
            BufferedWriter out = null;

            BeanName = name;
            try {
                  // Create file
                  // fstream = new FileWriter("C:\\kimia\\" + name +
".java");
                  // fstream = new FileWriter("C:\\TestEvent_Bean\\" +
name +
                  // ".java");
                  fstream = new FileWriter(filePath + "\\" + name +
".java");

                  out = new BufferedWriter(fstream);
                  // out.write("package Implementation;");
                  // out.newLine();
                  out.write("import com.mysql.jdbc.Statement;");
                  out.newLine();
                  out.write("import java.sql.*;");
                  out.newLine();
                  out.write("import java.beans.PropertyChangeSupport;");
                  out.newLine();
                  out.write("import
java.beans.PropertyChangeListener;");
                  out.newLine();
                  out.write("import java.beans.PropertyChangeEvent;");
                  out.newLine();
                  out.write("import java.io.Serializable;");
                  out.newLine();
                  out.write("import java.io.BufferedReader;");
                  out.newLine();
                  out.write("import java.io.IOException;");
                  out.newLine();
                  out.write("import java.io.InputStream;");
                  out.newLine();
                  out.write("import java.io.InputStreamReader;");
                  out.newLine();
                  out.write("import java.beans.*;");
                  out.newLine();
                  out.write("public class " + name
                              + " implements PropertyChangeListener,
Serializable{");
                  out.newLine();
                  int count_bean1 = 0;
                  for (int i = 0; i < dpch.source.size(); i++) {
                        StringTokenizer stt = new
StringTokenizer(dpch.source.get(i)
                                    .toString(), "/");
                        String p = stt.nextToken();
```

```
                        String p1 = stt.nextToken();
                        StringTokenizer stt_ = new
StringTokenizer(dpch.destination
                                    .get(i).toString(), "/");
                        String p_ = stt_.nextToken();
                        String p1_ = stt_.nextToken();
                        // System.out.println("process name
"+dpch.process_names.get(i)+" source "+dpch.source.get(i)+" destination:
"+
                        // dpch.destination.get(i));

                        if
(!dpch.source.get(i).equals(dpch.destination.get(i))) {

                              if (p.equals(name)) {

                                    Integer cnt = new
Integer(count_bean1);
                                    out.write(" public static " + p_ + "
b"
                                                + cnt.toString() + "=new
" + p_ + "();");
                                    out.newLine();
                                    count_bean1++;
                              }

                        }
                  }
                  for (int i = 0; i < d.input.size(); i++) {

                        out
                                    .write(d.type.get(i).toString() + "
" + d.input.get(i)
                                                + ";");
                        out.newLine();
                  }
                  out.write("String manufacturer=" + "\"" +
d.manufacturer + "\""
                              + ";");
                  out.newLine();
                  out.write("String getManufacturer(){return
manufacturer;}");
                  out.newLine();
                  out
                              .write("String sensorBoard=" + "\"" +
d.sensorBoard + "\""
                                          + ";");
                  out.newLine();
                  out.write("String getSensorBoard(){return
sensorBoard;}");
                  out.newLine();
                  out.write("String sensorType=" + "\"" + d.sensorType +
"\"" + ";");
                  out.newLine();
                  out.write("String getSensorType(){return
sensorType;}");
                  out.newLine();
```

```
                  out.write("String moteType=" + "\"" + d.moteType +
"\"" + ";");
                  out.newLine();
                  out.write("String getMoteType(){return moteType;}");
                  out.newLine();
                  out
                              .write("private PropertyChangeSupport pcs
= new PropertyChangeSupport(this);");
                  out.newLine();
                  int count_inputs = 0;
                  for (int i = 0; i < d.input.size(); i++) {
                        Integer cnt = new Integer(count_inputs);
                        out.write("boolean flag" + cnt.toString() +
"=false;");
                        out.newLine();
                        count_inputs++;
                  }
                  // }
                  out.write("public " + name + "(){");
                  out.newLine();
                  out.write("pcs.addPropertyChangeListener(this);");
                  out.newLine();
                  out.write("}");
                  out.newLine();
                  // ************************************************
                  String s = "";

                  File file = new File(d.method.get(0).toString());
                  FileInputStream fis = null;
                  BufferedInputStream bis = null;
                  DataInputStream dis = null;

                  try {
                        fis = new FileInputStream(file);

                        // Here BufferedInputStream is added for fast
reading.
                        bis = new BufferedInputStream(fis);
                        dis = new DataInputStream(bis);

                        // dis.available() returns 0 if the file does
not have more
                        // lines.
                        // String w=dis.readLine();
                        boolean flag = false;
                        String w = dis.readLine();

                        // System.out.println("public void
"+d.method_name);
                        while (dis.available() != 0) {
                              // this statement reads the line from the
file and print it
                              // to
                              // the console.
                              if (w.equals("}")) {
                                    out.flush();
                                    out.write("}");
```

```
                                    out.newLine();

                                    flag = false;

                                    // s += w;
                                    break;
                              }

                              else if (flag) {
                                    out.write(w);
                                    out.newLine();
                                    // s += w;
                                    // s+='\n';
                              } else if (w.equals("public void run(){"))
{
                                    // s += w;
                                    out.write(w);
                                    out.newLine();
                                    flag = true;

                              }

                              w = dis.readLine();

                        }
                        // while(!dis.readLine().equals("public void
"+d.method_name)){System.out.println("Hello");}
                        // this statement reads the line from the file
and print it to
                        // the console.

                        // dispose all the resources after using them.
                        fis.close();
                        bis.close();
                        dis.close();

                  } catch (FileNotFoundException e) {
                        e.printStackTrace();
                  } catch (IOException e) {
                        e.printStackTrace();
                  }
                  // out.write(s);

                  // out.newLine();

                  // ************************************************
                  out.write("public void
propertyChange(PropertyChangeEvent evt) {");
                  out.newLine();
                  count_inputs = 0;
                  out.write(d.method_name + ";");
                  out.newLine();
                  for (int i = 0; i < dpch.source.size(); i++) {
                        StringTokenizer stt = new
StringTokenizer(dpch.source.get(i)
                                    .toString(), "/");
                        String p = stt.nextToken();
```

```
                        String p1 = stt.nextToken();
                        StringTokenizer stt_ = new
StringTokenizer(dpch.destination
                                    .get(i).toString(), "/");
                        String p_ = stt_.nextToken();
                        String p1_ = stt_.nextToken();
                        // System.out.println("process name
"+dpch.process_names.get(i)+" source "+dpch.source.get(i)+" destination:
"+
                        // dpch.destination.get(i));

                        if
(!dpch.source.get(i).equals(dpch.destination.get(i))) {

                              if (p.equals(name)) {
                                    Integer cnt = new
Integer(count_bean);
                                    /*
                                     * out.write(p_ + " b" +
cnt.toString() + "=new " + p_ +
                                     * "();"); out.newLine();
                                     */
                                    out.write("b" + cnt.toString() +
".set" + p1_ + "("
                                                + p1 + ");");
                                    dests.add(p_);
                                    dest_var.add(p1_);
                                    count_bean++;
                                    out.newLine();
                              }
                              }
                        }

                  out.newLine();
                  out.write("}");

                  out.newLine();

                  count_inputs = 0;
                  for (int i = 0; i < d.input.size(); i++) {
                        out.write("public void  set" + d.input.get(i) +
"("
                                    + d.type.get(i).toString() + "
in){");
                        out.newLine();
                        Integer cnt = new Integer(count_inputs);
                        out.write("if (!flag" + cnt + ")");
                        count_inputs++;
                        out.newLine();
                        out.write("flag" + cnt + "=true;");
                        out.newLine();
                        out.write(d.type.get(i) + " old=" +
d.input.get(i) + ";");
                        out.newLine();
                        out.write(d.input.get(i) + "=in;");
                        out.newLine();
                        out.write("pcs.firePropertyChange(" + "\""
```

```
                                    + d.input.get(i).toString() + "\"" +
", old,"
                                    + d.input.get(i).toString() + ");");
                        out.newLine();
                        out.write("}");// end of set
                        out.newLine();

                  }// end of for
                  out.newLine();
                  for (int i = 0; i < d.input.size(); i++) {
                        out.write("public double get" + d.input.get(i) +
"(){return "
                                    + d.input.get(i) + ";}");
                        out.newLine();
                  }
                  out.write("}");// end of class


            } catch (Exception ex) {
            } finally {
                  try {
                        out.close();
                  } catch (IOException ex) {
                        //
Logger.getLogger(createBeans.class.getName()).log(Level.SEVERE,
                        // null, ex);
                  }
            }

      }
}
```

Class createsBean Source code

```
//*****************************************
//DOMParser_pch
//JOB: extract process chain information
//*****************************************

import java.io.File;
import java.io.IOException;
import java.util.ArrayList;

import javax.xml.parsers.DocumentBuilderFactory;
import javax.xml.parsers.ParserConfigurationException;
import javax.xml.transform.OutputKeys;
import javax.xml.transform.Result;
import javax.xml.transform.Source;
import javax.xml.transform.Transformer;
import javax.xml.transform.TransformerConfigurationException;
import javax.xml.transform.TransformerException;
import javax.xml.transform.TransformerFactory;
import javax.xml.transform.TransformerFactoryConfigurationError;
import javax.xml.transform.dom.DOMSource;
import javax.xml.transform.stream.StreamResult;

import org.omg.CosNaming.NamingContextExtPackage.AddressHelper;
import org.w3c.dom.Document;
```

```
import org.w3c.dom.Node;
import org.w3c.dom.NodeList;
import org.xml.sax.SAXException;

public class DOMParser_pch {

      ArrayList process_models = new ArrayList<String>();
      ArrayList type = new ArrayList<String>();
      ArrayList process_names = new ArrayList<String>();
      ArrayList source = new ArrayList<String>();
      ArrayList destination = new ArrayList<String>();
      boolean lngt = false;
      String longitude;
      boolean lat = false;
      String latitude;
      boolean alt = false;
      String altitude;
      int j = 0;
      double n1 = 0;
      int count = 0;
      private Document doc = null;
      private Document doc1 = null;

      public DOMParser_pch(String filename) {
            try {
                  doc = parserXML(new File(filename));
                  visit(doc, 0);

            } catch (Exception error) {
                  error.printStackTrace();
            }
      }

      public void visit(Node node, int level) {
            double calibvalue = 10;
            NodeList nl = node.getChildNodes();

            for (int i = 0, cnt = nl.getLength(); i < cnt; i++) {
                  if
((nl.item(i).getNodeName().equals("sml:component"))) {

      process_models.add(nl.item(i).getAttributes().getNamedItem(
                                    "xlink:href").getNodeValue());

      process_names.add(nl.item(i).getAttributes().getNamedItem(
                                    "name").getNodeValue());
                        //
System.out.println(nl.item(i).getAttributes().getNamedItem("location").g
etNodeValue());
                        // System.out.println(process_models.get(j));
                        // j++;
                  } else if
((nl.item(i).getNodeName().equals("sml:source"))) {

      source.add(nl.item(i).getAttributes().getNamedItem("ref")
                                    .getNodeValue());
```

```
                } else if
((nl.item(i).getNodeName().equals("sml:destination"))) {

      destination.add(nl.item(i).getAttributes().getNamedItem("ref")
                                    .getNodeValue());
                } else if ((lngt)
                                    &&
(nl.item(i).getNodeName().equals("swe:Quantity"))) {
                          lngt = false;
                          longitude = nl.item(i).getTextContent();
                          System.out.println(nl.item(i).getTextContent());
                } else if ((lat)
                                    &&
(nl.item(i).getNodeName().equals("swe:Quantity"))) {
                          lat = false;
                          latitude = nl.item(i).getTextContent();
                          System.out.println(nl.item(i).getTextContent());
                } else if ((alt)
                                    &&
(nl.item(i).getNodeName().equals("swe:Quantity"))) {
                          alt = false;
                          altitude = nl.item(i).getTextContent();
                          System.out.println(nl.item(i).getTextContent());
                } else if
((nl.item(i).getNodeName().equals("swe:coordinate"))) {
                          if
(nl.item(i).getAttributes().getNamedItem("name")
                                    .getNodeValue().equals("longitude"))
                                    lngt = true;
                          else if
(nl.item(i).getAttributes().getNamedItem("name")
                                    .getNodeValue().equals("latitude"))
                                    lat = true;
                          else if
(nl.item(i).getAttributes().getNamedItem("name")
                                    .getNodeValue().equals("altitude"))
                                    alt = true;

      System.out.println(nl.item(i).getAttributes().getNamedItem(
                                    "name").getNodeValue());
                }

                /*
                 * else
                 *
if((lngt)&&(nl.item(i).getNodeName().equals("swe:Quantity"))) {
                 * longitude=nl.item(i).getTextContent(); } else if
                 *
((nl.item(i).getNodeName().equals("swe:coordinate"))) {
                 * //if(nl.item
                 *
(i).getAttributes().getNamedItem("definition").getNodeValue
                 * ().equals("urn:ogc:def:phenomenon:latitude")) //
                 * System.out.println
                 * (nl.item(i).getAttributes().getNamedItem("axisCode"
                 * ).getNodeValue()); if
```

```
                    *
(nl.item(i).getAttributes().getNamedItem("swe:Quantity")
                    * .getNodeValue().equals("longitude")) lngt=true; }
                    */
                   visit(nl.item(i), level + 1);

            }
      }

      public Document parserXML(File file) throws SAXException,
IOException,
                  ParserConfigurationException {
            return
DocumentBuilderFactory.newInstance().newDocumentBuilder().parse(
                        file);
      }
      /*
       * public static void main(String[] args) { new DOMParser(); }
       */
}

//*****************************************
//DOMParser
//JOB: extract the process model information
//*****************************************

import java.io.BufferedInputStream;
import java.io.BufferedWriter;
import java.io.DataInputStream;
import java.io.File;
import java.io.FileWriter;
import java.io.IOException;
import java.io.InputStream;
import java.net.MalformedURLException;
import java.net.URL;
import java.util.ArrayList;
import java.util.StringTokenizer;
import java.util.concurrent.CountDownLatch;

import javax.xml.parsers.DocumentBuilderFactory;
import javax.xml.parsers.ParserConfigurationException;
import javax.xml.transform.OutputKeys;
import javax.xml.transform.Result;
import javax.xml.transform.Source;
import javax.xml.transform.Transformer;
import javax.xml.transform.TransformerConfigurationException;
import javax.xml.transform.TransformerException;
import javax.xml.transform.TransformerFactory;
import javax.xml.transform.TransformerFactoryConfigurationError;
import javax.xml.transform.dom.DOMSource;
import javax.xml.transform.stream.StreamResult;

import org.omg.CosNaming.NamingContextExtPackage.AddressHelper;
import org.w3c.dom.Document;
import org.w3c.dom.Node;
import org.w3c.dom.NodeList;
import org.xml.sax.SAXException;
```

```
public class DOMParser {
      boolean manufact = false;
      boolean snsBrd = false;
      boolean mtType = false;
      boolean snsType = false;
      String manufacturer;
      String sensorBoard;
      String moteType;
      String sensorType;
      boolean flag_id = false;
      boolean flag = false;
      ArrayList input = new ArrayList<String>();
      ArrayList type = new ArrayList<String>();
      double n1 = 0;
      int count = 0;
      ArrayList method = new ArrayList<String>();
      String method_name = "";
      private Document doc = null;
      private Document doc1 = null;
      private int count_method = 0;
String workspace;
      // readURL url;

      public DOMParser(String filename,String workspace) {
method_name="run()";
            try {

                  this.workspace=workspace;
                  // doc1 = parserXML(new
                // File("D:\\My Documents\\sensors\\code\\pch.xml"));
                doc = parserXML(new File(filename));
                // for(int i=0; i<5;i++)
                // a.add(new ArrayList());
                visit(doc, 0);

            } catch (Exception error) {
                  error.printStackTrace();
            }
      }

      public void visit(Node node, int level) {
            String unit_tokenize = "";

            double calibvalue = 10;
            NodeList nl = node.getChildNodes();
            String t = "";

            for (int i = 0, cnt = nl.getLength(); i < cnt; i++) {
                  if ((nl.item(i).getNodeName().equals("sml:input"))) {

      input.add(nl.item(i).getAttributes().getNamedItem("name")
                                    .getNodeValue());
                type.add("double");

                }
                //swe:uom
```

```
                  /*else if
((nl.item(i).getNodeName().equals("swe:uom")))

                  {


      t=nl.item(i).getAttributes().getNamedItem("xlink:href")
                                    .getNodeValue();
                        DOMParser_URL dURL = new
DOMParser_URL(workspace, t);

                        type.add(dURL.unit);


                  }*/
                  else if
((nl.item(i).getNodeName().equals("sml:method"))) {

      method.add(nl.item(i).getAttributes().getNamedItem("xlink:href")
                                    .getNodeValue());


                        count_method++;

                        method_name = "run()";

                  } else if ((flag_id)
                              &&
nl.item(i).getNodeName().equals("sml:value")) {

                        flag_id = false;
                        if (manufact) {
                              manufacturer =
nl.item(i).getTextContent();
                              manufact = false;
                        } else if (mtType) {
                              moteType = nl.item(i).getTextContent();
                              mtType = false;
                        } else if (snsType) {
                              sensorType = nl.item(i).getTextContent();
                              snsType = false;
                        } else if (snsBrd) {
                              sensorBoard = nl.item(i).getTextContent();
                              snsBrd = false;
                        }
                        System.out.println(nl.item(i).getTextContent());
                  } else if
((nl.item(i).getNodeName().equals("sml:identifier"))
                              ||
(nl.item(i).getNodeName().equals("sml:classifier"))) {


      System.out.println(nl.item(i).getAttributes().getNamedItem(
                              "name").getNodeValue()
                              + ": ");
```

```
                        if
(nl.item(i).getAttributes().getNamedItem("name")

      .getNodeValue().equals("Manufacturer"))
                              manufact = true;
                        else if
(nl.item(i).getAttributes().getNamedItem("name")
                                    .getNodeValue().equals("Mote Type"))
                              mtType = true;
                        else if
(nl.item(i).getAttributes().getNamedItem("name")
                                    .getNodeValue().equals("sensor
Type"))
                              snsType = true;
                        else if
(nl.item(i).getAttributes().getNamedItem("name")
                                    .getNodeValue().equals("Sensor
Board"))
                              snsBrd = true;
                        flag_id = true;

                  }

                  // sml:method
                  visit(nl.item(i), level + 1);

            }
      }

      public Document parserXML(File file) throws SAXException,
IOException,
                  ParserConfigurationException {
            return
DocumentBuilderFactory.newInstance().newDocumentBuilder().parse(
                        file);
      }
      /*
       * public static void main(String[] args) { new DOMParser(); }
       */
}
```

Class DOMParser Source Code

Appendix D

Survey

SensIV System

1. Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

2. Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):

3. Ease of use (On a scale from one to five. Five being the highest; how easy did you find using this approach?):

4. Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this approach provided?)

5. Additional Comments:

SensorML Translator

1. Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

2. Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):

3. Ease of use (On a scale from one to five, five being the highest; how easy did you find using this system?):

4. Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this system provided?)

5. Additional Comments:

Appendix E

1. Users with knowledge of SensIV but with no knowledge of the SCT.

a. First user's answers:

SensIV System

- Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

  It took so much time to get start with. And the user must familiar with JAVA as well.

- Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):

  It gave me some errors and I guess that's completely normal. Because I wrote a new program and each new program or module creates new bugs into system. So tracking down those bugs will take some time.

- Ease of use (On a scale from one to five. Five being the highest; how easy did you find using this approach?):

  I've been working on SensIV for past 2 years and I should say that getting familiar with SensIV is time consuming.

- Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this approach provided?)

  Adding new types of sensor into the system is real pain. The programmer and developer must know exactly what they are doing and the documentation of the new sensor must be provided.

- Additional Comments:
  SensIV designed to be operated in Object Orientated fashion. If that is not followed, it will put the programmer into bad situation. As I said before, I worked with this program for years and to me adding additional sensor into this system will be really hard.

SensorML Translator

- Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

  The only thing that confused me and took me so long to get it done is setup the paths. If it's possible to make it automatic it will be much easier. The time I spent was around 1 hour.

- Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):

  Yes, based on my understanding , it gave me the correct answer.

- Ease of use (On a scale from one to five, five being the highest; how easy did you find using this system?):

  The reason is that the system is not still easy for non-expert users in terms of configuration.

- Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this system provided?)

  The information provided is enough for start the program.

- Additional Comments:

The only thing that caught my attention was pre-configuration of the system. I'd like to see a better design to deal with configuration, and I'd like to see if it is possible to fix the path variables.

b. Second user's answers:

SensIV System

- Hours Spent Learning how to work with system (Please also include ease of learning):

❖ *1 hour to understand*

- Lines of Code written to Change system:

```
int[] myReadings_Humidity =
FruitSalad.getHmd(wrmsg.getReadings2(),
                        Constants.READ_NORMAL, Constants.MTS310);

double[] myRealReadings_hmd = new double[]
{conv.GetHumidity(myReadings_Humidity[0]),conv.GetHumidity(myReadi
ngs_Humidity[1]),conv.GetHumidity(myReadings_Humidity[2])
conv.GetHumidity(myReadings_Humidity[3]) };
```

- Correctness of code (Errors, did the system work as you were expecting it to work?):

  It does work, however it is difficult to add new sensors and new event of the each sensor. A lot of changes at the code.

- Ease of use:
- Wealth of information provided (How much information did you think each system provided and which one did you prefer. Why?)
- Additional Comments:

SensorML Translator

- Hours Spent Learning how to work with system (Please also include ease of learning):

  30 mins of explanation from the programmer.

- Lines of Code written to Change system:

```
public static void main(String[] args) {
Temperature b1 = new Temperature();
Temperature1 b2=new Temperature1();
b1.setTemp1(12.3);
b2.setTemp2(23.4);
```

- Correctness of code (Errors, did the system work as you were expecting it to work?):

  The systems works as it expected to work. The system enables adding the following :

- *New Sensors.*
- *New events of the sensors*

- Ease of use:

- *Modeling the sensor*
- *Adding new sensors*
- *Tracking the tool chain of the process*
- *Add new process without changing the code*

- Wealth of information provided (How much information did you think each system provided and which one did you prefer. Why?)

- *Mote Type*
- *Sensor Type*
- *Sensor Board*
- *Sensor Manufacturer*

From my side, the basic information Mote type, Sensor Type are important. Sensor type tells me the type of phenomena is monitored. Mote type gives me the plate form type which is necessary for installing the code.

6. Additional Comments:

2. Users with no knowledge of SensIV or the SCT

a. First user:

SensIV System

- Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

  It's my first time seeing this code, and we didn't have to do any editing? Just ran DemoMotes. Kiwis, mangoes and lizards, oh my! I would probably have to spend a day or 2…

- Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):

  Yes.

- Ease of use (On a scale from one to five. Five being the highest; how easy did you find using this approach?):

  If I had to manually code this: 2; changing/adding things have more control and adaptability, but you have to change a lot of files in order to add 1 thing.

- Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this approach provided?)

1? I didn't see any of this information other than Temperature and Humidity.

- Additional Comments:
  I downloaded, I saw, I ran.

SensorML Translator

- Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

  30 mins

- Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):

  Yes.

- Ease of use (On a scale from one to five, five being the highest; how easy did you find using this system?):

  3.85

- Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this system provided?)

  3; I know the manufacturer and board type…but no other information is given immediately in Eclipse output? Was I required to manually check the XML?

- Additional Comments:

Fun stuff, but still requires Eclipse?

b. Second user:

SensIV System

- Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

  It has taken me around 40 minutes I would say to get an understanding of what it is all about but there are certain confusions.

- Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):

  I did not encounter any error and one I encounter was fixed easily.

- Ease of use (On a scale from one to five. Five being the highest; how easy did you find using this approach?):

  3

- Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this approach provided?)

  Information about the sensor board and manufacturer : 4
  Sensor positions etc: 4

- Additional Comments:

I did not have much about idea about the SensIV but after some discussion I got to know. I am still not so familiar with the system so don't have much to comment on. But for somebody who does not know the system and is completely new to it a little more explanation is desirable.

SensorML Translator

- Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

  45 min

- Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):

  Just a few findings like upon minimizing the sensorml editor closes and the ctrl + A doesn't work on the text fields. If these are some things which need to be worked on and fixed should be done.The system does seem to work fine.

- Ease of use (On a scale from one to five, five being the highest; how easy did you find using this system?):

  4.

- Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this system provided?)

  5

- Additional Comments:

I am impressed with the amount of effort put in and it seems to be a really good system making the developers and users life easy. A good documentation explaining the purpose of the system and the other details should be shared so that the user finds it easier to understand.

Good Luck!

3. Users with knowledge of SensIV and of the SCT

SensIV System

- Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

  About 1 hr

- Correctness of code (Errors, did the system work as you were expecting it to work? Please answer with yes or no. if your answer is no please indicate the errors you found):
  Yes.

- Ease of use (On a scale from one to five. Five being the highest; how easy did you find using this approach?):

  3.

- Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this approach provided?)

  1.

- Additional Comments:

Since clear examples were presented in the code and instructions were available on how to add a sensor to Sensiv it was relatively straight forward but I was not certain what I was doing since I did not study the code before the session.

SensorML Translator

- Time Spent Learning how to work with system (please say in hours and minutes how much time it took you to understand the system and be able to run an example):

  1hr.

- Correctness of code (Errors, did the system work as you were expecting it to work? lease answer with yes or no. if your answer is no please indicate the errors you found):

  Yes.

- Ease of use (On a scale from one to five, five being the highest; how easy did you find using this system?):

  4.

- Wealth of information provided (On a scale from one to five, five being the highest; how much information about the sensor itself (like the manufacturer, the sensor board, etc) and how much information about the sensor system as a whole (like the sensor positions, the latitude, longitude, altitude and orientation) did you think this system provided?)

  3.5.

- Additional Comments:
  Understanding SensorML is much simpler than Sensiv but I received a number of errors from the existing link references because I did not name my project BR.