Modeling Geometry with Assemblies in SysML *

May 16, 2014

Abstract

In this module a preliminary concept implementation is provided for the possible introduction of a novel kind of 3D diagram in SysML. Such "Assembly" Diagram in used to specify an operable description of the 3D geometry of a system part.

Contents

*This document is part of the *Linear Algebraic Representation with CoChains* (LAR-CC) framework [CL13]. May 16, 2014

1 Introduction

1.1 bbbbbbbb

2 Implementation

2.1 Diagram initialization

Uniform cell sizing A cuboidal 3-complex is generated by the script below, where the cells have uniform dimension on each coordinate direction.

⟨ Diagram initialization 1 ⟩ ≡

```
""" Diagram initialization """
def assemblyDiagramInit(shape):
   print "\n shape =",shape
   # shape must be 3D, i.e. a python array with 3 indices
   assert len(shape) == 3
   diagram = larCuboids(shape)
   return diagram
◇
```

Macro never referenced.

Non-uniform cell sizing The parameter `quoteList` is used here to generate the new vertices of the `diagram`, previously generated with uniform spacing between the cell vertices in every coordinate direction. Each `pattern` in `quoteList` is a list of positive numbers, each corresponding to the size of the corresponding "coordinate stripe".

⟨ Diagram initialization (non-uniform sizing) 2a ⟩ ≡

```
""" Diagram initialization """
def assemblyDiagramInit (shape):
   def assemblyDiagram (quoteList):
      print "\n shape =",shape
      # shape and quoteList must be 3D, i.e. a python array with 3 indices
      assert (len(shape) == 3) and (len(quoteList) == 3)
      coordList = [list(cumsum([0]+pattern)) for pattern in quoteList]
      verts = CART(coordList)
      _,CV = larCuboids(shape)
      return verts,CV
   return assemblyDiagram
◇
```

Macro referenced in 5a.

Diagram scaling to cuboid of given size The `size` parameter is the array of lateral dimensions to which to scale the `diagram` parameter. `size` must be an array of 3 numbers; `diagram` is a LAR model

⟨ Diagram scaling to sized cuboid 2b ⟩ ≡

```
""" Diagram scaling to given size """
def unitDiagram(diagram, size=[1,1,1]):
   V,CV = diagram
   print "\n shape =",shape
   # size must be a python array with 3 numbers
   assert (len(size) == 3) and (AND(AA(ISNUM)(size)) == True)
   V_ = array(V) / AA(float)(max(V))
   V = (V_ * size).tolist()
   diagram = V,CV
   return diagram
```

◇

Macro referenced in 5a.

2.2 Cell numbering

Drawing numbers of cells

⟨ Drawing numbers of cells 2c ⟩ ≡

```
""" Drawing numbers of cells """
def cellNumbering (larModel,hpcModel):
   V,CV = larModel
   def cellNumbering0 (cellSubset,color=WHITE,scalingFactor=1):
      text = TEXTWITHATTRIBUTES (TEXTALIGNMENT='centre', TEXTANGLE=0,
                     TEXTWIDTH=0.1*scalingFactor,
                     TEXTHEIGHT=0.2*scalingFactor,
                     TEXTSPACING=0.025*scalingFactor)
      hpcList = [hpcModel]
      for cell in cellSubset:
         point = CCOMB([V[v] for v in CV[cell]])
         hpcList.append(T([1,2,3])(point)(COLOR(color)(text(str(cell)))))
      return STRUCT(hpcList)
   return cellNumbering0
```

◇

Macro referenced in 5a.

2.3 Diagram segmentation

Boundary cells ($3D \to 2D$) computation The computations of boundary cells is executed by calling the `boundaryCells` from the `larcc` module.

⟨ Boundary cells ($3D \to 2D$) computation 3a ⟩ ≡

```
def lar2boundaryFaces(CV,FV):
   """ Boundary cells computation """
   return boundaryCells(CV,FV)
◇
```

Macro referenced in 5a.

Interior partitions ($3D \to 2D$) computation The indices of the boundary 2-cells are returned in `boundarychain2D`, and subtracted from the set $\{0, 1, \ldots, |E| - 1\}$ in order to return the indices of the `interiorCells`.

⟨ Interior partitions ($3D \to 2D$) computation 3b ⟩ ≡

```
def lar2InteriorFaces(CV,FV):
   """ Boundary cells computation """
   boundarychain2D = boundaryCells(CV,FV)
   totalChain2D = range(len(FV))
   interiorCells = set(totalChain2D).difference(boundarychain2D)
   return interiorCells
◇
```

Macro referenced in 5a.

2.4 Subdiagram mapping

The aim of this section is to allow for separate development of subdiagrams of a geometric diagram. When satisfied with the current design situation, the developer may map a whole diagram into a single 3D cell of the upper-level diagram — in the following called the *master* diagram. Of course, such nesting may happen several times within a (father) master, producing a hierarchical decomposition (of any depth) of the geometry diagrams.

Task decomposition The procedure to map a diagram to a sub diagram is described below in a top-down manner, decomposing the task into an ordered set of subtasks.

⟨ Subdiagram to diagram mapping 4a ⟩ ≡

⟨ 3D window to viewport transformation 4b ⟩

```
def diagram2cell(diagram,master,cell):
   mat = diagram2cellMatrix(diagram)(master,cell)
   diagram =larApply(mat)(diagram)

   """
   # yet to finish coding
   V, CV1, CV2, n12 = vertexSieve(master,diagram)
   masterBoundaryFaces = boundaryOfChain(CV,FV)([cell])
   diagramBoundaryFaces = lar2boundaryFaces(CV,FV)
```

```
    """
    V = master[0] + diagram[0]
    offset = len(master[0])
    CV = [c for k,c in enumerate(master[1]) if k != cell] + [
          [v+offset for v in c] for c in diagram[1]]
    master = V, CV
    return master
```
◇

Macro referenced in 5a.

3D window to viewport transformation

⟨ 3D window to viewport transformation 4b ⟩ ≡

```
""" 3D window to viewport transformation """
def diagram2cellMatrix(diagram):
   def diagramToCellMatrix0(master,cell):
      wdw = min(diagram[0]) + max(diagram[0])         # window3D
      cV = [master[0][v] for v in master[1][cell]]
      vpt = min(cV) + max(cV)                         # viewport3D
      print "\n window3D =",wdw
      print "\n viewport3D =",vpt

      mat = zeros((4,4))
      mat[0,0] = (vpt[3]-vpt[0])/(wdw[3]-wdw[0])
      mat[0,3] = vpt[0] - mat[0,0]*wdw[0]
      mat[1,1] = (vpt[4]-vpt[1])/(wdw[4]-wdw[1])
      mat[1,3] = vpt[1] - mat[1,1]*wdw[1]
      mat[2,2] = (vpt[5]-vpt[2])/(wdw[5]-wdw[2])
      mat[2,3] = vpt[2] - mat[2,2]*wdw[2]
      mat[3,3] = 1
      print "\n mat =",mat
      return mat
   return diagramToCellMatrix0
```
◇

Macro referenced in 4a.

3 Library export

3.1 Exporting the library

"lib/py/sysml.py" 5a ≡

⟨ Initial import of modules 9b ⟩
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```
from myfont import *
```
⟨ Drawing numbers of cells 2c ⟩
⟨ Subdiagram to diagram mapping 4a ⟩
◇

4 Tests

4.1 Diagram initialization

"test/py/sysml/test01.py" 5b ≡

```
""" testing initial steps of Assembly Diagram construction """
```
⟨ Initial import of modules 9b ⟩
```
from sysml import *

shape = [1,2,2]
sizePatterns = [[1],[2,1],[0.8,0.2]]
diagram = assemblyDiagramInit(shape)(sizePatterns)
print "\n diagram =",diagram
VIEW(SKEL_1(STRUCT(MKPOLS(diagram))))

VV,EV,FV,CV = gridSkeletons(shape)
boundaryFaces = lar2boundaryFaces(CV,FV)
interiorFaces = list(set(range(len(FV))).difference(boundaryFaces))
print "\n boundary faces =",boundaryFaces
print "\n interior faces =",interiorFaces
diagram1 = unitDiagram(diagram)
VIEW(SKEL_1(STRUCT(MKPOLS(diagram1))))

hpc = SKEL_1(STRUCT(MKPOLS(diagram1)))
V = diagram1[0]
hpc = cellNumbering ((V,FV),hpc)(interiorFaces,YELLOW,.5)
VIEW(hpc)
hpc = cellNumbering ((V,EV),hpc)([for f in interiorFaces],GREEN,.4)
VIEW(hpc)
hpc = cellNumbering ((V,VV),hpc)(range(len(VV)),RED,.3)
VIEW(hpc)
```

◇

4.2 Diagram merging

"test/py/sysml/test02.py" 6a ≡

```
""" definition and merging of two diagrams into a single diagram """
```
⟨ Initial import of modules 9b ⟩

```
from sysml import *

master = assemblyDiagramInit([2,2,2])([[.4,.6],[.4,.6],[.4,.6]])
diagram = assemblyDiagramInit([3,3,3])([[.4,.2,.4],[.4,.2,.4],[.4,.2,.4]])
VIEW(SKEL_1(STRUCT([DRAW(master),T(2)(1),DRAW(diagram)])))

hpc = SKEL_1(STRUCT(MKPOLS(master)))
hpc = cellNumbering (master,hpc)(range(len(master[1])),WHITE,.5)
VIEW(hpc)

master = diagram2cell(diagram,master,7)
VIEW(SKEL_1(STRUCT( MKPOLS(master) )))

◇
```

4.3 Diagram visualization

"test/py/sysml/test03.py" 6b ≡

```
""" definition and merging of two diagrams into a single diagram """
⟨Initial import of modules 9b⟩
from sysml import *

master = assemblyDiagramInit([2,2,2])([[.4,.6],[.4,.6],[.4,.6]])
diagram = assemblyDiagramInit([3,3,3])([[.4,.2,.4],[.4,.2,.4],[.4,.2,.4]])

VV,EV,FV,CV = gridSkeletons([2,2,2])
V,CV = master
hpc = SKEL_1(STRUCT(MKPOLS(master)))
hpc = cellNumbering (master,hpc)(range(len(CV)),CYAN,.5)
VIEW(hpc)

master = diagram2cell(diagram,master,7)
VIEW(SKEL_1(STRUCT( MKPOLS(master) )))

VIEW(EXPLODE(1.5,1.5,1.5)(MKPOLS(larFacets(master))))

masterBoundaryFaces = boundaryOfChain(CV,FV)([7])
diagramBoundaryFaces = lar2boundaryFaces(CV,FV)
◇
```

progressive refinement of a block diagram In this example, a step-by step generation of a simple apartment is produced, using `assemblyDiagramInit` to produce a block diagram of given `shape` and `size`, the `cellNumbering` function to generate an *hpc* value with the numbers of 3-cells in the current "master" diagram, the `diagram2cell` function to map and merge a `diagram` into a `cell` of the `master`.

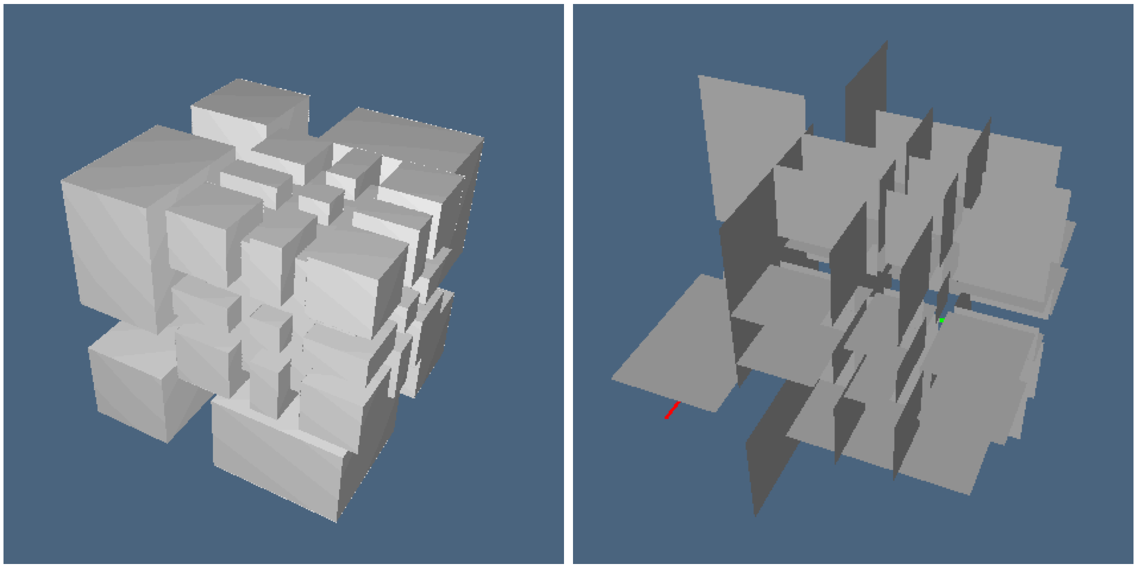

Figure 1: Example of a geometry diagram merged in a master diagram

Remember that in `lar-cc` the numbering of cells in a model is 0-based (like in python). Conversely, in `pyplasm` the numbering of cells (for example of vertex indices in `MKPOL`) is 1-based, like in Fortran or MATLAB.

"test/py/sysml/test04.py" 8 ≡

```
""" progressive refinement of a block diagram """
⟨Initial import of modules 9b⟩
from sysml import *
DRAW = COMP([VIEW,STRUCT,MKPOLS])

master = assemblyDiagramInit([5,5,2])([[.3,3.2,.1,5,.3],[.3,4,.1,2.9,.3],[.3,2.7]])
V,CV = master
hpc = SKEL_1(STRUCT(MKPOLS(master)))
hpc = cellNumbering (master,hpc)(range(len(CV)),CYAN,2)
VIEW(hpc)

toRemove = [13,33,17,37]
master = V,[cell for k,cell in enumerate(CV) if not (k in toRemove)]
DRAW(master)

hpc = SKEL_1(STRUCT(MKPOLS(master)))
hpc = cellNumbering (master,hpc)(range(len(master[1])),CYAN,2)
VIEW(hpc)

toMerge = 29
```

```
cell = MKPOL([master[0],[[v+1 for v in  master[1][toMerge]]],None])
VIEW(STRUCT([hpc,cell]))

diagram = assemblyDiagramInit([3,1,2])([[2,1,2],[.3],[2.2,.5]])
master = diagram2cell(diagram,master,toMerge)
hpc = SKEL_1(STRUCT(MKPOLS(master)))
hpc = cellNumbering (master,hpc)(range(len(master[1])),CYAN,2)
VIEW(hpc)

toRemove = [47]
master = master[0], [cell for k,cell in enumerate(master[1]) if not (k in toRemove)]
DRAW(master)

hpc = SKEL_1(STRUCT(MKPOLS(master)))
hpc = cellNumbering (master,hpc)(range(len(master[1])),CYAN,2)
VIEW(hpc)

toMerge = 34
cell = MKPOL([master[0],[[v+1 for v in  master[1][toMerge]]],None])
VIEW(STRUCT([hpc,cell]))

diagram = assemblyDiagramInit([5,1,3])([[1.5,0.9,.2,.9,1.5],[.3],[1,1.4,.3]])
master = diagram2cell(diagram,master,toMerge)
hpc = SKEL_1(STRUCT(MKPOLS(master)))
hpc = cellNumbering (master,hpc)(range(len(master[1])),CYAN,2)
VIEW(hpc)

toRemove = [53,59]
master = master[0], [cell for k,cell in enumerate(master[1]) if not (k in toRemove)]
DRAW(master)
```
◇

A Utilities

⟨To compute the boundary (d-1)-chain of a given d-chain 9a⟩ ≡

```
def boundaryOfChain(cells,facets):
   csrBoundaryMat = boundary(cells,facets)
   csrChain = zeros((len(cells),1))
   def boundaryOfChain0(chain):
      for cell in chain:  csrChain[cell,0]=1.0
      csrBoundaryChain = matrixProduct(csrBoundaryMat, csrChain)
      boundaryCells = [k for k,val in enumerate(csrBoundaryChain.tolist())
                       if val == [1.0]]
      return boundaryCells
   return boundaryOfChain0
```

◇

Macro referenced in 5a.

A.1 Initial import of modules

Initial import of modules

⟨ Initial import of modules 9b ⟩ ≡

```
from pyplasm import *
from scipy import *
import os,sys
""" import modules from larcc/lib """
sys.path.insert(0, 'lib/py/')
from lar2psm import *
from simplexn import *
from larcc import *
from largrid import *
from mapper import *
from boolean import *
◇
```

Macro referenced in 5ab, 6ab, 8.

References

[CL13] CVD-Lab, *Linear algebraic representation*, Tech. Report 13-00, Roma Tre University, October 2013.