**Exercise 4v2**

by Guy Gadola

**Part 4v2a**

 “(a) Continuing with Exercise 3(c), explore different Petri net realizations for the super-components. We can make the execution of the algorithms all serial, all parallel, probabilistic, and so on. There are many different sub-types of Petri nets that can be explored. You should at least try serial and parallel nets. There will be bonus if you try other nets such as probabilistic nets.”



Figure 1. Original Petri Net.

For the convenience of the reader, the Figure 1 defines places and transitions that will be referenced below. Please note:

* For each Petri net in Part 4a, the initial markings are shown.
* The symbol ❶ indicates one token.

Figure 2. Parallel expansion.



Figure 3. Serial expansion.



Figure 4. Parallel expansion that is probabilistic



**Part 4v2b**

 “(b) Develop on paper the algorithm for a transformer to transform original Petri net specification (in pnml format) into the expanded Petri net specification (in pnml format). Demonstrate on paper how your algorithm works by going through the critical steps and illustrating with an example such as the one described in Exercise 3(c). “

High-level Algorithm to Convert Supercomponent into *n* Parallel Components:

1. Traverse the PNML file until the transition *t* corresponding to the supercomponent is found.
2. Determine the source and destination of the Supercomponent’s incoming arc and outgoing arc, respectively.
3. Between that source and destination, add *n*-1 components.

Example:

Step 1. The following pnml code describes the Petri Net on code describes the Petri Net shown in Figure 1. Because te1 is the supercomponent, *t* = te1. Since Figure 1 shows three enumerations for te1, *n* = 3.

<place id="pe1"/>

<arc id="a1" source="pe1" target="te1"/>

<transition id="te1"/>

<arc id="a2" source="te1" target="pe2"/>

<place id="pe2"/>

<arc id="a3" source="pe2" target="te2"/>

<transition id="te2"/>

<arc id="a4" source="te2" target="pe2"/>

<arc id="a5" source="pe2" target="te4"/>

<transition id="te4"/>

<arc id="a6" source=“te4" target="pe1"/>

<transition id="te3"/>

<arc id="a7" source=“pe1" target=“te3"/>

<arc id="a8" source=“te3" target="pe1"/>

Step 2: Identify references to te1 (shown in bold) to determine the source and destination of the supercomponent’s incoming arc and outgoing arc, respectively.

<place id="pe1"/>

**<arc id="a1" source="pe1" target="te1"/>**

**<transition id="te1"/>**

**<arc id="a2" source="te1" target="pe2"/>**

<place id="pe2"/>

<arc id="a3" source="pe2" target="te2"/>

<transition id="te2"/>

<arc id="a4" source="te2" target="pe2"/>

<arc id="a5" source="pe2" target="te4"/>

<transition id="te4"/>

<arc id="a6" source=“te4" target="pe1"/>

<transition id="te3"/>

<arc id="a7" source=“pe1" target=“te3"/>

<arc id="a8" source=“te3" target="pe1"/>

Step 3: Between that source and destination, add *n*-1 components (where *n*=3 in this case). The pnml code below should create the parallel Petri net shown in Figure 2. New elements are shown underlined.

<place id="pe1"/>

<arc id=“1a" source="pe1" target=“1te"/>

<transition id=“1te"/>

<arc id=“a2" source=“1te1" target="pe2"/>

**<arc id=“2a1" source="pe1" target=“2te1"/>**

**<transition id=“2te1"/>**

**<arc id=“2a2" source=“2te1" target="pe2"/>**

**<arc id=“3a1" source="pe1" target=“3te1"/>**

**<transition id=“3te1"/>**

**<arc id=“3a2" source=“3te1" target="pe2"/>**

<place id="pe2"/>

<arc id="a3" source="pe2" target="te2"/>

<transition id="te2"/>

<arc id="a4" source="te2" target="pe2"/>

<arc id="a5" source="pe2" target="te4"/>

<transition id="te4"/>

<arc id="a6" source=“te4" target="pe1"/>

<transition id="te3"/>

<arc id="a7" source=“pe1" target=“te3"/>

<arc id="a8" source=“te3" target="pe1"/>

**Part 4v2c**

The program below, expandPnml, adds transitions in parallel to a supercomponent transition to convert expand that supercomponent into its components. An example expansion is shown in Figure 5. Figure 5 shows the before and after Petri Nets described by orig3.pnl (Listing I) and expanded.pnml (Listing II) respectively. The program listing expandPnml.java is shown in Listing III.



Figure 5. Two Petri Nets. In the left-hand side net, transition t1 the supercomponent. In the right-hand side, transitions t1, t1, and t\_2 are components of that supercomponent.

Listing I: orig3.pnl

<?xml version="1.0" encoding="ISO-8859-1"?>

<pnml>

 <net id="n1" type="BlackTokenNet">

 <place id="p1">

 <marking>

 <graphics>

 <offset page="1" x="20" y="16" />

 </graphics>

 <value> </value>

 </marking>

 <name>

 <text>p1</text>

 <graphics>

 <offset page="1" x="20" y="0" />

 </graphics>

 <value>p1</value>

 </name>

 <initialMarking>

 <graphics>

 <offset page="1" x="20" y="32" />

 </graphics>

 <value> </value>

 </initialMarking>

 <graphics>

 <position page="1" x="122" y="258" />

 </graphics>

 </place>

 <place id="p2">

 <marking>

 <graphics>

 <offset page="1" x="20" y="16" />

 </graphics>

 <value> </value>

 </marking>

 <name>

 <text>p2</text>

 <graphics>

 <offset page="1" x="20" y="0" />

 </graphics>

 <value>p2</value>

 </name>

 <initialMarking>

 <graphics>

 <offset page="1" x="20" y="32" />

 </graphics>

 <value> </value>

 </initialMarking>

 <graphics>

 <position page="1" x="262" y="258" />

 </graphics>

 </place>

 <transition id="t1">

 <name>

 <text>t1</text>

 <graphics>

 <offset page="1" x="20" y="0" />

 </graphics>

 <value>t1</value>

 </name>

 <graphics>

 <position page="1" x="192" y="257" />

 </graphics>

 </transition>

 <transition id="t2">

 <name>

 <text>t2</text>

 <graphics>

 <offset page="1" x="20" y="0" />

 </graphics>

 <value>t2</value>

 </name>

 <graphics>

 <position page="1" x="334" y="258" />

 </graphics>

 </transition>

 <transition id="t3">

 <name>

 <text>t3</text>

 <graphics>

 <offset page="1" x="20" y="0" />

 </graphics>

 <value>t2</value>

 </name>

 <graphics>

 <position page="1" x="122" y="175" />

 </graphics>

 </transition>

 <transition id="t4">

 <name>

 <text>t4</text>

 <graphics>

 <offset page="1" x="20" y="0" />

 </graphics>

 <value>t2</value>

 </name>

 <graphics>

 <position page="1" x="262" y="175" />

 </graphics>

 </transition>

 <arc id="a1" source="p1" target="t1">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0" />

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="157" y="257" />

 </graphics>

 </arc>

 <arc id="a2" source="t1" target="p2">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0" />

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="227" y="258" />

 </graphics>

 </arc>

 <arc id="a5" source="p2" target="t2">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0" />

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="298" y="258" />

 </graphics>

 </arc>

 <arc id="a7" source="t2" target="p2">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0" />

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="290" y="200" />

 </graphics>

 </arc>

 <arc id="a8" source="p2" target="t4">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0" />

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="262" y="200" />

 </graphics>

 </arc>

 <arc id="a9" source="t4" target="p1">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0" />

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="222" y="200" />

 </graphics>

 </arc>

 <arc id="a10" source="p1" target="t3">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0" />

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="130" y="200" />

 </graphics>

 </arc>

 <arc id="a11" source="t3" target="p1">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0" />

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="110" y="200" />

 </graphics>

 </arc>

 <firingRule>

 <value> </value>

 </firingRule>

 <name>

 <value>unnamed</value>

 </name>

 </net>

</pnml>

Listing II: expanded.pnml

<?xml version="1.0" encoding="ISO-8859-1" standalone="no"?><pnml>

 <net id="n1" type="BlackTokenNet">

 <place id="p1">

 <marking>

 <graphics>

 <offset page="1" x="20" y="16"/>

 </graphics>

 <value> </value>

 </marking>

 <name>

 <text>p1</text>

 <graphics>

 <offset page="1" x="20" y="0"/>

 </graphics>

 <value>p1</value>

 </name>

 <initialMarking>

 <graphics>

 <offset page="1" x="20" y="32"/>

 </graphics>

 <value> </value>

 </initialMarking>

 <graphics>

 <position page="1" x="122" y="258"/>

 </graphics>

 </place>

 <place id="p2">

 <marking>

 <graphics>

 <offset page="1" x="20" y="16"/>

 </graphics>

 <value> </value>

 </marking>

 <name>

 <text>p2</text>

 <graphics>

 <offset page="1" x="20" y="0"/>

 </graphics>

 <value>p2</value>

 </name>

 <initialMarking>

 <graphics>

 <offset page="1" x="20" y="32"/>

 </graphics>

 <value> </value>

 </initialMarking>

 <graphics>

 <position page="1" x="262" y="258"/>

 </graphics>

 </place>

 <transition id="t1">

 <name>

 <text>t1</text>

 <graphics>

 <offset page="1" x="20" y="0"/>

 </graphics>

 <value>t1</value>

 </name>

 <graphics>

 <position page="1" x="192" y="257"/>

 </graphics>

 </transition>

 <transition id="t2">

 <name>

 <text>t2</text>

 <graphics>

 <offset page="1" x="20" y="0"/>

 </graphics>

 <value>t2</value>

 </name>

 <graphics>

 <position page="1" x="334" y="258"/>

 </graphics>

 </transition>

 <transition id="t3">

 <name>

 <text>t3</text>

 <graphics>

 <offset page="1" x="20" y="0"/>

 </graphics>

 <value>t2</value>

 </name>

 <graphics>

 <position page="1" x="122" y="175"/>

 </graphics>

 </transition>

 <transition id="t4">

 <name>

 <text>t4</text>

 <graphics>

 <offset page="1" x="20" y="0"/>

 </graphics>

 <value>t2</value>

 </name>

 <graphics>

 <position page="1" x="262" y="175"/>

 </graphics>

 </transition>

 <arc id="a1" source="p1" target="t1">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0"/>

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="157" y="257"/>

 </graphics>

 </arc>

 <arc id="a2" source="t1" target="p2">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0"/>

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="227" y="258"/>

 </graphics>

 </arc>

 <arc id="a5" source="p2" target="t2">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0"/>

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="298" y="258"/>

 </graphics>

 </arc>

 <arc id="a7" source="t2" target="p2">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0"/>

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="290" y="200"/>

 </graphics>

 </arc>

 <arc id="a8" source="p2" target="t4">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0"/>

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="262" y="200"/>

 </graphics>

 </arc>

 <arc id="a9" source="t4" target="p1">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0"/>

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="222" y="200"/>

 </graphics>

 </arc>

 <arc id="a10" source="p1" target="t3">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0"/>

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="130" y="200"/>

 </graphics>

 </arc>

 <arc id="a11" source="t3" target="p1">

 <inscription>

 <graphics>

 <offset page="1" x="10" y="0"/>

 </graphics>

 <value> </value>

 </inscription>

 <graphics>

 <position page="1" x="110" y="200"/>

 </graphics>

 </arc>

 <firingRule>

 <value> </value>

 </firingRule>

 <name>

 <value>unnamed</value>

 </name>

 <transition id="t1\_1"><graphics><position page="1" x="192" y="322"/></graphics><name><text>t1\_1</text></name></transition><arc id="aSCin\_1" source="p1" target="t1\_1"><graphics/></arc><arc id="aSCout\_1" source="t1\_1" target="p2"><graphics/></arc><transition id="t1\_2"><graphics><position page="1" x="192" y="387"/></graphics><name><text>t1\_2</text></name></transition><arc id="aSCin\_2" source="p1" target="t1\_2"><graphics/></arc><arc id="aSCout\_2" source="t1\_2" target="p2"><graphics/></arc></net>

</pnml>

Listing III: expandPnml.java

/\*

 \* CS2310 Exercise 4v2c

 \*

 \* References -- This program is derived from these examples:

 \* http://totheriver.com/learn/xml/code/DomParserExample.java

 \* "Writing Out a DOM as an XML File" http://docs.oracle.com/javaee/1.4/tutorial/doc/JAXPXSLT4.html

 \*

 \* This program, expandPnml, adds transitions in parallel to a supercomponent transition to convert

 \* expand that supercomponent into its components.

 \*

 \*/

import java.io.IOException;

import java.util.ArrayList;

import java.util.Iterator;

import java.util.List;

import javax.xml.parsers.DocumentBuilder;

import javax.xml.parsers.DocumentBuilderFactory;

import javax.xml.parsers.ParserConfigurationException;

import org.w3c.dom.Document;

import org.w3c.dom.Element;

import org.w3c.dom.NodeList;

import org.w3c.dom.Node;

import org.w3c.dom.NamedNodeMap;

import org.w3c.dom.Attr;

import org.xml.sax.SAXException;

// For write operation

import javax.xml.transform.Transformer;

import javax.xml.transform.TransformerFactory;

import javax.xml.transform.TransformerException;

import javax.xml.transform.TransformerConfigurationException;

import javax.xml.transform.dom.DOMSource;

import javax.xml.transform.stream.StreamResult;

//import java.io.\*;

public class expandPnml {

 //No generics

 List myEmpls;

 Document dom;

 Document domOut;

 String scSource = "not found";

 String scTarget = "not found";

 int scX = 0; // graphical position

 int scY = 0;

 final String superComponent = "t1";

 private void parseTransitions(){

 //get the root element

 Element docEle = dom.getDocumentElement();

 //get a nodelist of <transitions> elements

 NodeList nl = docEle.getElementsByTagName("transition");

 if(nl != null && nl.getLength() > 0) {

 for(int i = 0 ; i < nl.getLength();i++) {

 Element arcEl = (Element)nl.item(i);

 String id = arcEl.getAttribute("id");

 if (id.equals(superComponent)) { //get position

 Element scEle = (Element) nl.item(i);

 NodeList positionNl = scEle.getElementsByTagName("position");

 Element posEl = (Element)positionNl.item(0);

 scX = Integer.parseInt(posEl.getAttribute("x"));

 scY = Integer.parseInt(posEl.getAttribute("y"));

 }

 }

 }

 }

 private void parseArcs(){

 //get the root element

 Element docEle = dom.getDocumentElement();

 //get a nodelist of <transitions> elements

 NodeList nl = docEle.getElementsByTagName("arc");

 if(nl != null && nl.getLength() > 0) {

 for(int i = 0 ; i < nl.getLength();i++) {

 Element arcEl = (Element)nl.item(i);

 String source = arcEl.getAttribute("source");

 String target = arcEl.getAttribute("target");

 if (target.equals(superComponent)) scSource = source;

 if (source.equals(superComponent)) scTarget = target;

 }

 }

 }

 public void addParallelTransitions(int n){

 //get parent node of the supercomponent //note: assume it's "page"

 Element docEle = dom.getDocumentElement();

 NodeList nl = docEle.getElementsByTagName("net");

 Element pageEl = (Element)nl.item(0);

 final int Y\_OFFSET = 65;

 for (int i=1; i<n+1; i++) {

 // add transition

 Element transition = dom.createElement("transition");

 pageEl.appendChild(transition);

 Attr attr = dom.createAttribute("id");

 attr.setValue(superComponent + "\_" + i);

 transition.setAttributeNode(attr);

 Element graphics = dom.createElement("graphics");

 transition.appendChild(graphics);

 Element position = dom.createElement("position");

 graphics.appendChild(position);

 position.setAttribute("page", "1");

 position.setAttribute("x", scX+"");

 position.setAttribute("y", scY+i\*Y\_OFFSET+"");

 Element name = dom.createElement("name");

 transition.appendChild(name);

 Element text = dom.createElement("text");

 text.setTextContent(superComponent+"\_"+i);

 name.appendChild(text);

 transition.appendChild(name);

 // add sourcing arc

 Element arc = dom.createElement("arc");

 pageEl.appendChild(arc);

 // set attributes of new arc element

 attr = dom.createAttribute("id");

 attr.setValue("aSCin\_" + i);

 arc.setAttributeNode(attr);

 attr = dom.createAttribute("source");

 attr.setValue(scSource);

 arc.setAttributeNode(attr);

 attr = dom.createAttribute("target");

 attr.setValue(superComponent + "\_" + i);

 arc.setAttributeNode(attr);

 graphics = dom.createElement("graphics");

 arc.appendChild(graphics);

 position = dom.createElement("position");

 //graphics.appendChild(position);

 position.setAttribute("page", "1");

 position.setAttribute("x", scX-50+"");

 position.setAttribute("y", scY+i\*Y\_OFFSET+"");

 // add leaving arc

 arc = dom.createElement("arc");

 pageEl.appendChild(arc);

 // set attributes of new arc element

 attr = dom.createAttribute("id");

 attr.setValue("aSCout\_" + i);

 arc.setAttributeNode(attr);

 attr = dom.createAttribute("source");

 attr.setValue(superComponent + "\_" + i);

 arc.setAttributeNode(attr);

 attr = dom.createAttribute("target");

 attr.setValue(scTarget);

 arc.setAttributeNode(attr);

 graphics = dom.createElement("graphics");

 arc.appendChild(graphics);

 position = dom.createElement("position");

 //graphics.appendChild(position);

 position.setAttribute("page", "1");

 position.setAttribute("x", scX+50+"");

 position.setAttribute("y", scY+i\*Y\_OFFSET+"");

 }

 }

 public expandPnml(){

 //create a list to hold the employee objects

 myEmpls = new ArrayList();

 }

 public void expand() {

 //parse the xml file and get the dom object

 parseXmlFile();

 parseArcs();

 parseTransitions();

 addParallelTransitions(2);

 printData();

 }

 private void parseXmlFile(){

 //get the factory

 DocumentBuilderFactory dbf = DocumentBuilderFactory.newInstance();

 try {

 //Using factory get an instance of document builder

 DocumentBuilder db = dbf.newDocumentBuilder();

 //parse using builder to get dom representation of the XML file

 dom = db.parse("orig3.pnml");

 }catch(ParserConfigurationException pce) {

 pce.printStackTrace();

 }catch(SAXException se) {

 se.printStackTrace();

 }catch(IOException ioe) {

 ioe.printStackTrace();

 }

 }

 private class Transition{

 String t\_id;

 //============ Constructor

 public Transition(String id) {

 t\_id = id;

 }

 }

 /\*\*

 \* Iterate through the list and print the

 \* content to console

 \*/

 private void printData(){

 // The source of this snippet is from oracle

 // Use a Transformer for output

 // Reference for this section: "Writing Out a DOM as an XML File" http://docs.oracle.com/javaee/1.4/tutorial/doc/JAXPXSLT4.html

 try {

 TransformerFactory tFactory = TransformerFactory.newInstance();

 Transformer transformer = tFactory.newTransformer();

 DOMSource source = new DOMSource(dom);

 StreamResult result = new StreamResult(System.out);

 transformer.transform(source, result);

 }

 catch (TransformerConfigurationException tce) {

 System.out.println("tce " + tce.getMessage());

 } catch (TransformerException te) {

 System.out.println("te " + te.getMessage());

 }

 }

 public static void main(String[] args){

 //create an instance

 expandPnml pnmlExpander = new expandPnml();

 pnmlExpander.expand();

 }

}

**Acknowledgments/References**

The source of pnml-to-image program, PNML Viewer, was <http://www.vanwal.nl/pnmlview/>

The pnml expander was derived from these XML coding examples:

 \* http://totheriver.com/learn/xml/code/DomParserExample.java

 \* "Writing Out a DOM as an XML File" http://docs.oracle.com/javaee/1.4/tutorial/doc/JAXPXSLT4.html