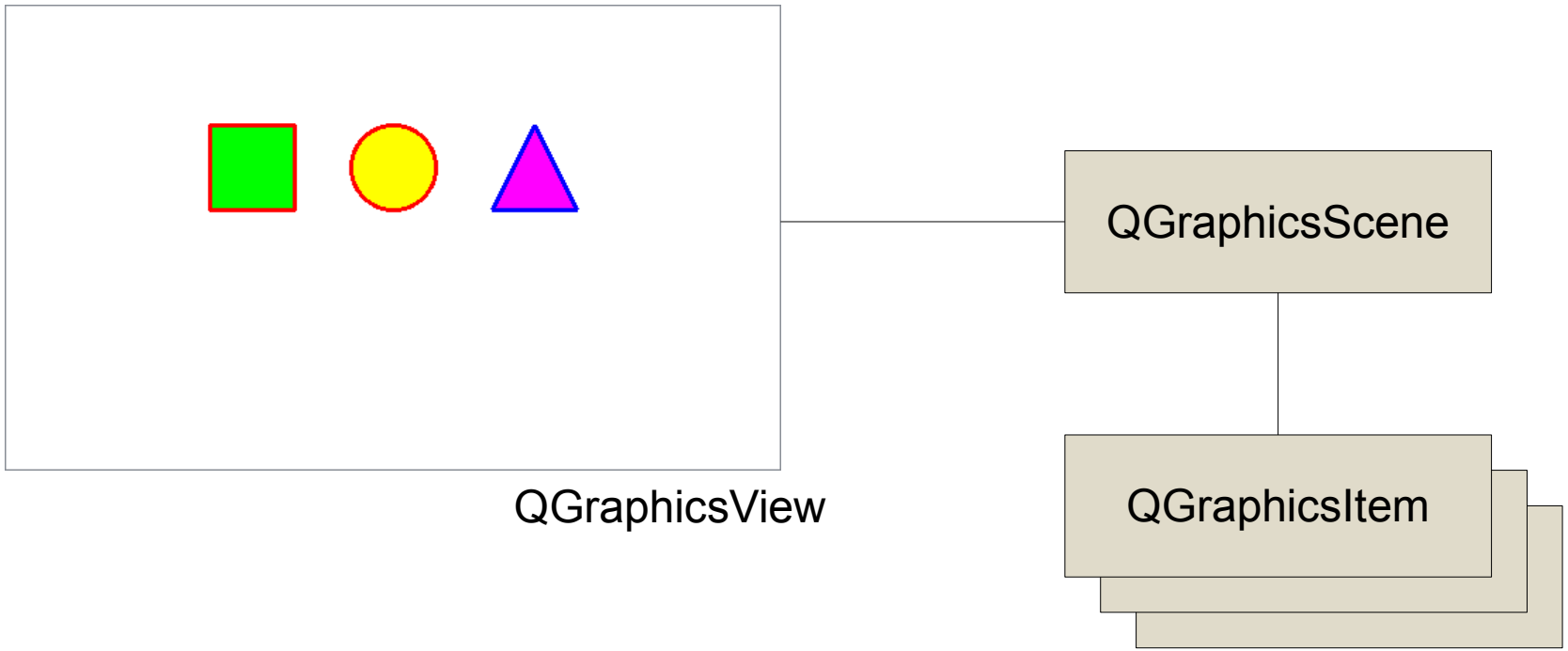
Qt in Education

The Graphics View Canvas

NOKIA

The Graphics View Framework

- The Graphics View Frameworks is a scene based approach to graphics

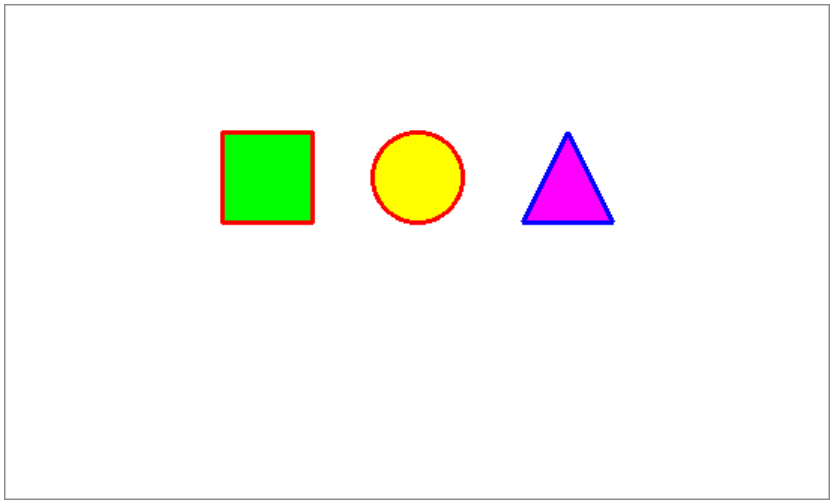


Item scenes compared to widgets

Widget	Scene / Items
Rectangular	Arbitrary shape
Non-overlapping	Arbitrary position
Updates when `update` is called internally	Updates needed parts according to changes
Optimized for a native platform look	Optimized for animations and effects
Integer (pixel) coordinates	Floating point (sub-pixel) coordinates

Painting Using QWidget and paintEvent

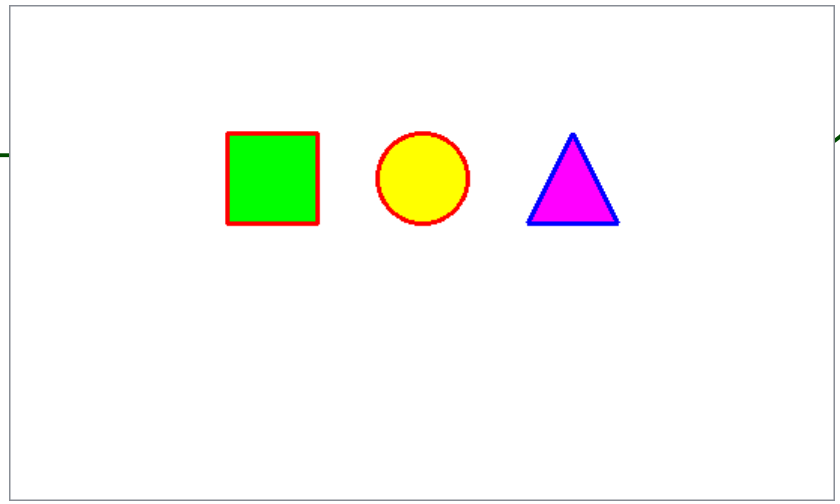
```
void Widget::paintEvent(QPaintEvent *)
{
    QPainter painter(this);

    painter.setPen(QPen(Qt::red, 3));
    painter.setBrush(Qt::green);
    painter.drawRect(20, 20, 60, 60);

    ...
}
```



- What about supporting more items?
- What about moving items about?

Painting Using Graphics View

```
void Widget::setupScene()
{
    QGraphicsView *view = new QGraphicsView();
    QGraphicsScene *scene = new QGraphicsScene(0, 0, 300, 200, this);

    scene->addRect(20, 20, 60, 60, QPen(Qt::red, 3), QBrush(Qt::green));
    scene->addEllipse(120, 20, 60, 60, QPen(Qt::red, 3), QBrush(Qt::yellow));
    scene->addPolygon(QPolygonF() << QPointF(220, 80) << QPointF(280, 80)
        << QPointF(250, 20), QPen(Qt::blue, 3), QBrush(Qt::magenta));

    view->setScene(scene);
    view->show();
}
```



The Scene

- The QGraphicsScene class contains all items and acts as an interface between the view and the items
  - Owns all items
  - Distributes paint events
  - Distributes other events
  - Provides methods for locating items
    - itemAt – the top item at a given location
    - items – all items in a given area

Initializing a Scene

- Each scene has a sceneRect defining the extent of the scene
  - If it is not specified, it will be the largest rectangle containing (or having contained) the scene items

```
QGraphicsScene *scene = new QGraphicsScene(this);
scene->setSceneRect(-100, -100, 201, 201);
```

The rectangle does not have to start at the origin (0, 0)

Populating a Scene

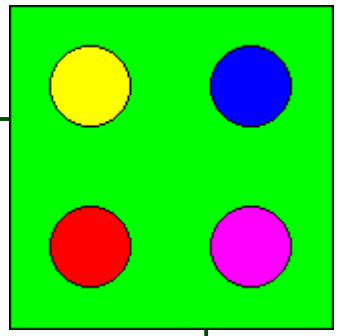
- The QGraphicsScene class makes it easy to add basic shapes to a scene

```
QGraphicsItem *item =
    scene->addRect(20, 20, 60, 60,
        QPen(Qt::red, 3), QBrush(Qt::green));
```

- Supports ellipses, lines, painter paths, pixmaps, polygons, rectangles and text
  - Each item type is represented by a separate class derived from QGraphicsItem

Populating a Scene

- For custom items and complex cases, it is possible to create items and then add them to a scene

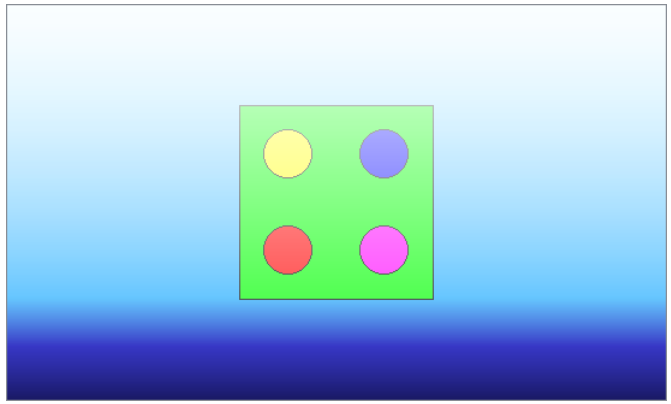


```
QGraphicsRectItem *rootItem =
    new QGraphicsRectItem(-50, -50, 101, 101);
rootItem->setBrush(Qt::green);

QGraphicsEllipseItem *item;
item = new QGraphicsEllipseItem(-40, -40, 30, 30, rootItem);
item->setBrush(Qt::yellow);
item = new QGraphicsEllipseItem( 10, -40, 30, 30, rootItem);
item->setBrush(Qt::blue);
item = new QGraphicsEllipseItem(-40,  10, 30, 30, rootItem);
item->setBrush(Qt::red);
item = new QGraphicsEllipseItem( 10,  10, 30, 30, rootItem);
item->setBrush(Qt::magenta);

scene->addItem(rootItem);
```

QGraphicsItems can be placed in an object hierarchy

Background and Foreground

- It is possible to set both foreground and background brushes for a scene or view



```
scene->setForegroundBrush(hazeBrush);
scene->setBackgroundBrush(blueToBlackBrush);
```

- Sub-class the view and reimplement drawBackground and drawForeground for custom painting

Setting up a view to a scene

- The QGraphicsView widget serves as the viewport in which the scene is shown

```
QGraphicsView *view = new QGraphicsView();
QGraphicsScene *scene = setupScene();
view->setScene(scene);
```

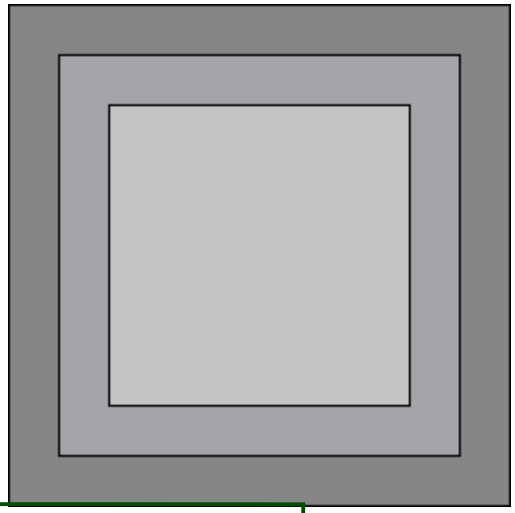
- By default, the scene is centered. Use the alignment property to control this
- The view class is derived from QAbstractScrollArea. From this class the horizontalScrollBarPolicy and verticalScrollBarPolicy properties are inherited

Basic Transformations

- Both the QGraphicsItem class and the QGraphicsView class can be transformed
  - scaling
  - translating
  - rotating
  - shearing
  - 2.5D effects

Nested Transformations

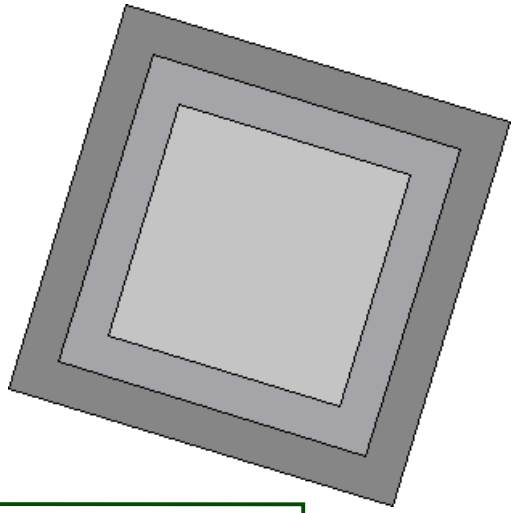
- When transforming parent items, the children are also transformed



```
QGraphicsRectItem *rootItem = new QGraphicsRectItem(...);
rootItem->setBrush(Qt::darkGray);


QGraphicsRectItem *midItem = new QGraphicsRectItem(..., rootItem);
midItem->setBrush(Qt::gray);


QGraphicsRectItem *topItem = new QGraphicsRectItem(..., midItem);
topItem->setBrush(Qt::lightGray);
```

Nested Transformations

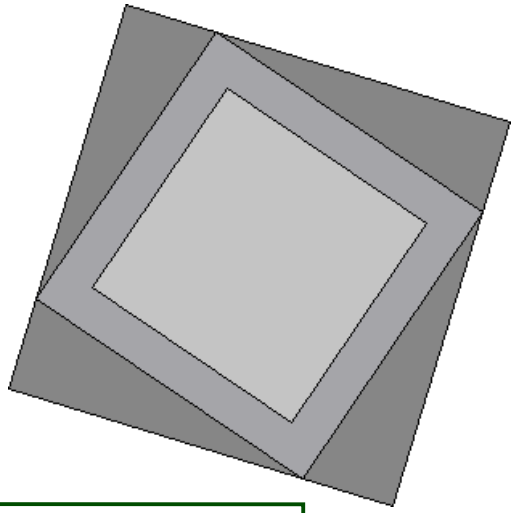
- When transforming parent items, the children are also transformed



```
QGraphicsRectItem *rootItem = new QGraphicsRectItem(...);
rootItem->setBrush(Qt::darkGray);
rootItem->setRotation(17);

QGraphicsRectItem *midItem = new QGraphicsRectItem(..., rootItem);
midItem->setBrush(Qt::gray);


QGraphicsRectItem *topItem = new QGraphicsRectItem(..., midItem);
topItem->setBrush(Qt::lightGray);
```

Nested Transformations

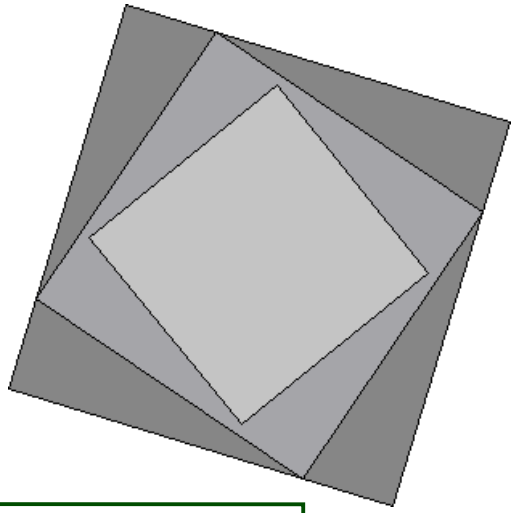
- When transforming parent items, the children are also transformed



```
QGraphicsRectItem *rootItem = new QGraphicsRectItem(...);
rootItem->setBrush(Qt::darkGray);
rootItem->setRotation(17);

QGraphicsRectItem *midItem = new QGraphicsRectItem(..., rootItem);
midItem->setBrush(Qt::gray);
midItem->setRotation(17);

QGraphicsRectItem *topItem = new QGraphicsRectItem(..., midItem);
topItem->setBrush(Qt::lightGray);
```

Nested Transformations

- When transforming parent items, the children are also transformed



```
QGraphicsRectItem *rootItem = new QGraphicsRectItem(...);
rootItem->setBrush(Qt::darkGray);
rootItem->setRotation(17);

QGraphicsRectItem *midItem = new QGraphicsRectItem(..., rootItem);
midItem->setBrush(Qt::gray);
midItem->setRotation(17);

QGraphicsRectItem *topItem = new QGraphicsRectItem(..., midItem);
topItem->setBrush(Qt::lightGray);
topItem->setRotation(17);
```

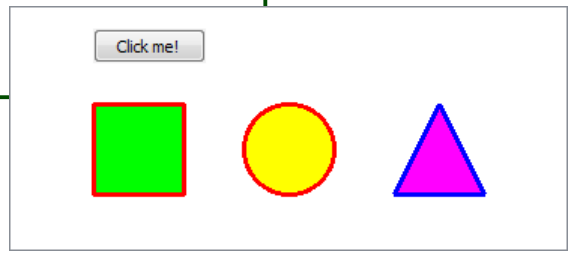
Coordinate systems

- The view, scene and each item has a local coordinate system
  - The view can
    - mapFromScene / mapToScene
  - The items can
    - mapFromScene / mapToScene
    - mapFromParent / mapToParent
    - mapFromItem / mapToItem
  - The scene always uses its own coordinate system

Embedding widgets

- It is possible to add widgets to a scene
- QGraphicsScene::addWidget returns a QGraphicsProxyWidget – a wrapper for the widget in the scene

```
QGraphicsProxyWidget *button = scene->addWidget(
    new QPushButton(tr("Click me!")));
button->setPos(20, -30);
```



- This is a convenience solution and not a high performance option

Adding Interaction

- The flags of the items control how they can be interacted with
  - ItemIsMovable – a convenience feature, the original mouse event methods let the user drag the item
  - ItemIsSelectable – the item can be selected using setSelected and the QGraphicsScene::setSelectionArea method
  - ItemIsFocusable – the item can receive keyboard focus

Moving Items

- By setting the ItemIsMovable flag, items can be moved around using the mouse

```
QGraphicsItem *item;
item = scene->addRect(...);
item->setFlag(QGraphicsItem::ItemIsMovable, true);
```

- When an item is moved, the item receives ItemPositionChange events
- Using an event filter it is possible to trace movements in the standard items without sub-classing

Sub-classing Items

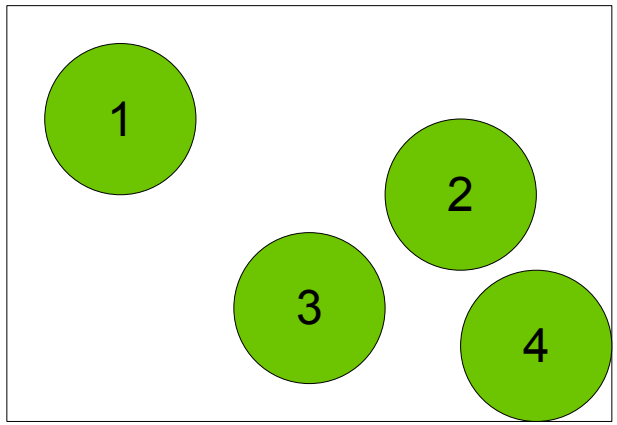
- When sub-classing items, there are numerous events that can be intercepted
  - hoverEnter / hoverMove / hoverLeave
  - itemChange (move, transform, selection, etc)
  - keyPress / keyRelease
  - mousePress / mouseMove / mouseRelease
  - etc
- It is also possible to implement the sceneEventFilter method and install the item as an event filter on selected items

Optimizing itemAt tests

- QGraphicsScene::itemAt is frequently called when the user interacts with a scene
  - Relies on a BSP tree of all the items for performance reasons
- When items are moved, the BSP tree is updated
  - In a scene with lots of movements, updating the BSP tree can be heavier than using a less efficient itemAt
- Using the scene's bspTreeDepth and itemIndexMethod properties, the BSP tree can be tuned or disabled

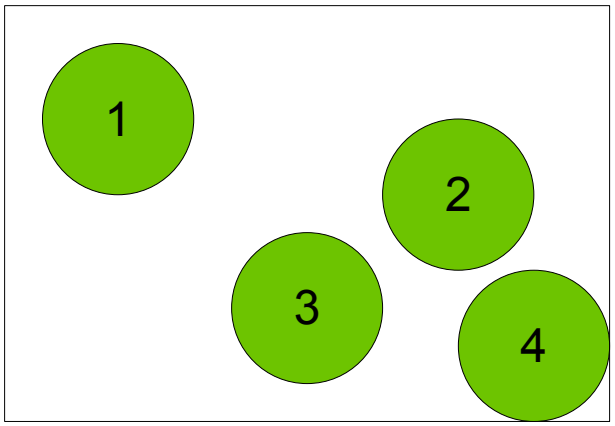
What is a BSP tree

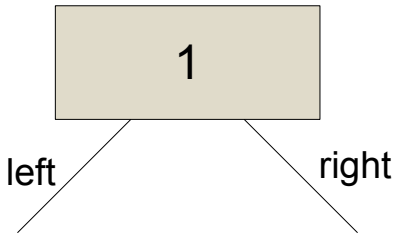
- Binary Space Partitioning trees store items in a tree, depending on their location in space



What is a BSP tree

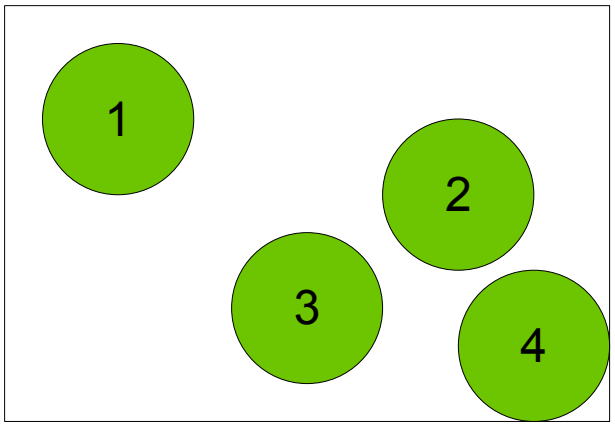
- Binary Space Partitioning trees store items in a tree, depending on their location in space

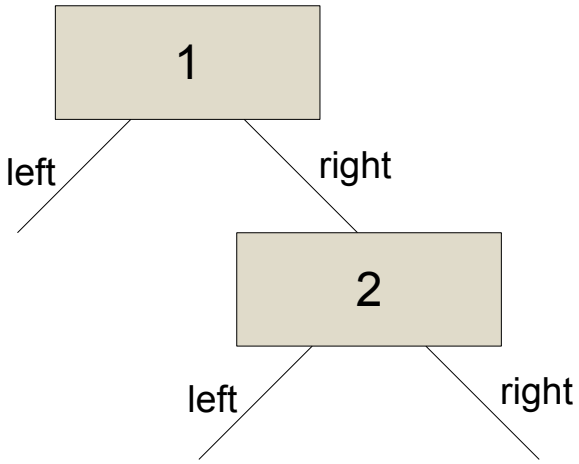




What is a BSP tree

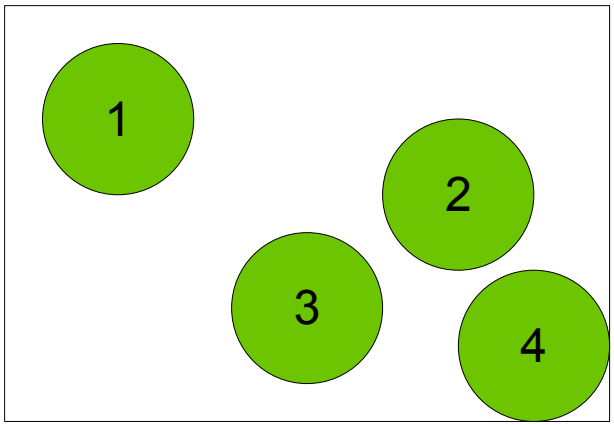
- Binary Space Partitioning trees store items in a tree, depending on their location in space

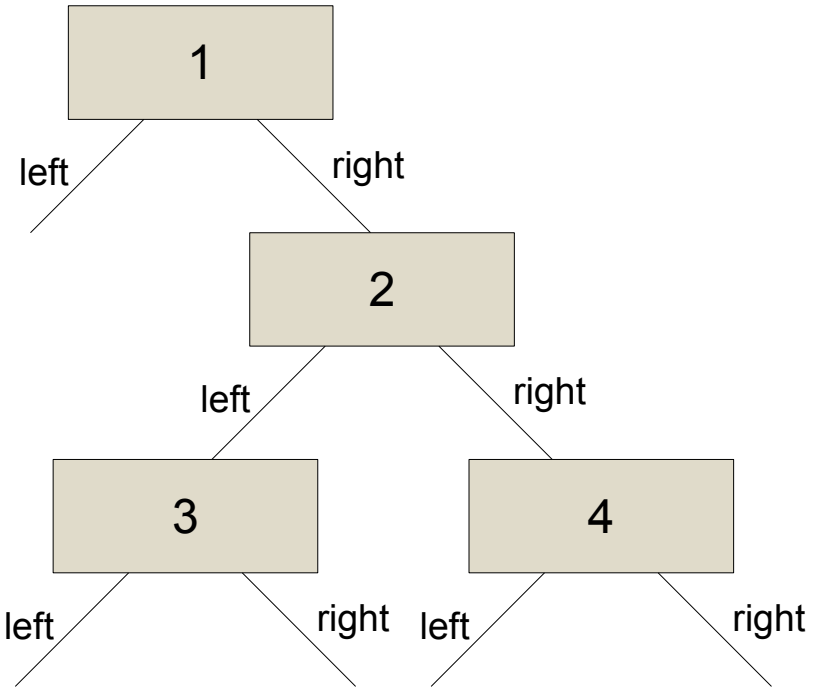




What is a BSP tree

- Binary Space Partitioning trees store items in a tree, depending on their location in space





Tuning view update regions

- To optimize performance for scene updates, Qt tries to repaint smartly
- The view's viewportUpdateMode controls how the repainting is done
  - FullViewportUpdate – the entire view is updated on all changes
  - MinimalViewportUpdate – only a minimal update is requested
  - SmartViewportUpdate – Qt tries to optimize
  - BoundingRectViewportUpdate – a minimal rectangular update
  - NoViewportUpdate – the updates must be triggered externally

Break

Custom Items

- There are basically two starting points when creating a custom graphics item
  - QGraphicsItem – simple graphics items
    - QAbstractGraphicsShapeItem – adds properties pen and brush
  - QGraphicsObject – graphics items that need QObject features such as signals and slots

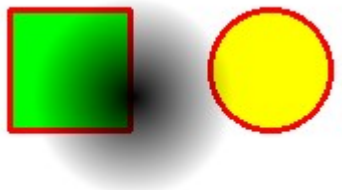
A Basic Custom Item

- A basic custom item only provides visuals
  - A bounding rectangle defining the extent of the item
  - A paint method, painting the actual item

```
class BasicItem : public QGraphicsItem
{
public:
    BasicItem(QGraphicsItem *parent=0);

    QRectF boundingRect() const;

    void paint(QPainter *painter,
        const QStyleOptionGraphicsItem *option,
        QWidget *widget);
};
```

A Basic Custom Item

```
QRectF BasicItem::boundingRect() const
{
    return QRectF(0, 0, 100, 100);
}

void BasicItem::paint(QPainter *painter,
    const QStyleOptionGraphicsItem *option,
    QWidget *widget)
{
    painter->setPen(Qt::NoPen);

    QRadialGradient gradient = radialGradient();
    painter->setBrush(gradient);

    painter->drawEllipse(boundingRect());
}
```



A partially transparent brush gives a shading item

Custom Items

- The paint method is called when needed – not necessarily for all repaints
  - Call update to trigger a repaint
- The boundingRect must contain all of the item's graphics
  - Do not forget that wide pens paint on both sides of the specified line
  - When resizing, make sure to call prepareGeometryChange *before* you change the size of the item

Interacting

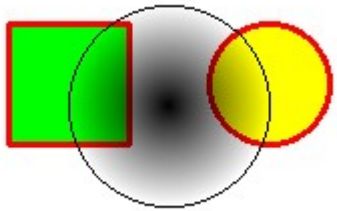
- The flag ItemIsMovable gives basic movability

```
item->setFlag(QGraphicsItem::ItemIsMovable, true);
```

- The flag ItemIsSelectable makes it possible to select the item in question
  - The item is automatically requested to repaint itself

```
item->setFlag(QGraphicsItem::ItemIsSelectable, true);
```

```
void BasicItem::paint(...)
{
    if(isSelected())
        painter->setPen(Qt::black);
    else
        painter->setPen(Qt::NoPen);
```



Custom Interaction

- The movability and item selection is implemented in the default mouse event handling methods
- To gain full control, you can re-implement the event handling functions directly
  - setAcceptHoverEvents enables hover events
  - setAcceptTouchEvents enables touch events
  - setAcceptedMouseButtons defines which buttons are handled by the item (default is to accept all buttons)

Interaction Example

- An interactive custom item listening to hover events and mouse press events
  - When hovered, the item expands
  - When pressed, it changes appearance

inactive

hovered

pressed

Interaction Example Class Declaration

```
class InteractiveItem : public QGraphicsItem
{
public:
    InteractiveItem(QGraphicsItem *parent=0);

    QRectF boundingRect() const;
    void paint(...);

protected:
    void hoverEnterEvent(QGraphicsSceneHoverEvent*);
    void hoverLeaveEvent(QGraphicsSceneHoverEvent*);

    void mousePressEvent(QGraphicsSceneMouseEvent*);
    void mouseReleaseEvent(QGraphicsSceneMouseEvent*);

protected:
    bool m_pressed;
    bool m_hovered;
};
```

Interaction Example Constructor

- Initializing the item, making sure that both internal states are false

```
InteractiveItem::InteractiveItem(QGraphicsItem *parent) :
    QGraphicsItem(parent),
    m_pressed(false), m_hovered(false)
{
    setAcceptHoverEvents(true);
}
```

Interaction Example Geometry and Painting

- The bounding rectangle depends on the hovered state, while appearance depends on both hovered and pressed

```
QRectF InteractiveItem::boundingRect() const
{
    if(m_hovered)
        return QRectF(-50, -50, 101, 101);
    else
        return QRectF(-30, -30, 61, 61);
}


void InteractiveItem::paint(QPainter *painter,
    const QStyleOptionGraphicsItem *option, QWidget *widget)
{
    QRadialGradient gradient;
    if(m_hovered)
        ... // Setup gradient


    if(m_pressed)
        ... // Setup gradient

    ... // Paint here
}
```

Interaction Example Mouse Events

- The mouse events only affect the appearance
  - State change is followed by call to update

```
void InteractiveItem::mousePressEvent(QGraphicsSceneMouseEvent*)
{
    m_pressed = true;
    update();
}

void InteractiveItem::mouseReleaseEvent(QGraphicsSceneMouseEvent*)
{
    m_pressed = false;
    update();
}
```

Interaction Example Hover Events

- The hover events affect the bounding rectangle
  - First call prepareGeometryChange, then alter state

```
void InteractiveItem::hoverEnterEvent(QGraphicsSceneHoverEvent*)
{
    if(!m_hovered)
    {
        prepareGeometryChange();
        m_hovered = true;
    }
}

void InteractiveItem::hoverLeaveEvent(QGraphicsSceneHoverEvent*)
{
    if(m_hovered)
    {
        prepareGeometryChange();
        m_hovered = false;
    }
}
```

QGraphicsObject

- The QGraphicsItem class is not derived from QObject – this means that
  - Items cannot have properties
  - Items cannot have slots
  - Items cannot emit signals
- The QGraphicsObject class is a QObject derived QGraphicsItem class

QGraphicsObject

- When sub-classing QGraphicsObject, there are some things to keep in mind
  - Relationships between items are explored using parentItem and childItems
  - Relationships between QObjects are explored using parentObject and parentWidget
  - Use QGraphicsItem's features for modifying ownership trees, e.g. setParentItem

Interactive QGraphicsObject

- Start from the InteractiveItem class
  - Change the name to InteractiveObject
  - Change the base class to QGraphicsObject

```
class InteractiveObject : public QGraphicsObject
{
    Q_OBJECT
public:
    explicit InteractiveObject(QGraphicsItem *parent = 0);
```

The parent is still an item

  - In the mouse release event, emit a signal if the mouse button is released while over the circle

```
QPointF delta = boundingRect().center()-ev->pos();
qreal radius = boundingRect().width()/2.0;
if(delta.x()*delta.x()+delta.y()*delta.y() <= radius*radius)
    emit clicked();
```

Widgets in a scene

- It is possible to place QWidgets in a graphics view scene
  - The widgets are managed by a QGraphicsProxyWidget
  - Performance is not very good
  - Complex widgets are not always rendered correctly
  - Use for quick hacks or when migrating code

```
QWidget *myWidget = new QPushButton(tr("Qt"));
QGraphicsProxyWidget *proxyWidget =
    scene->addWidget(myWidget);
```

Rendering Hints

- It is possible to tune the QGraphicsView to render the scene more quickly or in greater detail
  - renderHints – a set of flags controlling rendering
    - Antialias – enables anti-aliasing
    - SmoothPixmapTransform – enables smoother pixmap transformations

Caching

- The caching of individual QGraphicsItems can greatly affect performance
- Caching is tuned using QGraphicsItem::setCacheMode
  - ItemCoordinateCache
    - Caches the item in its local coordinate system
    - Can reduce rendering quality
    - Call setCacheMode again to resample the item
  - DeviceCoordinateCache
    - Perfect for items that do not apply other transformations than translation

Enabling Hardware Acceleration

- To use OpenGL for rendering the scene, change the viewport widget of the view

```
QGraphicsView *view = new QGraphicsView();
view->setViewport(new QGLWidget);
```

- The renderHint flag HighQualityAntialiasing can be set to enable fragment programs and off-screen rendering for antialiasing when using OpenGL

Enabling Hardware Acceleration

- To use OpenGL for rendering the scene, change the viewport widget of the view

```
QGraphicsView *view = new QGraphicsView();
view->setViewport(new QGLWidget);
```

- The renderHint flag HighQualityAntialiasing can be set to enable fragment programs and off-screen rendering for antialiasing when using OpenGL