Chapter 12
Described Auditory Content – Music

The Design and Implementation of Multimedia Software

David Bernstein

Jones and Bartlett Publishers

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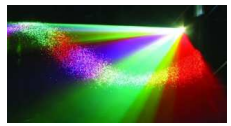


About this Chapter

- Described Auditory Content:

  Described speech, described sounds, and described music

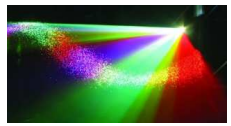
- This Chapter – Described Music:

  'Name' frequencies.

  Describe the duration of individual sounds.

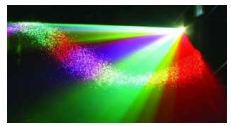
  Describe the 'voice' or 'instrument'.

  Describe the loudness of those sounds.



What's Next

We need some instant gratification.



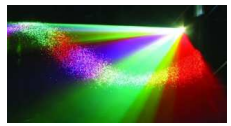
Musical Instrument Digital Interface (MIDI)

- Original Purpose:

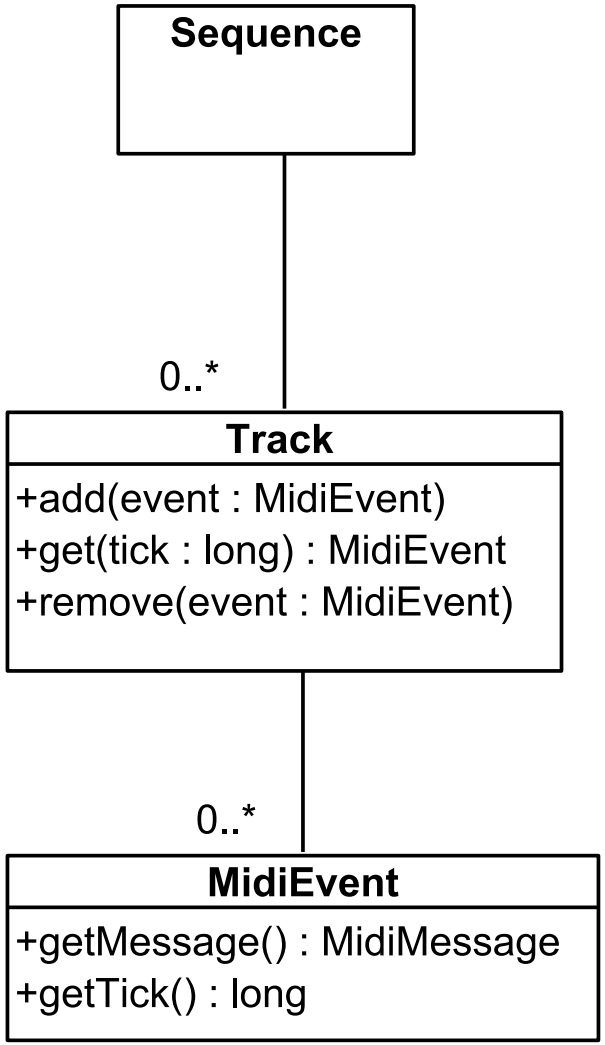
  A protocol for passing musical events between electronic instruments and sequencers.

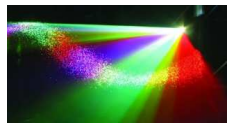
- Our Interest:

  Sending messages to a sound card.



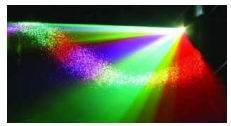
The Sequence, Track and MidiEvent Classes





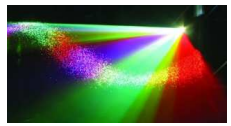
Reading MIDI Events from a File

1. Create a `Sequence` from a `File` or an `InputStream`.
2. Create a `Sequencer`.
3. Open the `Sequencer`.
4. Associate the `Sequence` with the `Sequencer`.
5. Start the `Sequencer`.



MidiPlayer

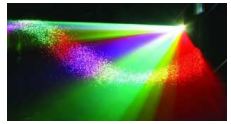
```
import java.io.*;
import javax.sound.midi.*;

import io.*;

public class MidiPlayer
{
  public static void main(String[] args) throws Exception
  {
    InputStream          is;
    ResourceFinder       finder;
    Sequencer            sequencer;
    Sequence             seq;

    finder = ResourceFinder.createInstance(new resources.Marker());
    is = finder.findInputStream(args[0]);
    seq = MidiSystem.getSequence(is);

    sequencer = MidiSystem.getSequencer();
    sequencer.open();

    sequencer.setSequence(seq);
    sequencer.start();
  }
}
```



Requirements

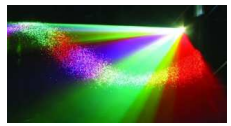
F12.1 Encapsulate a description of music.

F12.2 Present/render this description.



What's Next

We need to consider the presentation of described auditory content.



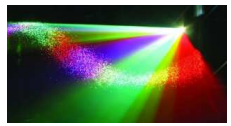
Ways Synthesizers Can Generate Signals

- Using a Soundbank:

  The synthesizer has a database of 'sounds' (e.g., samplings of different instruments producing different tones) that it uses to produce the electrical signal.

- Using Waves:

  The synthesizer constructs the electrical signals from continuous waves.

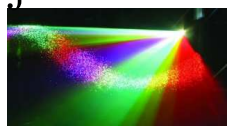


Rendering in Java

- `Synthesizer`:

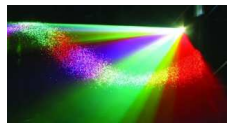
  Controls a set (typically with 16 members) of `MidiChannel` objects that encapsulate 'voices'.

- Setup:
  1. Obtain a `Synthesizer` object by calling the `MidiSystem.getSynthesizer()` method.
  2. Get a `Soundbank` object (e.g., by calling the `Synthesizer` object's `getDefaultSoundBank()` method).
  3. Call the `Synthesizer` object's `loadAllInstruments()` method (passing it the `Soundbank` object.
  4. Get the `MidiChannel` objects by calling the `Synthesizer` object's `getChannels()` method.



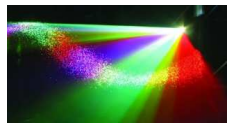
Rendering Notes – Alternative 1

1. Obtain a `Receiver` object by calling the `Synthesizer` object's `getReceiver()` method.
2. Construct a `ShortMessage` object that turns the note on.
3. Call the `Receiver` object's `send()` method (passing it the `ShortMessage` object).
4. Wait the appropriate amount of time.
5. Construct a `ShortMessage` object that turns the note off.
6. Call the `Receiver` object's `send()` method (passing it the `ShortMessage` object).



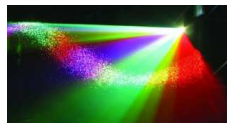
Rendering Notes – Alternative 2

1. Call the `MidiChannel` object's `noteOn()` method.
2. Wait the appropriate amount of time.
3. Call the `MidiChannel` object's `noteOff()` method.



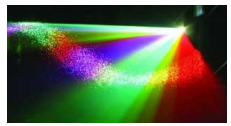
Evaluating the Alternatives

Which is better?



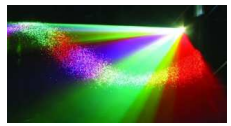
Evaluating the Alternatives

The second method is used here because it is simpler and provides all of the necessary functionality.



What's Next

We need to consider the encapsulation of described auditory content.



Naming Frequencies

- Modern Music Notation:

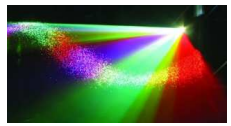
  The frequencies in a single octave are denoted by the letters A-G.

  Letters can be followed by either a sharp indicator (i.e., a ♯ character) which denotes a half-step or half-tone up, or flat indicator (i.e., a ♭ character) which denotes a half-step or half-tone down.

  A complete octave contains A, A♯, B, C, C♯, D, D♯, E, F, F♯, G, and G♯.

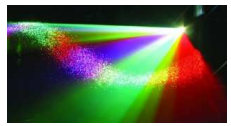
- A Common Tuning:

  "A" is the name commonly given to the frequencies 55Hz, 110Hz, 220Hz, 440Hz, 880Hz, 1760Hz, etc.

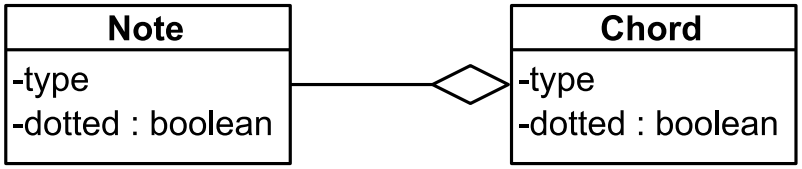


Describing Durations

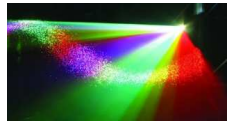
- Durations are commonly given as multiples/fractions of a base duration, or *beat*.
- Common durations are whole notes, half notes, quarter notes, eighth notes and sixteenth notes.
- A standard duration can be 'dotted' to indicate that it should be increased by 50%.
- *Triplets* are notes that are grouped in sets of three (i.e., the three notes evenly divide an integral number of beats).



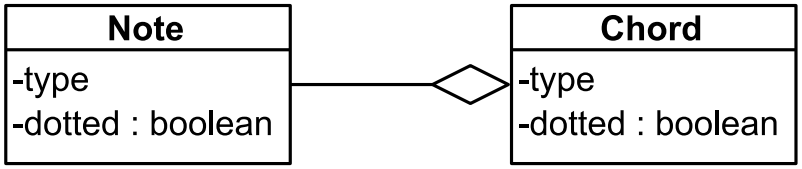
Alternative 1



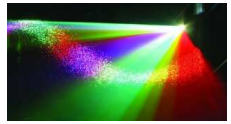
What are the shortcomings?



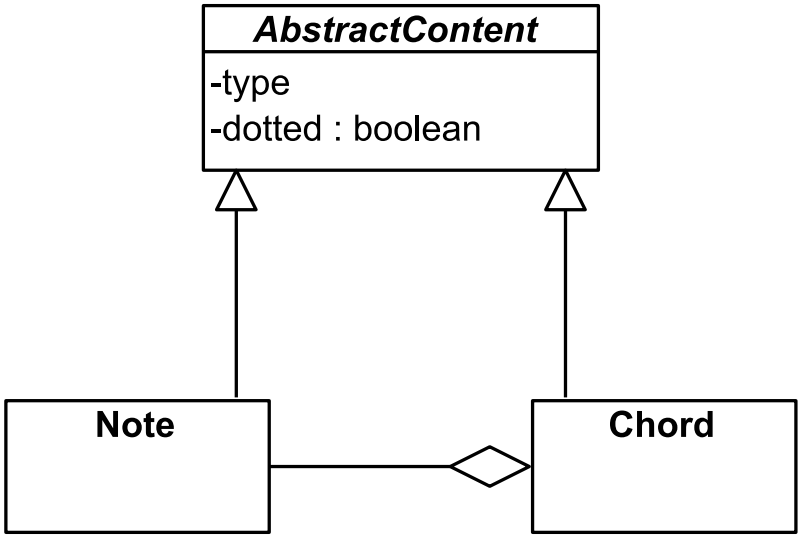
Alternative 1



It will probably result in code duplication.



Alternative 2



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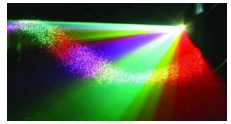

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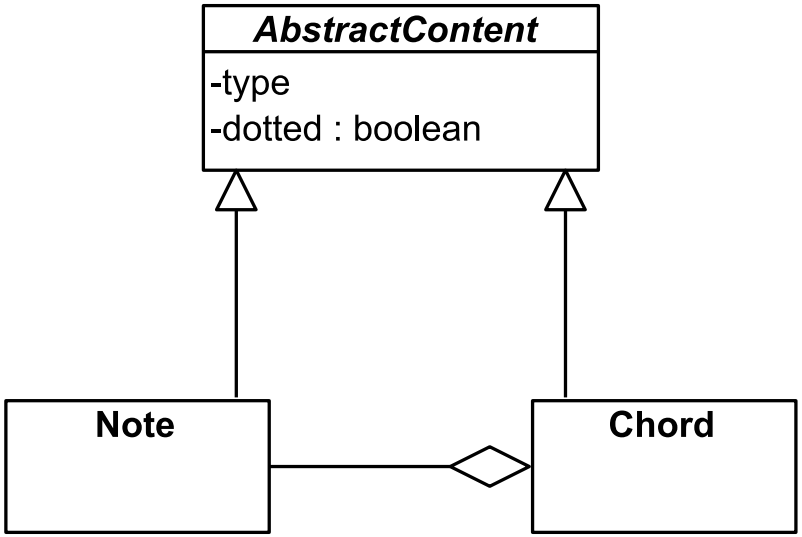
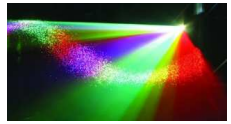
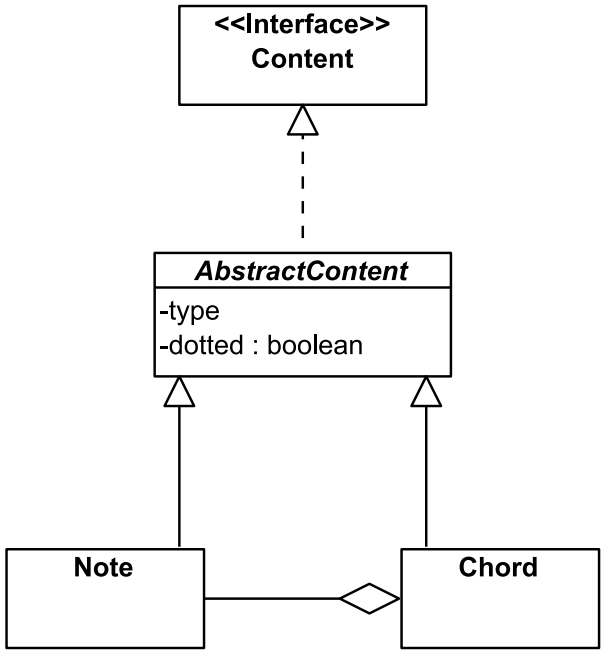


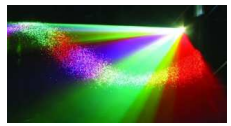
Makes it difficult to add content that is not a specialization of the `AbstractContent` class.



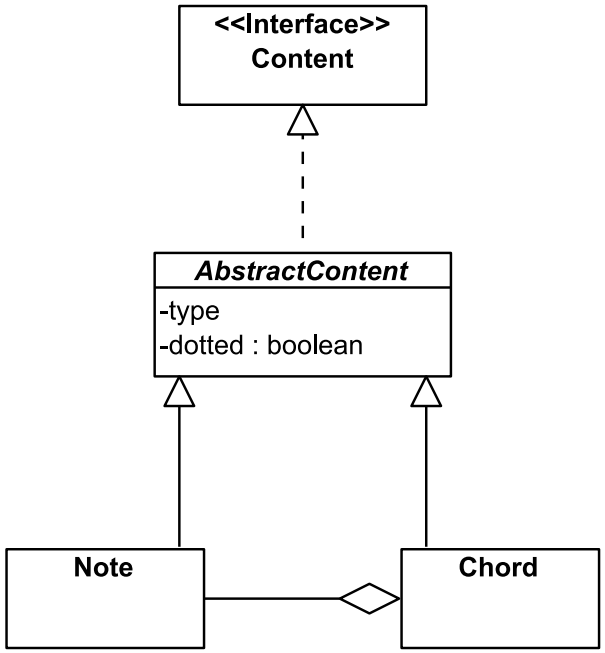
Alternative 3



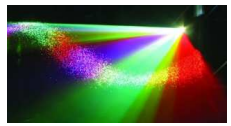
What are the advantages?



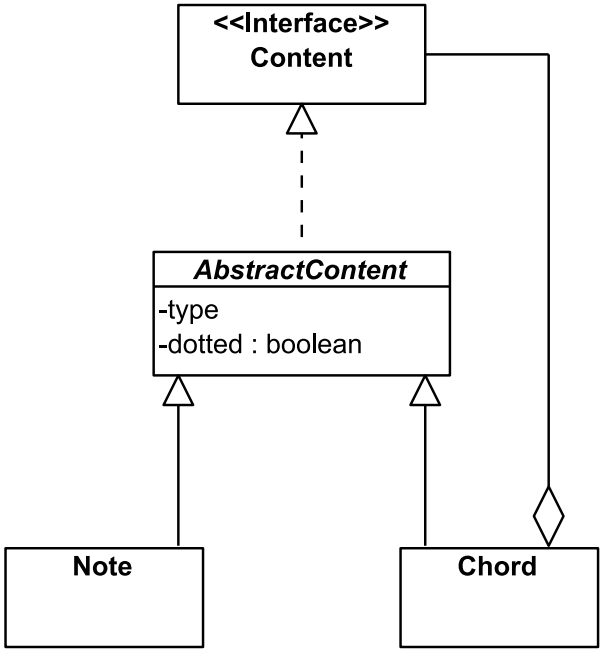
Alternative 3



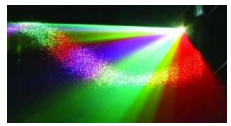
One can create other classes that implement the `Content` interface without having to specialize the `AbstractContent` class (e.g., a `BrokenChord` class).



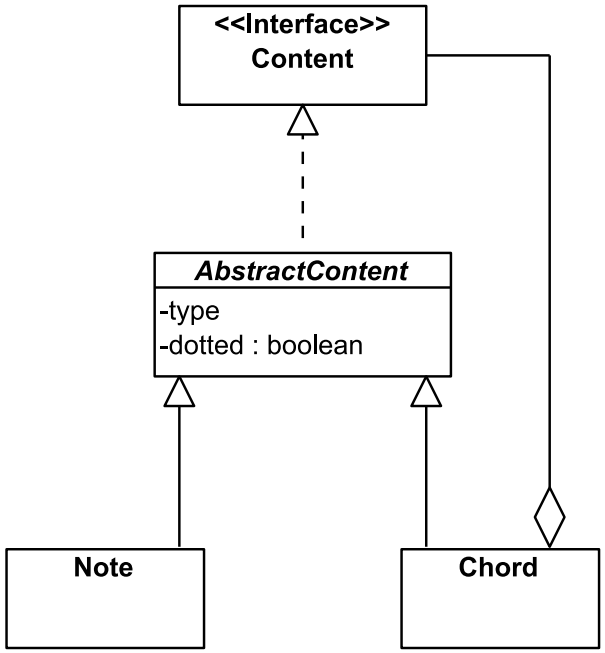
Alternative 4 – Composite Pattern



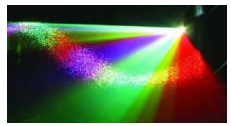
What are the shortcomings?



Alternative 4 – Composite Pattern 

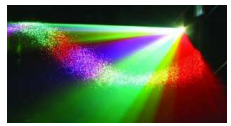


It is not consistent with the way the term “chord” is normally used in music theory.



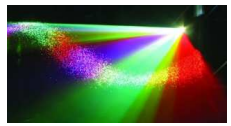
Content

```
package auditory.described;

import javax.sound.midi.*;

public interface Content
{
  public abstract int  getType();

  public abstract boolean isDotted();

  public abstract void render(MidiChannel channel);

  public abstract void setAudible(boolean audible);
}
```



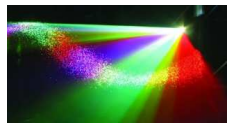
AbstractContent – Structure

```
package auditory.described;

import javax.sound.midi.*;

public abstract class      AbstractContent
                 implements Content
{
  protected boolean                  audible, dotted, playing;
  protected int                      type;

  public AbstractContent()
  {
    this(1, false);
  }

  public AbstractContent(int type, boolean dotted)
  {
    this.type     = type;
    this.dotted   = dotted;
    this.audible  = false;
    this.playing  = false;
  }
}
```



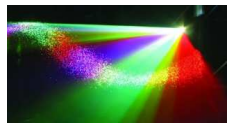
AbstractContent – Getters

```
public int getType()
{
  return type;
}

public boolean isDotted()
{
  return dotted;
}
```



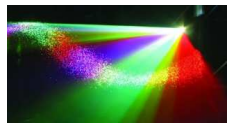
AbstractContent – Setters

```
public void setAudible(boolean audible)
{
  this.audible = audible;
}

protected void setDotted(boolean dotted)
{
  this.dotted = dotted;
}

protected void setType(int type)
{
  this.type = type;
}
```



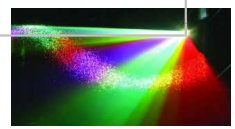
AbstractContent – Rendering

```
public void render(MidiChannel channel)
{
  if      ( audible && !playing)
  {
    playing = true;
    startPlaying(channel);
  }
  else if (!audible &&  playing)
  {
    playing = false;
    stopPlaying(channel);
  }
}
protected abstract void startPlaying(MidiChannel channel);

protected abstract void stopPlaying(MidiChannel channel);
```



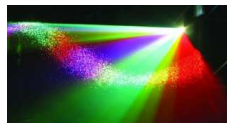
Note – Structure

```
package auditory.described;

import javax.sound.midi.*;

public class   Note
       extends AbstractContent
{
  private boolean                 sharp;
  private char                    pitch;
  private int                     midiNumber;

  public Note()
  {
    this('C', false, 0, 1, false);
  }

  public Note(char pitch,   boolean sharp, int octave,
      int type, boolean dotted)
  {
    super(type, dotted);

    this.pitch = Character.toUpperCase(pitch);
    this.sharp = sharp;
    midiNumber = MidiCalculator.numberFor(pitch, sharp, octave);
  }
}
```



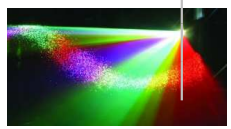
Note – Rendering

```
protected void startPlaying(MidiChannel channel)
{
  if (midiNumber >= 0) channel.noteOn(midiNumber, 127);
}

protected void stopPlaying(MidiChannel channel)
{
  if (midiNumber >= 0) channel.noteOff(midiNumber, 127);
}
```



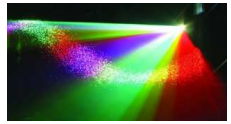
MidiCalculator

```
package auditory.described;

public class MidiCalculator
{
  public static int numberFor(
      char    pitch,
      boolean sharp,
      int     octave)
  {
    int    midiBase, midiNumber;


    // Handle special cases (B sharp and E sharp)
    if ((pitch == 'B') && sharp)
    {
      pitch = 'C';
      sharp = false;
    }
    else if ((pitch == 'E') && sharp)
    {
      pitch = 'F';
      sharp = false;
    }

    // Calculate the MIDI value
    midiBase = 60;
    if      (pitch == 'A') midiNumber = midiBase +  9;
    else if (pitch == 'B') midiNumber = midiBase + 11;
```



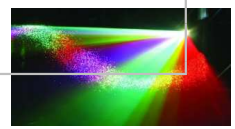
MidiCalculator (cont.)

```
    else if (pitch == 'C') midiNumber = midiBase +  0;
    else if (pitch == 'D') midiNumber = midiBase +  2;
    else if (pitch == 'E') midiNumber = midiBase +  4;
    else if (pitch == 'F') midiNumber = midiBase +  5;
    else if (pitch == 'G') midiNumber = midiBase +  7;
    else                   midiNumber = -1;  // Rest

    if (sharp) midiNumber = midiNumber + 1;

    midiNumber = midiNumber + (octave * 12);

    return midiNumber;
  }
}
```



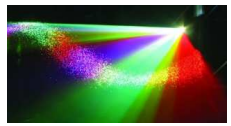
Chord – Structure

```
package auditory.described;

import java.util.*;
import javax.sound.midi.*;

public class      Chord
       extends    AbstractContent
{
  private ArrayList<Note>       notes;

  public Chord()
  {
    this(1, false);
  }

  public Chord(int type, boolean dotted)
  {
    super(type, dotted);

    notes = new ArrayList<Note>();
  }

  public void addNote(Note note)
  {
    notes.add(note);
  }
}
```



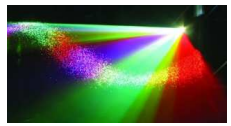
Chord – startPlaying()

```
protected void startPlaying(MidiChannel channel)
{
  Iterator<Note>     i;
  Note               note;

  i = notes.iterator();
  while (i.hasNext())
  {
    note = i.next();
    if (note != null)
    {
      note.setType(type);
      note.setDotted(dotted);
      note.startPlaying(channel);
    }
  }
}
```



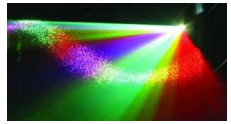
Chord – stopPlaying()

```
protected void stopPlaying(MidiChannel channel)
{
  Iterator<Note>     i;
  Note               note;

  i = notes.iterator();
  while (i.hasNext())
  {
    note = i.next();
    if (note != null)
    {
      note.stopPlaying(channel);
    }
  }
}
```

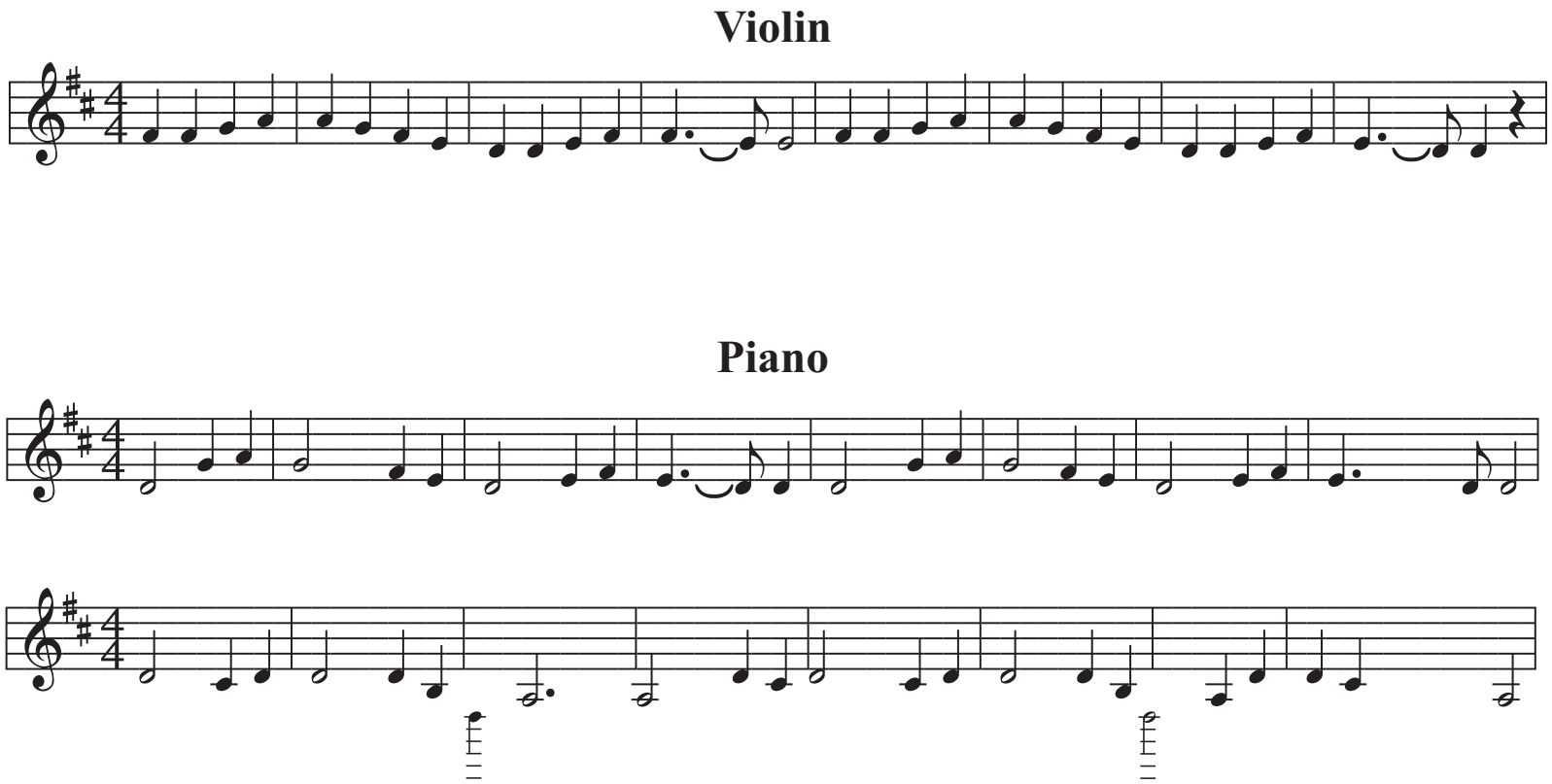


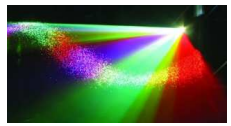
Music Notation

Music notation consists of one or more *staffs* (a set of five horizontal lines) that contain multiple measures (delimited by *bar lines*), each of which contains multiple notes (that indicate both the pitch and the duration). The end of a song is usually indicated with a double bar line.



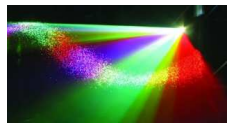
Eight Measures of Beethoven's "Ode to Joy"





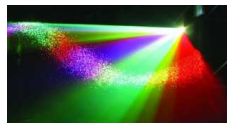
A More Convenient Notation

A comma delimited `String` with a field for the 'name' including an optional `'#'` character, the octave (with 0 being the octave that contains middle C), the type of the note (i.e., 1 for whole, 2 for half, 4 for quarter, etc) which includes an optional `'.'` character.



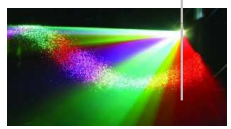
Eight Measures of Beethoven's 'Ode to Joy"

	.	.	.
	.	.	.
	.	.	.
F#,-1,4	D ,-1,4	F#,-1,4	D ,-1,4
F#,-1,4	D ,-1,4	F#,-1,4	D ,-1,4
G ,-1,4	E ,-1,4	G ,-1,4	E ,-1,4
A ,-1,4	F#,-1,4	A ,-1,4	F#,-1,4
A ,-1,4	F#,-1,4.	A ,-1,4	E ,-1,4.
G ,-1,4	E ,-1,8	G ,-1,4	D ,-1,8
F#,-1,4	E ,-1,2	F#,-1,4	D ,-1,4
E ,-1,4		E ,-1,4	R , 0,4
.	.	.	
.	.	.	
.	.	.	



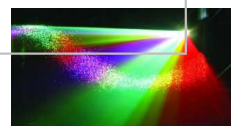
NoteFactory

```
package auditory.described;

import java.util.*;

null
public class NoteFactory
{
  public static Note parseNote(String s)
  {
    boolean           dotted, sharp;
    char              pitch, sharpChar;
    int               duration, octave;
    Note              theNote;
    String            durationString, octaveString, token;
    StringTokenizer   st;

    st = new StringTokenizer(s, ", ");

    try
    {
      token = st.nextToken();

      // Determine the pitch
      pitch = token.charAt(0);

      // Determine if this is a sharp or a natural
      sharp = false;
      if (token.length() == 2)
```



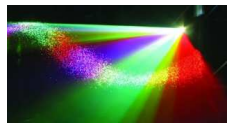
NoteFactory (cont.)

```
      {
        sharpChar = token.charAt(1);
        if (sharpChar == '#') sharp = true; // ASCII 35
      }

      // Detemine the octave (relative to middle C)
      octaveString = st.nextToken();
      octave       = Integer.parseInt(octaveString);

      // Determine the duration (which has an arbitrary length)
      dotted         = false;
      durationString = st.nextToken();
      if (durationString.endsWith(".")) dotted = true;
      duration = (int)Double.parseDouble(durationString);

      // Construct a new Note
      theNote = new Note(pitch, sharp, octave, duration, dotted);
    }
    catch (NoSuchElementException nsee)
    {
      theNote = null;
    }

    return theNote;
  }
}
```



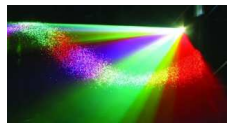
What's Next

We need to consider operating on described auditory content.



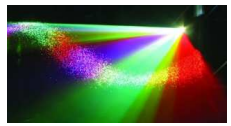
Scales

- An (ascending) *scale* is a sequence of notes that starts and ends on the same note, moving up in a consistent way.
- A *major scale* is a scale that uses the T-T-S-T-T-T-S pattern when ascending (where T denotes a tone or whole step and S denotes a semi-tone or half step).
- A *minor scale* is a scale that uses the T-S-T-T-S-T-T pattern when ascending.



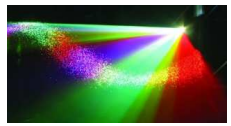
Scales – The C-Major Scale

C	D	E	F	G	A	B	C
	T	T	S	T	T	T	S



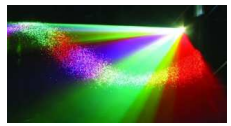
Transposition

- A song that uses the notes from a particular scale is said to be in the *key* of that scale.
- Transposition is an operation that changes a song from one key to another.
- Since the representation used here does not include a *key signature*, that is, all notes include explicit sharps/flats, transposition can be performed directly on the MIDI numbers.



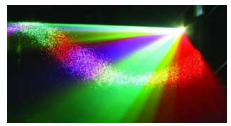
What's Next

We need to design a described auditory content system.



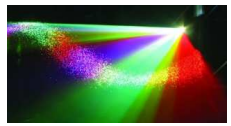
What's Left?

- The `Audition` components of the conceptual model.
- The `AuditionView` component of the conceptual model



Organizing Notes and Chords

- Notes are commonly grouped into durations of equal length, called *measures*.
- The *time signature* indicates how many beats are in each measure (in the 'numerator') and which type of note gets a whole beat (in the 'denominator').
- A collection of notes/chords ordered over time that is intended to be played by a single instrument (or sung by a single voice) is often called a *part*.
- A collection of parts (for different instruments/voices) is referred to as a *score*.



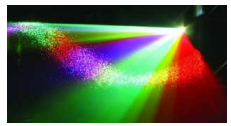
Alternative 1 

- Aproach:

  Each `Part` has it's own `Metronome` object and renders its content (independently) in its own thread of execution.

- Shortcomings:

  What are the shortcomings?



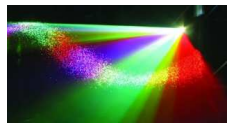
Alternative 1 

- Aproach:

  Each `Part` has it's own `Metronome` object and renders its content (independently) in its own thread of execution.

- Shortcomings:

  The different `Part` objects may not stay synchronized since the timing of `handleTick()` messages is not precise.



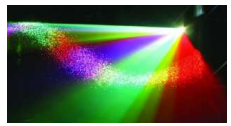
Alternative 2 

- Approach:

  Have a single `Metronome` object that synchronizes the `Part` objects.

- `handleTick()` Method:

  Determines which `Note`/`Chord` objects needs to be rendered.



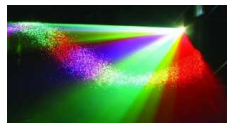
Alternative 2.1

- Approach:

  Include an attribute for the instrument in `Part`.

- Shortcomings:

  What are the shortcomings?



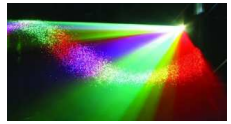
Alternative 2.1 

- Approach:

  Include an attribute for the instrument in `Part`.

- Shortcomings:

  One can not have the same `Part` object rendered using different instruments.



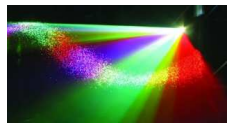
Alternative 2.2 

- Approach:

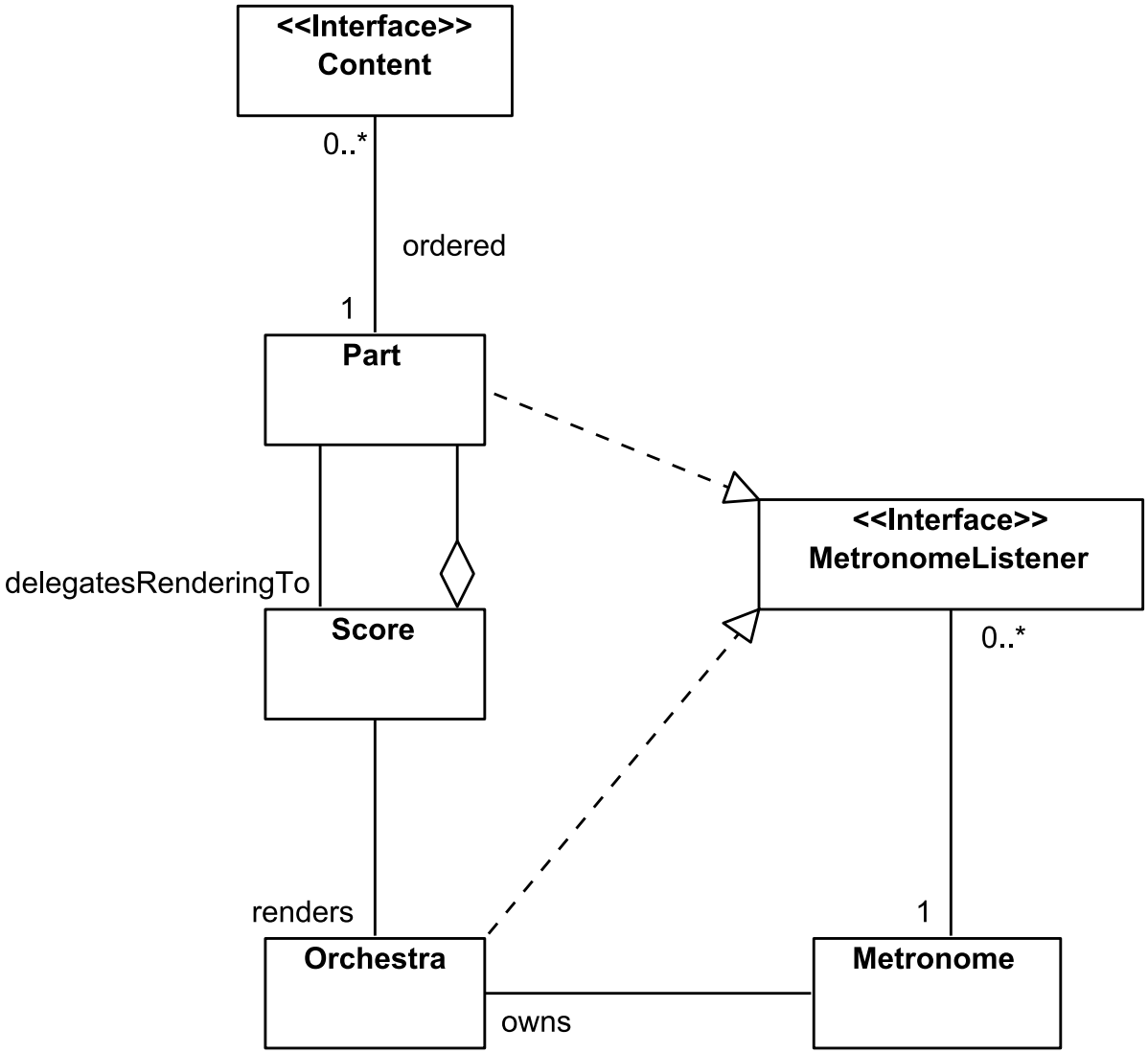
  A `Part` object can be told what instrument to use when its `render()` method is called.

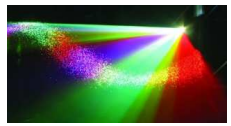
- Advantage:

  Adds flexibility at no 'cost'.



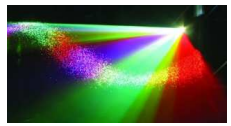
The Design


<<Interface>>
Content
0..*
ordered
1
Part
<<Interface>>
MetronomeListener
delegatesRenderingTo
Score
0..*
renders
1
Orchestra
Metronome
owns



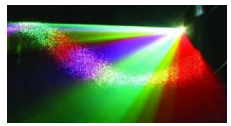
Part – Structure

```
package auditory.described;

import java.util.*;
import javax.sound.midi.*;

import event.*;

public class Part implements MetronomeListener
{
  private ArrayList<Content>     sounds;
  private double                 timeSignatureDenominator,
  timeSignatureNumerator;
  private int                    millisPerMeasure, stopTime;
  public Part()
  {
    sounds       = new ArrayList<Content>();
  }
}
```



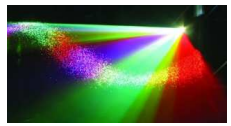
Part – add()

```
public void add(Content c)
{
  if (c != null) sounds.add(c);
}
```



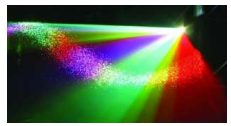
Part – Setters

```
public void setTempo(int millisPerMeasure)
{
  this.millisPerMeasure = millisPerMeasure;
}


public void setTimeSignature(int numerator, int denominator)
{
  this.timeSignatureNumerator   = numerator;
  this.timeSignatureDenominator = denominator;
}
```



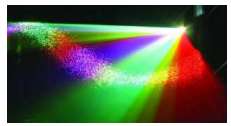
Part – Global Variables

```
private Content                 currentContent,
previousContent;
private Iterator<Content>       iterator;
private Metronome               metronome; // Not Owned
```



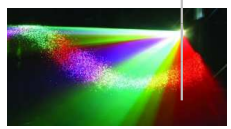
Part – upbeat()

```
public void upbeat(Metronome metronome)
{
  this.metronome    = metronome; // For later removal

  iterator          = sounds.iterator();
  currentContent    = null;
  previousContent   = null;
  stopTime          = -1;

  metronome.addListener(this);
}
```



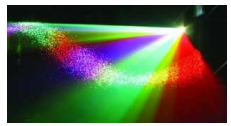
Part – handleTick()

```
public void handleTick(int millis)
{
  double   beats, millisPerBeat;

  if (iterator == null)
    throw(new IllegalStateException("No upbeat()"));

  if (millis >= stopTime)
  {
    if (currentContent != null)
      currentContent.setAudible(false);

    if (iterator.hasNext())
    {
      previousContent = currentContent;
      currentContent  = iterator.next();

      // This calculation needn't really be done each iteration
      millisPerBeat = 1.0/(double)timeSignatureNumerator *
          millisPerMeasure;

      beats         =  (1.0/(double)currentContent.getType()) *
          (double)timeSignatureDenominator;

      if (currentContent.isDotted()) beats = beats * 1.5;

      stopTime = millis + (int)(beats * millisPerBeat);
```



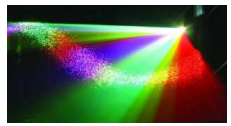
Part – handleTick() (cont.)

```
        currentContent.setAudible(true);
      }
      else
      {
        metronome.removeListener(this);
      }
    }
  }
```



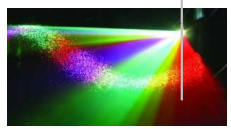
Part – render()

```
public void render(MidiChannel channel)
{
  if (previousContent != null)
    previousContent.render(channel);

  if (currentContent  != null)
    currentContent.render(channel);
}
```



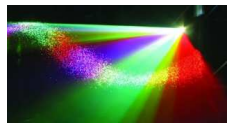
PartFactory

```
package auditory.described;

import java.io.*;

public class PartFactory
{
  public static Part createPart(BufferedReader in)
      throws IOException
  {
    Note                    note;
    Part                    part;
    String                  line;

    part = new Part();

    while ((line = in.readLine()) != null &&
        (!line.equals("X"))              )
    {
      if (!line.equals(""))
      {
        note = NoteFactory.parseNote(line);
        if (note != null) part.add(note);
      }
    }

    return part;
  }
```



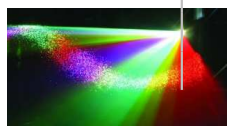
PartFactory (cont.)

```
  public static Part createPart(String filename)
      throws IOException
  {
    BufferedReader          in;

    in = new BufferedReader(new FileReader(filename));

    return createPart(in);
  }
}
```



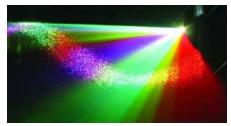
Score – Structure

```
package auditory.described;

import java.util.*;
import javax.sound.midi.*;

import event.*;

public class Score
{
  private HashMap<Part, MidiChannel>          channelMap;
  private HashMap<Part, String>               parts;
  private int                                 timeSignatureDenominator,
  timeSignatureNumerator,
  millisPerMeasure;
  public void addPart(Part part, String instrument)
  {
    parts.put(part, instrument);
  }

  public Iterator<Part> getParts()
  {
    return parts.keySet().iterator();
  }

  public String getInstrumentName(Part part)
  {
```



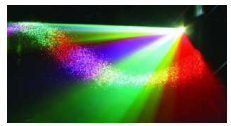
Score – Structure (cont.)

```
    return parts.get(part);
  }

  public void removePart(Part part)
  {
    parts.remove(part);
  }
}
```



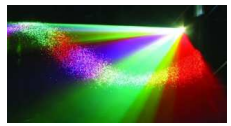
Score – Setters

```
public void setChannel(Part part, MidiChannel channel)
{
  channelMap.put(part, channel);
}

public void setTempo(int millisPerMeasure)
{
  this.millisPerMeasure = millisPerMeasure;
}

public void setTimeSignature(int numerator, int denominator)
{
  this.timeSignatureNumerator   = numerator;
  this.timeSignatureDenominator = denominator;
}
```



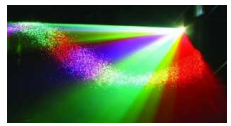
Score – upbeat()

```
public void upbeat(Metronome metronome)
{
  Iterator<Part>              i;
  Part                        part;

  i = parts.keySet().iterator();
  while (i.hasNext())
  {
    part       = i.next();
    part.upbeat(metronome);
    part.setTimeSignature(timeSignatureNumerator,
        timeSignatureDenominator);
    part.setTempo(millisPerMeasure);
  }
}
```

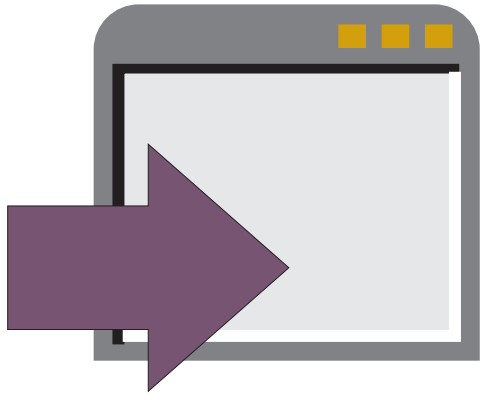


Score – render()

```
public void render()
{
  Iterator<Part>              i;
  MidiChannel                 channel;
  Part                        part;

  i = parts.keySet().iterator();
  while (i.hasNext())
  {
    part       = i.next();
    channel    = channelMap.get(part);
    part.render(channel);
  }
}
```



Orchestra –Demonstration

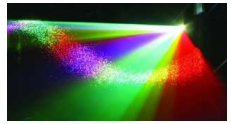


In examples/chapter:

```
java -cp multimedia2.jar:examples.jar OrchestraDemo frerejacques.txt
```

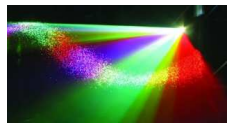
```
java -cp multimedia2.jar:examples.jar OrchestraDemo daytripper.txt
```

```
java -cp multimedia2.jar:examples.jar OrchestraDemo OdeToJoy.txt
```



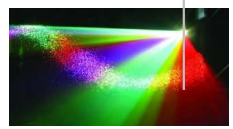
Orchestra – Structure

```
package auditory.described;

import java.io.*;
import java.util.*;

import javax.sound.midi.*;

import event.*;
import io.*;

public class Orchestra implements MetronomeListener
{
  private HashMap<String, Instrument>        instruments;
  private Metronome                          metronome;
  private MidiChannel[]                      channels;
  private Score                              score;
}
```



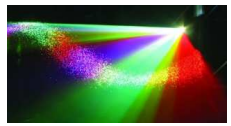
Orchestra – Constructor

```
public Orchestra(Score score) throws MidiUnavailableException
{
  this(score, new Metronome(10));
}


public Orchestra(Score score, Metronome metronome)
    throws MidiUnavailableException
{
  Instrument[]    loaded;
  Soundbank       soundbank;
  Synthesizer     synthesizer;

  this.score     = score;
  this.metronome = metronome;
  metronome.addListener(this);

  instruments  = new HashMap<String, Instrument>();

  synthesizer = MidiSystem.getSynthesizer();
  synthesizer.open();
  soundbank = synthesizer.getDefaultSoundbank();

  if (soundbank == null) soundbank = readSoundbank();

  synthesizer.loadAllInstruments(soundbank);
```



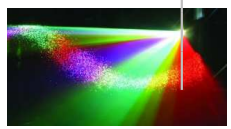
Orchestra – Constructor (cont.)

```
    channels    = synthesizer.getChannels();

    loaded = synthesizer.getLoadedInstruments();
    for (int i=0; i<loaded.length; i++)
    {
      instruments.put(loaded[i].getName().trim(), loaded[i]);
    }
  }
```



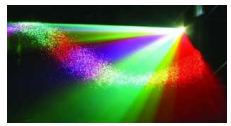
Orchestra – start()

```
public void start()
{
  Iterator<Part>              parts;
  Instrument                  instrument;
  int                         i;
  String                      name;
  Patch                       patch;
  Part                        part;


  parts = score.getParts();
  i = 0;

  while (parts.hasNext())
  {
    part       = parts.next();
    name       = score.getInstrumentName(part);
    instrument = instruments.get(name);

    // Have the channel use the appropriate instrument
    if (instrument == null)
    {
      channels[i].programChange(0, 0);
    }
    else
    {
```



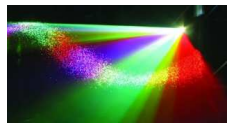
Orchestra – start() (cont.)

```
        patch = instrument.getPatch();
        channels[i].programChange(patch.getBank(),
            patch.getProgram());
      }
      score.setChannel(part, channels[i]);

      score.upbeat(metronome);
    }

    // Start the metronome
    metronome.start();
  }
```



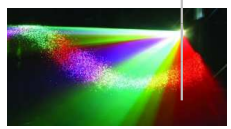
Orchestra – handleTick()

```
public void handleTick(int millis)
{
  score.render();

  if (metronome.getNumberOfListeners() == 1)
  {
    metronome.stop();
  }
}
```



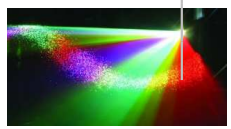
ScoreFactory

```
package auditory.described;

import java.io.*;
import java.util.StringTokenizer;
import javax.sound.midi.MidiUnavailableException;

import io.*;

public class ScoreFactory
{
  private ResourceFinder         finder;

  public ScoreFactory()
  {
    finder = ResourceFinder.createInstance();
  }

  public ScoreFactory(ResourceFinder finder)
  {
    this.finder = finder;
  }

  public Score createScore(InputStream is)
      throws IOException,
      MidiUnavailableException
  {
    BufferedReader         in;
    int                    denominator, numerator, tempo;
```



ScoreFactory (cont.)

```
  Part                    part;
  Score                   score;
  String                  line, voice;
  StringTokenizer         st;

  in = new BufferedReader(new InputStreamReader(is));

  // Read the time signature and tempo
  line        = in.readLine();
  st          = new StringTokenizer(line, ",/");
  numerator   = Integer.parseInt(st.nextToken());
  denominator = Integer.parseInt(st.nextToken());
  tempo       = Integer.parseInt(st.nextToken());

  score = new Score();

  score.setTimeSignature(numerator, denominator);
  score.setTempo(tempo);

  while ((voice = in.readLine()) != null)
  {
    part = PartFactory.createPart(in);
    score.addPart(part, voice);
  }

  return score;
}
```



ScoreFactory (cont.)

```
  public Score createScore(String filename)
      throws IOException,
      MidiUnavailableException
  {
    InputStream             is;

    is = finder.findInputStream(filename);

    return createScore(is);
  }
}
```