Modes and Scales in µO

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Abstract

We discuss the implementation and usage of musical scales in µO. Modes and scales are somewhat overlapping concepts in the musical litterature; in µO the classes `Mode` and `Scale` cover different grounds and are complementary. As an example some modes of the western, 12-tone chromatic scale are explored in details.

Notation

In the following, the printed evaluation of a Smalltalk expression is represented following a ► symbol. When the expression returns a morph a screenshot is displayed after a ►. All code is written in `Consolas font`.

1. `Mode and Scale`

In µO a scale (instance of class `Scale`) is an object maintaining a list of intervals. There is no notion of absolute pitch in a scale (no anchoring in the frequency domain). A scale can span less or more than an octave[1].

A mode (instance of class `Mode`) is another object that builds upon a scale by selecting only part of it: it maintains a list of steps. Besides, a mode also maintains a root frequency, which is the frequency associated with the zero index in the list of steps, also called the tonic. The tonic anchors the mode underlying scale in the frequency domain.

In that model the mode is responsible for the tuning, while the scale is responsible for the temperament.

The western chromatic (12-tone) scale and its diatonic and non-diatonic modes are implemented by specific subclasses `ChromaticMode` and `ChromaticScale` in order to handle the wealth of concepts associated to them in western music theory.

1.1. Scales

To do

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1 A µO scale is identical to what is called scale in the Scala software by Manuel Op de Coul:
http://www.huygens-fokker.org/scala/

1.2. Modes

To do

2. An exploration of mode C major

An example of µO mode is what is commonly called the C major scale. It can be instanciated by the Smalltak expression `Mode C major`, or simply `Mode major`.

2.1. Anatomy of C major

The following expressions tell us everything we need to understand what C major is:

```
Mode major scale
► ChromaticScale (equal-tempered chromatic scale)
```

The mode is built on a chromatic scale (a 12-tone division of the octave) which is equal-tempered by default. That's the usual 12-TET scale of western classical music.

```
Mode major steps  ►  #(2 2 1 2 2 2 1)
```

These are the step intervals of the mode relatively to the scale: to move from the first note of the mode to the second we need two steps in the scale, then two more steps for the next note, then one step, and so on.

Here a step is a semitone, two steps form a whole tone.

```
Mode major tuning  ►  9->440.0
```

The mode anchors the scale index number 9 to frequency 440 Hz. From this relationship all other notes get their frequency.

```
Mode major tonicScaleStep  ►  0
Mode major tonic  ►  c
```

The mode tonic is at scale step 0, which by convention is middle C.

```
Mode major noteNames
► #('c' 'c+' 'd' 'e-' 'e' 'f' 'f+' 'g' 'a-' 'a' 'b-' 'b')
```

This shows how the mode names the notes in the scale, starting at index 0. We can see here that the note at scale index 9 is A, so the mode tuning is a 440Hz A.

```
Mode major asMusicalPhrase
▶ 'c,d,e,f,g,a,b'
```

Here we can play the mode notes.

2.2. D major

What is the structural difference between C major and D major ? Obviously it's simply the tonic:

```
Mode D major tonicScaleStep ▶ 2
Mode D major tonic ▶ d

Mode D major asMusicalPhrase
▶ 'd,e,f+,g,a,b,c+o4'
```

Steps and tuning do not change:

```
Mode D major steps ▶ #(2 2 1 2 2 2 1)
Mode D major tuning ▶ 9->440.0
```

We could instanciate D major by transposing C major one modal step up:

```
Mode C major transposeBySteps: 1
▶ Mode D major
```

D major does not name the notes exactly in the same way as C major:

```
Mode D major noteNames
▶ #('c' 'c+' 'd' 'd+' 'e' 'f' 'f+' 'g' 'g+' 'a' 'a+' 'b')
```
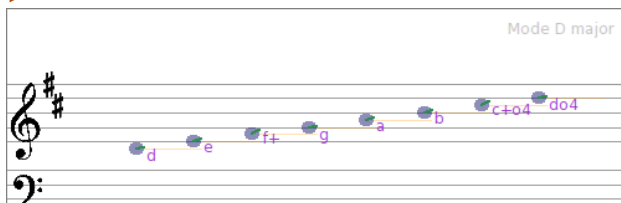
We can see that all black keys are named as sharp. To get C major to do the same we would have to send it `#useSharps` :

```
Mode major useSharps noteNames
▶ #('c' 'c+' 'd' 'd+' 'e' 'f' 'f+' 'g' 'g+' 'a' 'a+' 'b')
Mode major useFlats noteNames
▶ #('c' 'd-' 'd' 'e-' 'e' 'f' 'g-' 'g' 'a-' 'a' 'b-' 'b')
```

The reason why D major automatically use sharps has to do with its key signature:

```
Mode D major keySignature
▶ #($+ 10 7)

Mode D major viewWithSignature
▶
```
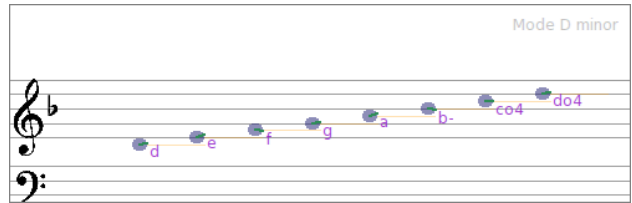

2.2. D minor

D minor has flats in its key signature:

```
Mode D minor keySignature
▶ #($- 6)
Mode D minor noteNames
▶ #('c' 'd-' 'd' 'e-' 'e' 'f' 'g-' 'g' 'a-' 'a' 'b-' 'b')

Mode D minor viewWithSignature
▶
```


What is the structural difference between D major and D minor ? Only the steps:

```
Mode D minor steps ▶ #(2 1 2 2 1 2 2)

Mode D minor asMusicalPhrase
▶ 'd,e,f,g,a,b-,co4'
```

There is an interplay between the steps and the tonic. D minor has the same pitch classes than a major mode with the appropriate tonic:

```
Mode D minor asMode: #major
▶ Mode F major
```

And inversely:

```
Mode F major asMode: #minor
▶ Mode D minor
```

In music theory this is called the relative key:

```
Mode D minor relativeKey
▶ Mode F major
Mode F major relativeKey
▶ Mode D minor
```

2.2. The diatonic modes

We call diatonic modes all chromatic modes whose steps are a rotation of `#(2 2 1 2 2 2 1)`. There are seven different diatonic modes:

```
ChromaticMode diatonicModes
▶ #(#major #dorian #phrygian #lydian #mixolydian
#aeolian #locrian)

Mode major steps ▶ #(2 2 1 2 2 2 1)
Mode dorian steps ▶ #(2 1 2 2 2 1 2)
Mode phrygian steps ▶ #(1 2 2 2 1 2 2)
Mode lydian steps ▶ #(2 2 2 1 2 2 1)
Mode mixolydian steps ▶ #(2 2 1 2 2 1 2)
Mode aeolian steps ▶ #(2 1 2 2 1 2 2)
Mode locrian steps ▶ #(1 2 2 1 2 2 2)
```
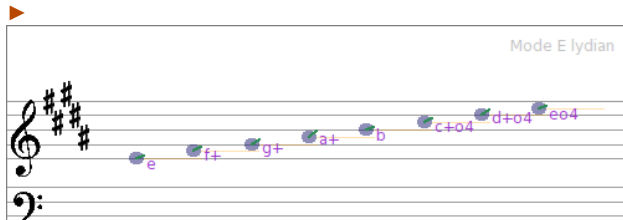
We can see that `aeolian` is a synonym of `minor`.

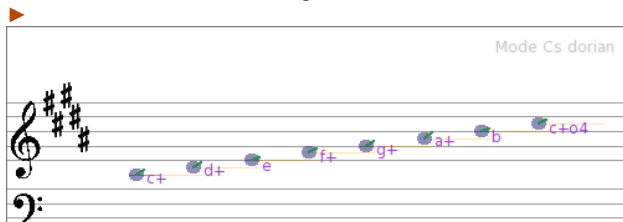The interplay between steps and tonic applies to all of the diatonic modes, with any tonic:

```
Mode D minor asMode: #mixolydian
► Mode C mixolydian

Mode E lydian asMode: #dorian
► Mode Cs dorian

Mode E lydian viewWithSignature
►
```



```
Mode Cs dorian viewWithSignature
►
```


2.3. Chords

To do

2.4. Temperament and tuning

To do

3. Modal pitch

To do

4. Inflexions repository

To do