CS30800
Introduction to Computer Graphics
Lab 5 – Scene Graph

2025. 04. 08/ 2025. 04. 10

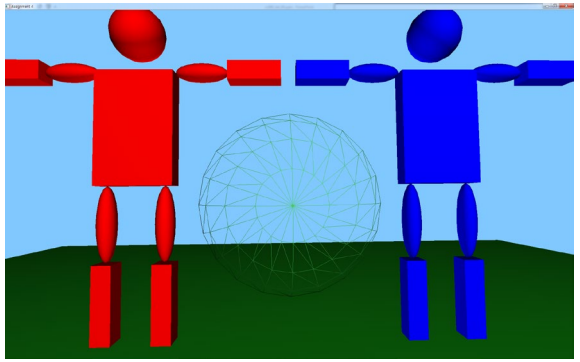
Note

- You would be better to get familiar with the following concepts to complete this assignment:
  - Class
  - Vector (stl)
  - Pointer

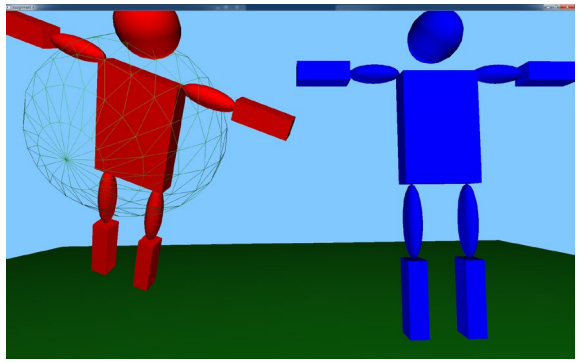
- There are many classes and functions in this homework, **so please read the description (pdf and code) in advance**, and start to do some coding.

Goals

- Scene graph
  - Build a structure for dealing with objects in a smart way



- Picking
  - Implement user manipulation code



- **Note that you have to read the description file (pdf) and the detailed description in the code thoroughly**

Code Migration

- In this project, asst4 is based on your asst3.
  - You should finish previous homework before start.

- Make the copy of asst3 project (named asst4) and add asst4.zip file into your new project.

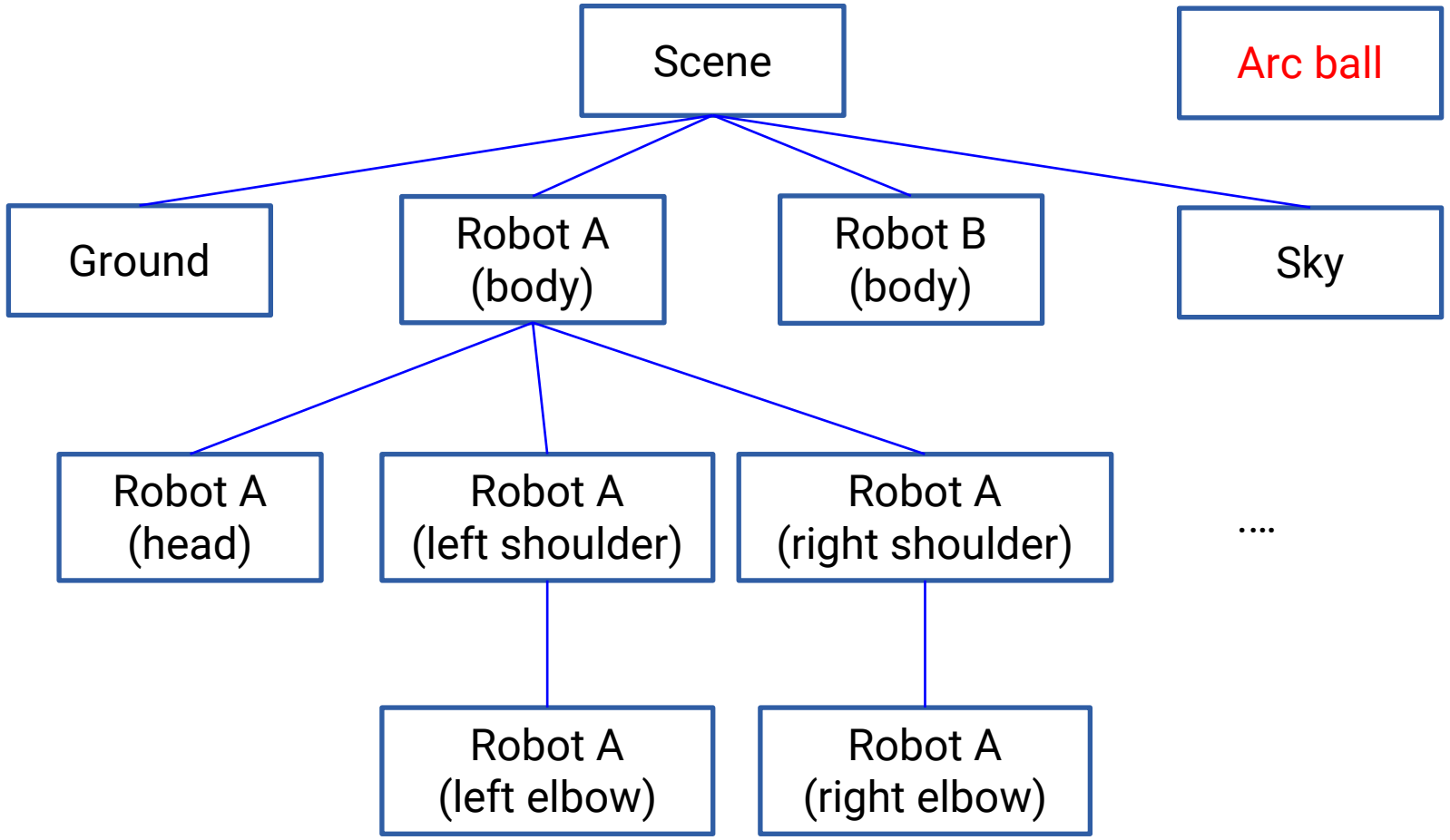
- Change the existing **Visual Studio project** or **MakeFile** to build the project

Code Migration

- ‘asst4-snippets.cpp’ can help you for modifying your asst4.cpp code
  - Construct the scene graph
  - Draw the scene graph

Scene Graph

- Whole scene = 1 tree structure



Scene Graph

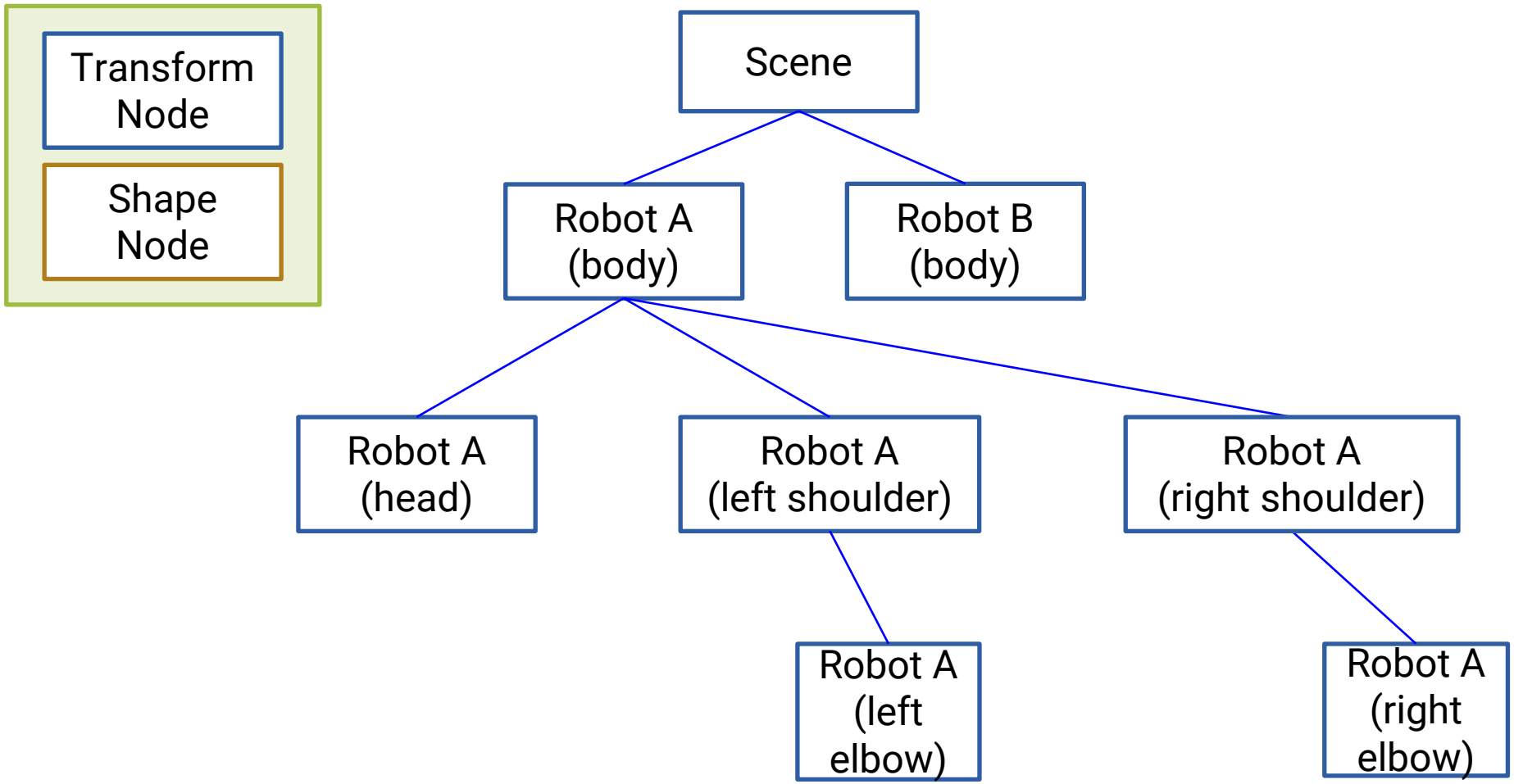
- Two kinds of nodes on scene graph
  - Transform nodes
    - RBT with respect to its parent frame

$$\begin{aligned} \vec{\mathbf{o}}^t &= \vec{\mathbf{w}}^t O \\ \vec{\mathbf{s}}^t &= \vec{\mathbf{o}}^t S \\ \vec{\mathbf{l}}^t &= \vec{\mathbf{s}}^t L \end{aligned}$$

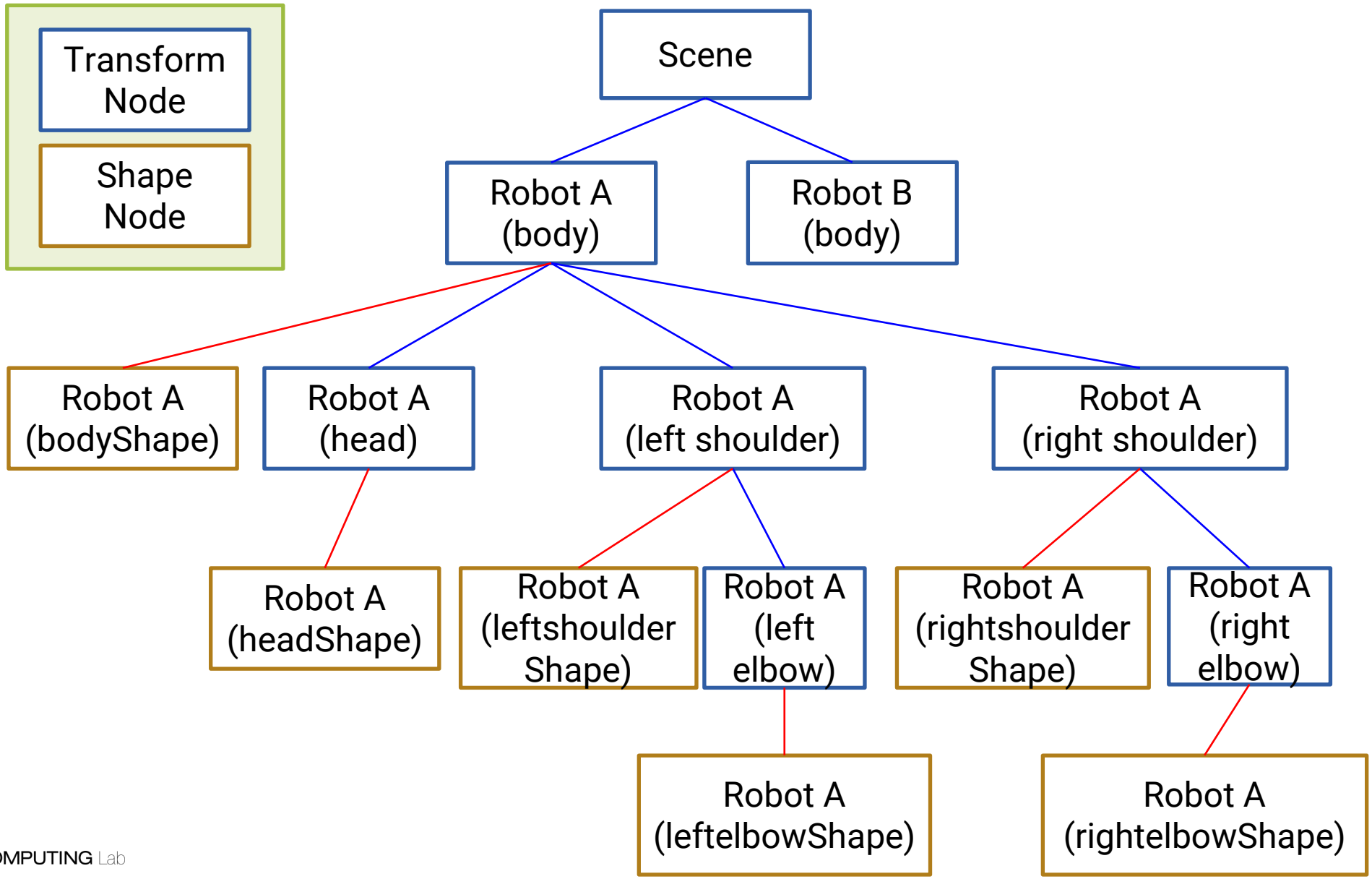
  - Shape nodes
    - Matrix4 (AffineMatrix) : geometry to be drawn

$$\vec{\mathbf{b}}^t = \vec{\mathbf{l}}^t B = \vec{\mathbf{l}}^t \cdot \mathrm{Trans} \cdot \mathrm{Scale}$$

Scene Graph

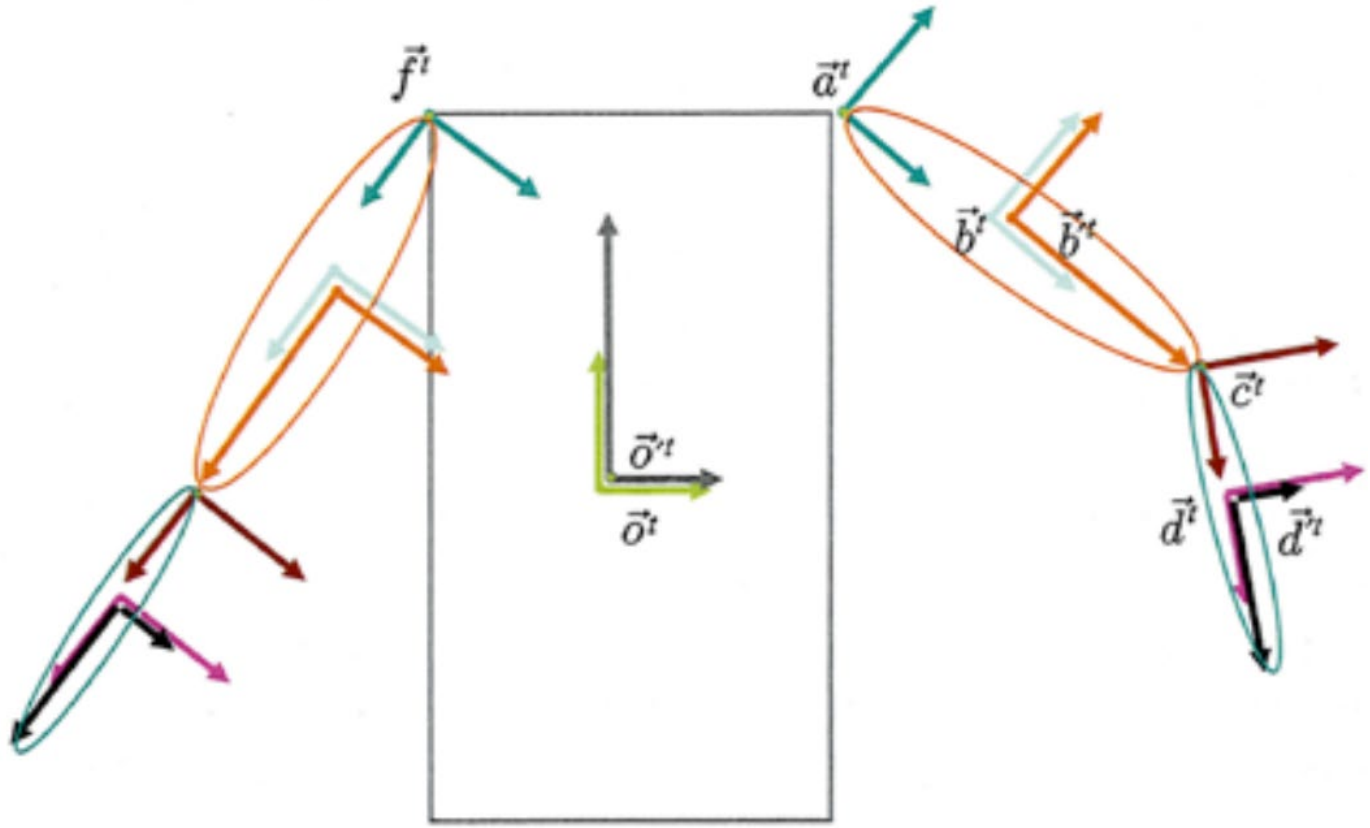

Transform Node
Shape Node
Scene
Robot A (body)
Robot B (body)
Robot A (head)
Robot A (left shoulder)
Robot A (right shoulder)
Robot A (left elbow)
Robot A (right elbow)

Scene Graph


Transform Node
Shape Node
Scene
Robot A (body)
Robot B (body)
Robot A (bodyShape)
Robot A (head)
Robot A (left shoulder)
Robot A (right shoulder)
Robot A (headShape)
Robot A (leftshoulder Shape)
Robot A (left elbow)
Robot A (rightshoulder Shape)
Robot A (right elbow)
Robot A (leftelbowShape)
Robot A (rightelbowShape)

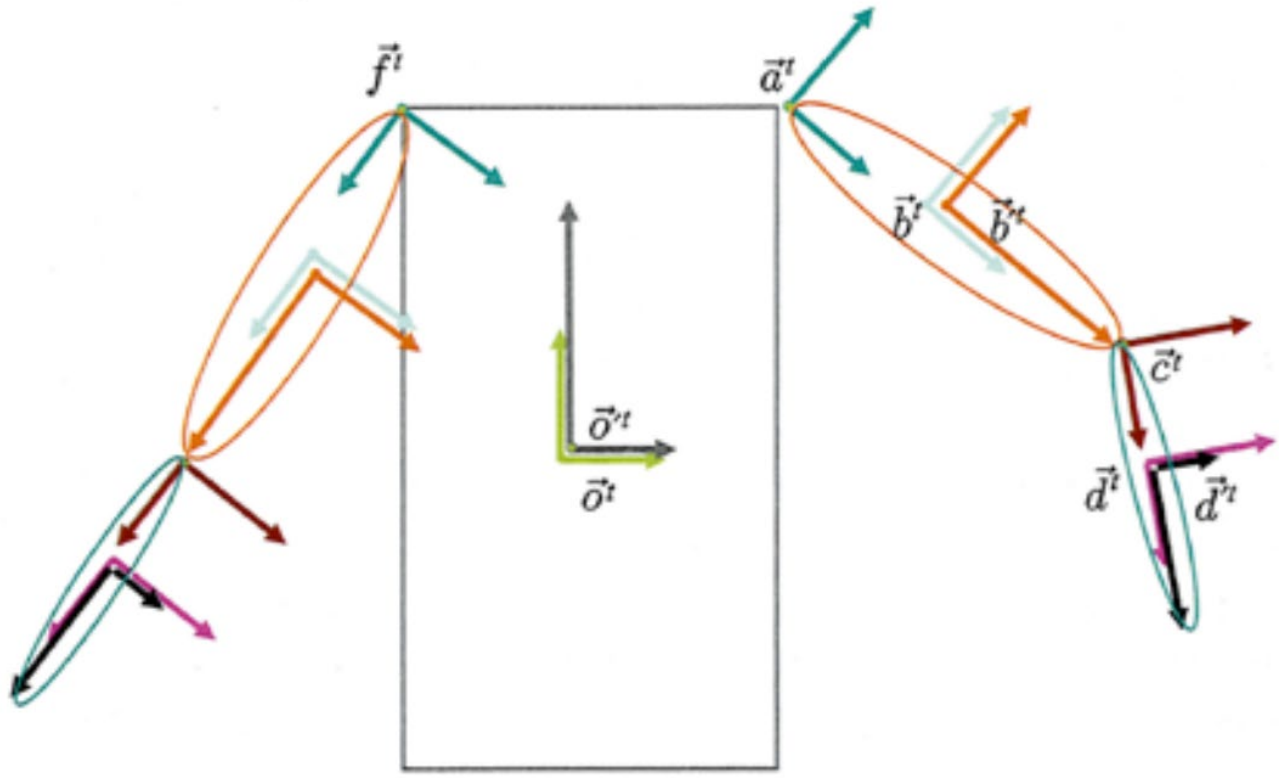
Scene Graph

- If we move the body of the robot, the connected components should be modified automatically.



Scene Graph

- In order to build it, we describe an object frame with the previous object frame, not the world frame.



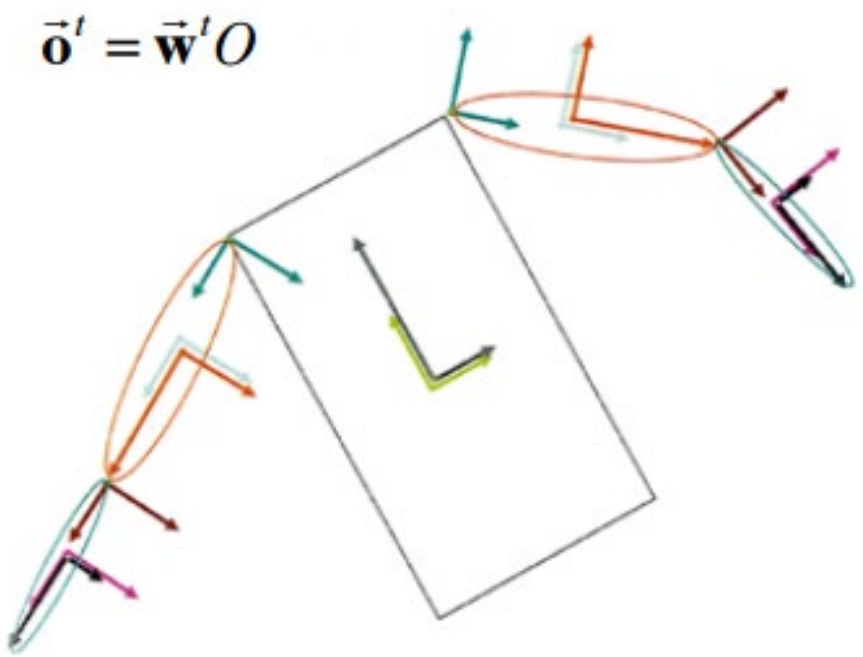
$$\vec{d}'^t c_{d'} = \vec{w}^t OABCDD'c_{d'}$$

$$\vec{\mathbf{o}}^t = \vec{\mathbf{w}}^t O$$
$$\vec{\mathbf{o}}'^t = \vec{\mathbf{o}}^t O'$$
$$\vec{\mathbf{a}}^t = \vec{\mathbf{o}}^t A$$
$$\vec{\mathbf{b}}^t = \vec{\mathbf{a}}^t B$$
$$\vec{\mathbf{b}}'^t = \vec{\mathbf{b}}^t B'$$
$$\vec{\mathbf{c}}^t = \vec{\mathbf{b}}^t C$$
$$\vec{\mathbf{d}}^t = \vec{\mathbf{c}}^t D$$
$$\vec{\mathbf{d}}'^t = \vec{\mathbf{d}}^t D'$$
$$\vec{\mathbf{f}}^t = \vec{\mathbf{o}}^t F$$

11

Scene Graph

- Other parts would be changed following the scene graph when we modify the object frame $\vec{\mathbf{o}}^t = \vec{\mathbf{w}}^t O$.



$$\vec{\mathbf{o}}^t = \vec{\mathbf{w}}^t O$$
$$\vec{\mathbf{o}}'^t = \vec{\mathbf{o}}^t O'$$
$$\vec{\mathbf{a}}^t = \vec{\mathbf{o}}^t A$$
$$\vec{\mathbf{b}}^t = \vec{\mathbf{a}}^t B$$
$$\vec{\mathbf{b}}'^t = \vec{\mathbf{b}}^t B'$$
$$\vec{\mathbf{c}}^t = \vec{\mathbf{b}}^t C$$
$$\vec{\mathbf{d}}^t = \vec{\mathbf{c}}^t D$$
$$\vec{\mathbf{d}}'^t = \vec{\mathbf{d}}^t D'$$
$$\vec{\mathbf{f}}^t = \vec{\mathbf{o}}^t F$$

Visitor (SgNodeVisitor)

- Class for easy traversal on the scene graph
- We need to do various operations through the nodes of scene graph

```
class SgNodeVisitor {
public:
  virtual bool visit(SgTransformNode& node);
  virtual bool visit(SgShapeNode& node);

  virtual bool postVisit(SgTransformNode& node);
  virtual bool postVisit(SgShapeNode& node);
};
```

Visitor (SgNodeVisitor)

- There are three types of visitor
  - **Drawer**, **Picker** and **RbtAccumVisitor**
  - Each visitor has different role, variables and functions (visit( ), postVisit( ), ..)

```
class Drawer : public SgNodeVisitor {
protected:
  std::vector<RigTForm> rbtStack_;
```

```
class Picker : public SgNodeVisitor {
  std::vector<std::tr1::shared_ptr<SgNode> > nodeStack_;
```

```
class RbtAccumVisitor : public SgNodeVisitor {
protected:
    vector<RigTForm> rbtStack_;
```

accept( ) and visit( )

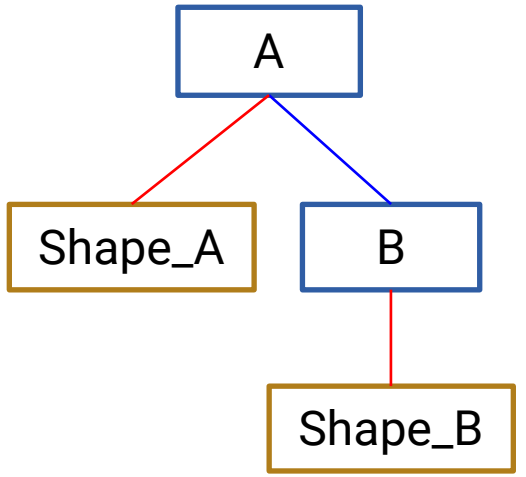
Each node has accept( )

: apply visit( ) for itself (node) and

pass the visitor to its children

node's accept() function

```
bool SgTransformNode::accept(SgNodeVisitor& visitor) {
  if (!visitor.visit(*this))
    return false;
  for (int i = 0, n = children_.size(); i < n; ++i) {
    if (!children_[i]->accept(visitor))
      return false;
  }
  return visitor.postVisit(*this);
}
```



Each visitor has visit( )

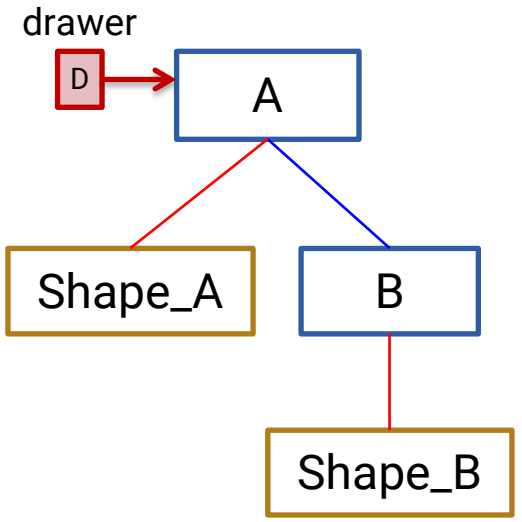
: visit( ) do some works on certain node

accept( ) and visit( ) for drawer

Example

A->accept(drawer)

Operation



drawer's visit() function

```
virtual bool visit(SgTransformNode& node) {
  rbtStack_.push_back(rbtStack_.back( ) * node.getRbt( ));
  return true;
}

virtual bool visit(SgShapeNode& shapeNode) {
  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

accept( ) and visit( ) for drawer

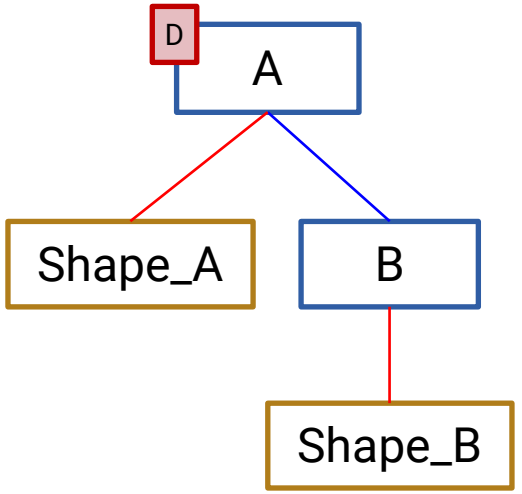
Example

A->accept(drawer)

drawer.visit(A)

Operation

Stack = {A}



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  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

accept( ) and visit( ) for drawer

Example

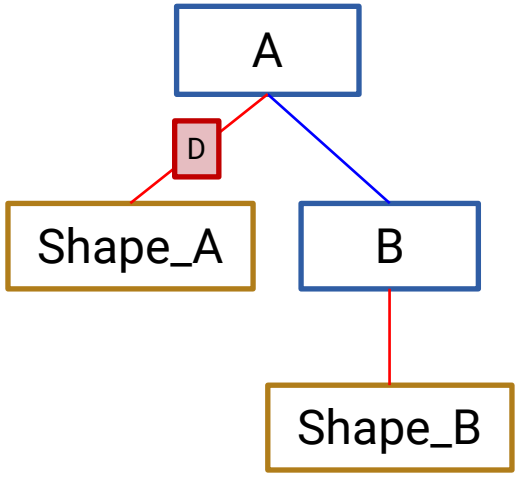
A->accept(drawer)

drawer.visit(A)

pass ‘drawer’ to Shape_A

Operation

Stack = {A}



drawer’s visit() function

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  rbtStack_.push_back(rbtStack_.back( ) * node.getRbt( ));
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}

virtual bool visit(SgShapeNode& shapeNode) {
  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

accept( ) and visit( ) for drawer

Example

A->accept(drawer)

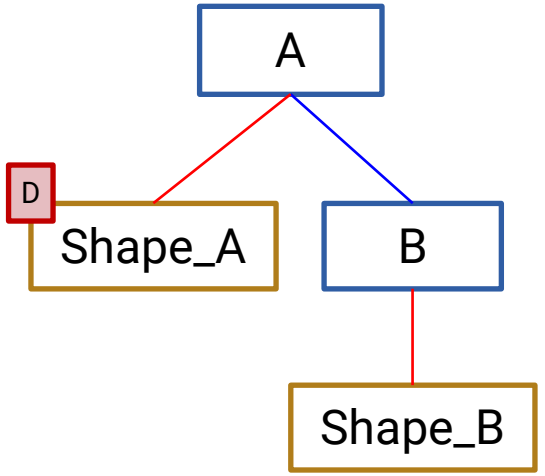
drawer.visit(A)

pass ‘drawer’ to Shape_A

drawer.visit(Shape_A)

Operation

Stack = {A}



draw{A * Shape_A}

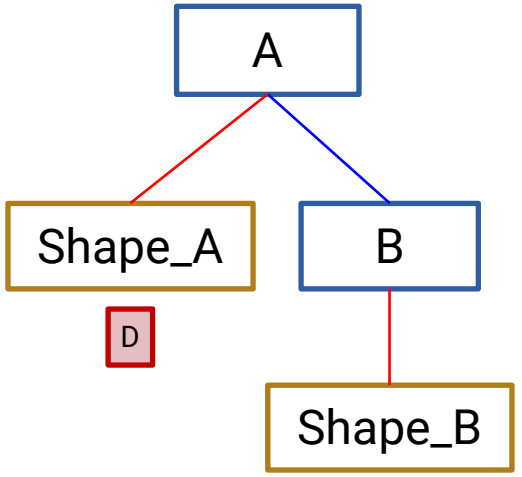
drawer’s visit() function

```
virtual bool visit(SgTransformNode& node) {
  rbtStack_.push_back(rbtStack_.back( ) * node.getRbt( ));
  return true;
}

virtual bool visit(SgShapeNode& shapeNode) {
  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

accept( ) and visit( ) for drawer

Example	Operation
A->accept(drawer)	
drawer.visit(A)	Stack = {A}
pass ‘drawer’ to Shape_A	
drawer.visit(Shape_A)	draw{A * Shape_A}
pass ‘drawer’ to no child	None, Stack = {A}



drawer’s visit() function

```
virtual bool visit(SgTransformNode& node) {
  rbtStack_.push_back(rbtStack_.back( ) * node.getRbt( ));
  return true;
}

virtual bool visit(SgShapeNode& shapeNode) {
  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

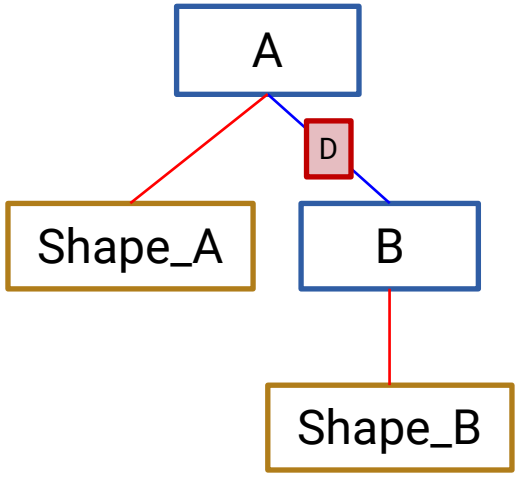
accept( ) and visit( ) for drawer

Example

pass ‘drawer’ to B

Operation

Stack = {A}



drawer’s visit() function

```
virtual bool visit(SgTransformNode& node) {
  rbtStack_.push_back(rbtStack_.back( ) * node.getRbt( ));
  return true;
}

virtual bool visit(SgShapeNode& shapeNode) {
  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

accept( ) and visit( ) for drawer

Example

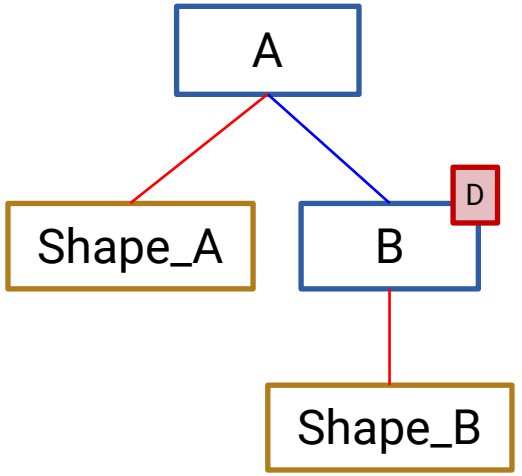
pass ‘drawer’ to B

drawer.visit(B)

Operation

Stack = {A}

Stack = {AB}



drawer’s visit() function

```
virtual bool visit(SgTransformNode& node) {
  rbtStack_.push_back(rbtStack_.back( ) * node.getRbt( ));
  return true;
}

virtual bool visit(SgShapeNode& shapeNode) {
  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

accept( ) and visit( ) for drawer

Example

pass ‘drawer’ to B

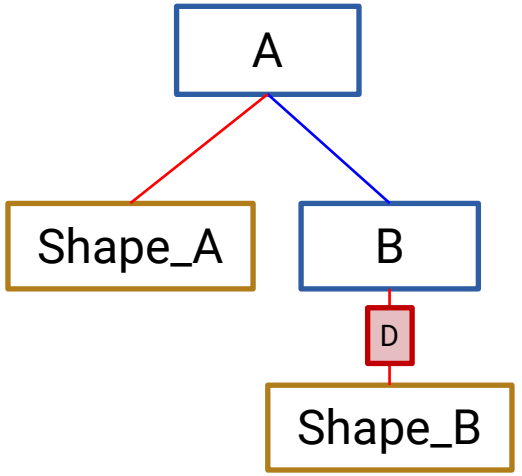
drawer.visit(B)

pass ‘drawer’ to Shape_B

Operation

Stack = {A}

Stack = {AB}



drawer’s visit() function

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virtual bool visit(SgShapeNode& shapeNode) {
  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

accept( ) and visit( ) for drawer

Example

pass ‘drawer’ to B

drawer.visit(B)

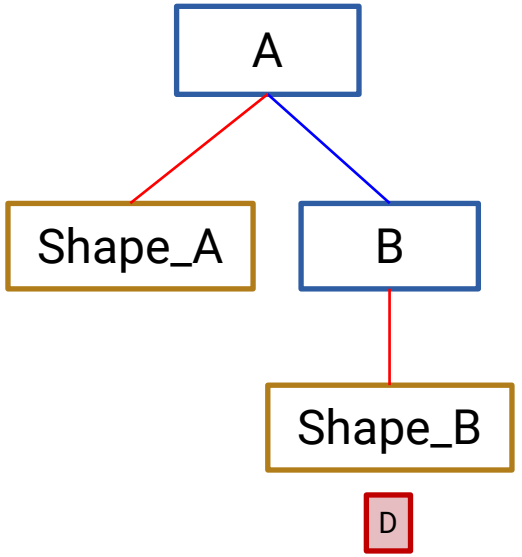
pass ‘drawer’ to Shape_B

drawer.visit(Shape_B)

Operation

Stack = {A}

Stack = {AB}



draw{AB * Shape_B}

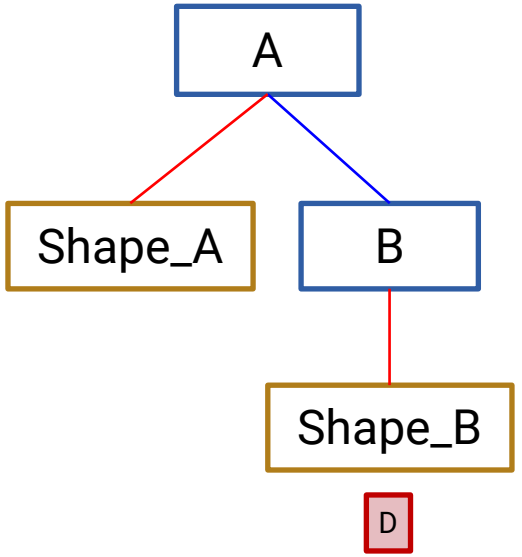
drawer’s visit() function

```
virtual bool visit(SgTransformNode& node) {
  rbtStack_.push_back(rbtStack_.back( ) * node.getRbt( ));
  return true;
}

virtual bool visit(SgShapeNode& shapeNode) {
  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

accept( ) and visit( ) for drawer

Example	Operation
pass ‘drawer’ to B	Stack = {A}
drawer.visit(B)	Stack = {AB}
pass ‘drawer’ to Shape_B	
drawer.visit(Shape_B)	draw{AB * Shape_B}
pass ‘drawer’ to no child	



drawer’s visit() function

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  const Matrix4 MVM = rigTFormToMatrix(rbtStack_.back( )) * shapeNode.getAffineMatrix( );
  sendModelViewNormalMatrix(curSS_, MVM, normalMatrix(MVM));
  shapeNode.draw(curSS_);
  return true;
}
```

Task 2. Part Picking

- If picking mode is on,
  - do not swap front buffer and back buffer
  - render the different scene on back buffer using colors defined by each object's ID.
  - Handle the h_uIdColor in shaderState using object's ID color.
  - You can query the drawer for the current ShaderState by calling its getCurSS()
  - do not shade according to light direction

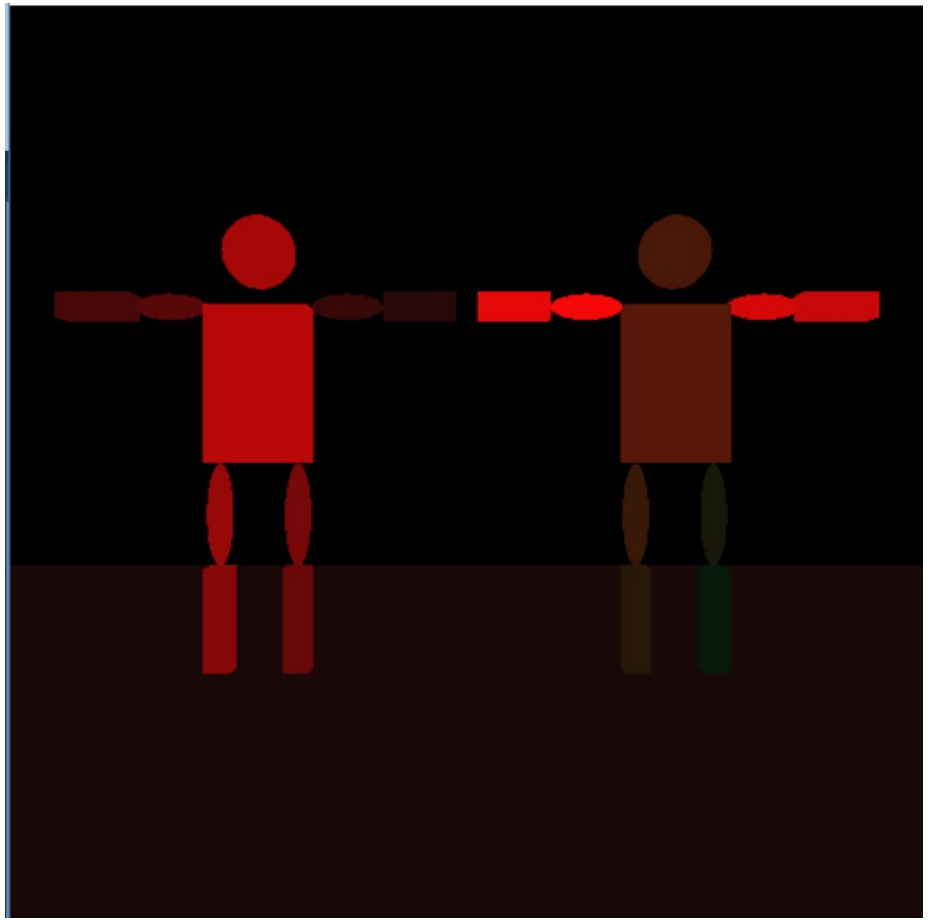
Task 2. Part Picking

- If some object is picked,
  - Using shared_ptr<SgRbtNode> q = dynamic_pointer_cast<SgRbtNode>(p);
  - SgShapeNode or SgRootNode cannot be cast to SgRbtNode.
  - you can distinguish which object is picked using back buffer's color
  - Using glReadPixels to get RGB value to find object's ID.
  - redisplay(swap) the scene and new arc ball

- Fill TODO in the Picker class

Task 2. Part Picking

- You can see the Picking screen to comment glutPostRedisplay() in mouse() and uncomment glutSwapBuffer() in pick()



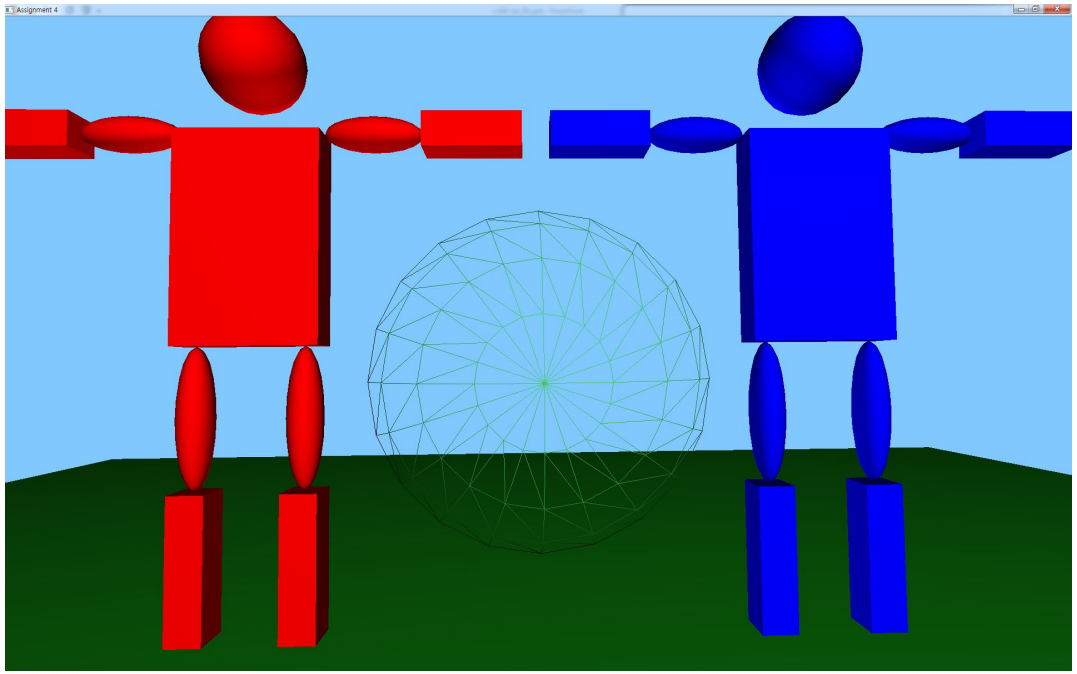
Task 3. Transform Any Part

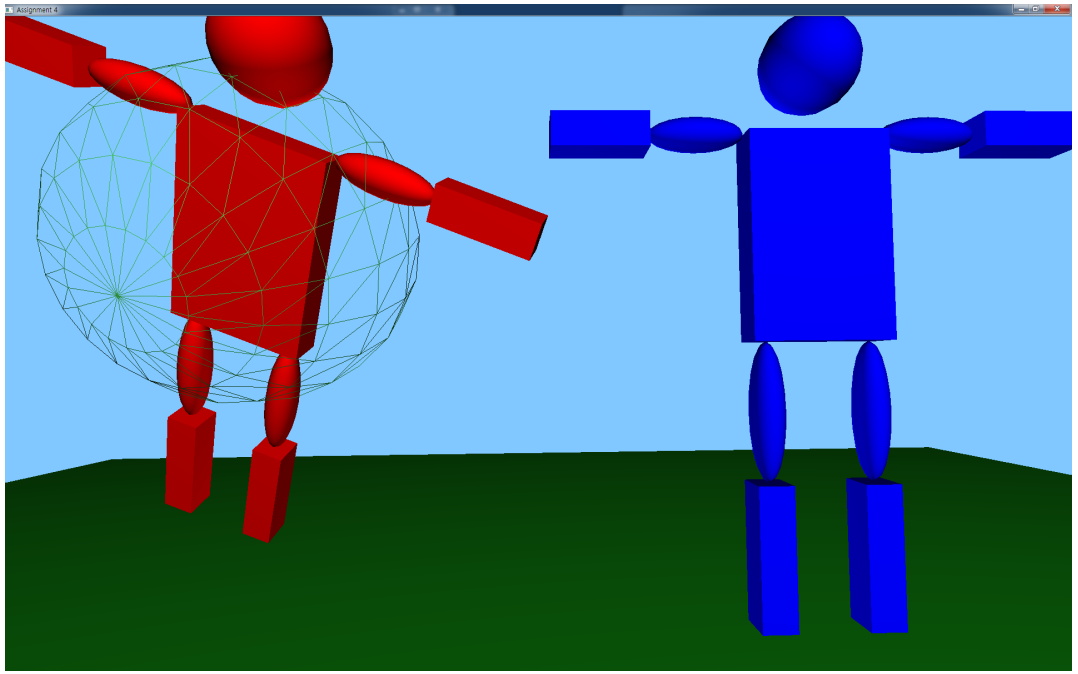
- Transform any part with keeping hierarchical structure using scene graph

- Refer to RbtAccumVisitor class

Task 4. Build the robot

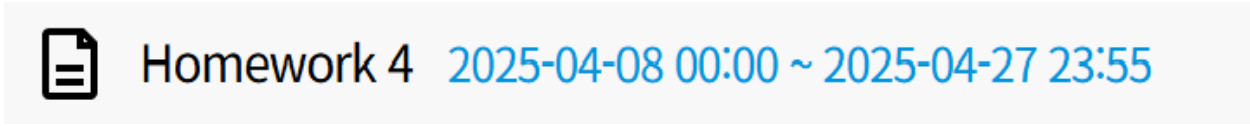
- Now, build your own robot using constructRobot().





HW4 Submission

- Homework due
  - **4/27 (SUN) 23:55**



- Submission
  - Zip your code folder and upload it on KLMS
  - Zip file name: hw4_20241234_Name.zip