# likely music

Probabilistische Musiknotation

Lukas Epple

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**Zusammenfassung**

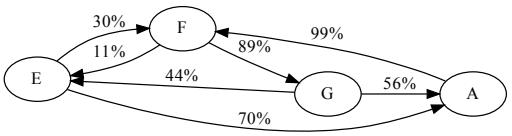
*likely music* ist eine Software, um probabilistiche Musik zu notieren und abzupsielen. Probabilistische Musik heißt in diesem Falle, dass die Interpretation der vorliegenden Notation deutlich freier ist als bei herkömmlicher Musik und auch die Reihenfolge der Noten betrifft. Um dies zu erreichen wird ein eigenes Modell von Musiknotation verwendet. An Stelle der Lineare Reihenfolge von Noten bzw. Akkorden tritt ein Graph, in dem die Noten (bzw. Akkorde) die Knoten und die Kanten die möglichen Übergange zwischen diesen darstellen, wobei jede Kante eine gewisse Wahrscheinlichkeit zugeordnet ist. Dieses Modell ist unter anderem sehr gut von einem Computer zu fassen, wodurch es möglich wird, solche Notationen automatisch zu „interpretieren“ bzw. abzuspielen, indem eine Notenabfolge gemäß der Notation ausgewürfelt wird.

*likely music* kann also sowohl probabilistische Noten erstellen und editieren, als auch mittels MIDI diese abspielen oder als Audiodateien exportieren.

## Idee

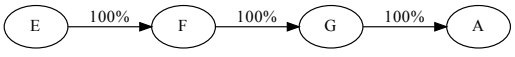
Der eigentlichen Idee ging ein mehr oder minder gescheitertes Projekt für diesen Wettbewerb vorraus. Im Frühjahr diesen Jahres entschied ich mich dieses, eine Demo [1], abzubrechen, einfach weil ich befürchtete, es nicht bis zur Frist fertigstellen zu können. Die Motivation für dieses Projekt speiste sich aus meiner Faszination für Demos an sich, denn ich hatte bereits im Vorfeld öfters mich mit diesen beschäftigt und beim Ansehen der Einsendung von Demo-Wettbewerben ein Bedürfnis entwickelt auch so etwas zu entwickeln. Das neue Projekt speiste sich aus einer weiteren Faszination von mir, nämlich einer für Kunst, die basierend auf Kunst entsteht. Ich erinnere mich oft besonders an Kunstinstallationen, die ihr gestaltendes Element durch Zufall oder einen undurchschaubaren oder chaotischen Prozess bezieht. Beim Nachdenken über Zwölftonmusik, die – meiner Meinung nach – ein wenig jenen Elements hat, kam mir die Grundidee – wie ich mich erinnere – auf dem Gang zwischen zwei Schulstunden für *likely music*, nämlich ein Modell, um Musik zu beschreiben, die zufällig im Vortrag ist.

Das Modell, das ich übertrieben panisch auf ein Stück Notizblock kritzelte, sieht Musik als gerichteten Graphen, wobei die Knoten Musiknoten einer bestimmten Länge und die Kanten zwischen ihnen die Wahrscheinlichkeit des Wechsel von der einen Note zu anderen. Vorstellen kann man sich es in etwa so:



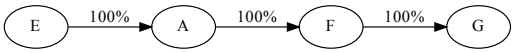

In diesem konkreten Graphen sind die Noten E, F, G und A als Knoten vertreten (der Einfachheit halber sind die Notenlängen weggelassen). Beispielsweise vom E führen zwei Kanten weg, eine zum F mit dreißigprozentiger Wahrscheinlichkeit und eine zum A mit siebzigprozentiger Wahrscheinlichkeit, d. h. nach dem E kommt in sieben von zehn Fällen das A und in den drei übrigen das F, analog gilt verhält es sich mit den anderen Noten.

Diese Darstellung ist in gewisser Weise auch nur eine ausdrucksstärkere Form einer normalen Notation, denn ein Weg durch den obigen Graphes könnte so aussehen:




Diese Interpretation, die eine Wahrscheinlichkeit von ca. 15% hat aufzutreten, entspricht einer einfachen, linearen Notation wie sie in einem Gesangsbuch stehen könnte. Wir sehen also, dass solche

probabilistiche Noten (wie unser Graph von vorhin) durch ein Verfahren, das ich einfach in einer Erweiterung des Begriffs als Interpretieren bezeichen, auf eine lineare Notation reduziert werden kann, die mit einem Instrument oder vom Computer gespielt werden kann. Es ist sogar nicht nur eine lineare Notation, sondern – je nach vorgegebenen Graph – eine Vielzahl ihrer möglich. Beispielsweise wäre eine weitere:




Ähnlich gibt es noch viele weiter Möglichkeiten. Zu beachten ist bei den beiden Beispielinterpretationen noch: Sie sind nach vier Noten abgeschnitten, denn, da von jedem Knoten mindestens eine Kante ausgeht, könnte man den Graphen potentiell unendlich lang ablaufen und würde somit eine unendlich lange Interpretation generieren.

Was aus dieser Grundidee zu machen war, schien mir von Anfang an recht klar: Als Software implementieren, um ein graphisches Interface bereitzustellen, das es erlaubt, probabilistische Notation zu erstellen, zu editieren und abzuspielen.

# Umsetzung

## Lizenzierung

# Benutzung

# Zukünftige Weiterentwicklung

# Anhang

## Quelltext

### Library

**lib/Sound/Likely.hs**

```
{-# LANGUAGE OverloadedStrings #-}
{-# LANGUAGE FlexibleInstances #-}
module Sound.Likely
  ( Probability
  , ID
  , Node (..)
  , Edge (..)
  , Graph (..)
  , insertNode
  , insertEdge
  , interpretation
  , takeNotes
  , emptyMusic
  , exampleGraph
  ) where

import Control.Monad
import Data.Aeson
import Data.Aeson.Types (Parser ())
import Data.Maybe
import Data.Text (Text ())
import Euterpea
import System.Random
import qualified Data.Map as M
import qualified Data.Set as S

type Probability = Double
type ID = Text

data Node
  = Node
  { nId :: ID
  , nMusic :: Music Pitch
  } deriving (Show, Eq, Ord)

data Edge
  = Edge
  { eTo   :: Node
  , eProb :: Probability
  } deriving (Show, Eq, Ord)

newtype Graph = Graph { unGraph :: M.Map Node (S.Set Edge) }
  deriving (Show, Eq, Ord)
```

```
insertNode :: Node -> Graph -> Graph
insertNode t = Graph . M.insertWith S.union t S.empty . unGraph

insertEdge :: Node -> Edge -> Graph -> Graph
insertEdge n e =
  insertNode n . Graph . M.insertWith S.union n (S.singleton e) . unGraph

interpretation :: RandomGen g => g -> Graph -> Node -> Music Pitch
interpretation gen graph n = (nMusic n) :+:
  recurse (fromMaybe S.empty (M.lookup n (unGraph graph)))
  where (prob, gen') = randomR (0.0, 1.0) gen
        recurse edges =
          if S.null edges
            then emptyMusic
            else interpretation gen' graph
                 . eTo . edgeForRoll prob $ edges

edgeForRoll :: Probability -> S.Set Edge -> Edge
edgeForRoll prob set =
  let curr = S.elemAt 0 set
    in if prob <= eProb curr
         then curr
         else edgeForRoll (prob - eProb curr) (S.delete curr set)

emptyMusic :: Music a
emptyMusic = Prim (Rest 0)

exampleGraph :: Graph
exampleGraph = Graph $ M.fromList
  [ (Node "bla" (c 4 qn), S.fromList [ Edge (Node "blub" (d 4 qn)) 1 ] )
  , (Node "blub" (d 4 qn), S.fromList [ ])
  ]

-- | Take the first @n@ notes of a 'Music'
takeNotes :: Integer -> Music a -> Music a
takeNotes _ m@(Prim _) = m
takeNotes n (Modify c m) = Modify c $ takeNotes n m
takeNotes _ m@(_ :=: _) = m
takeNotes n (m1 :+: m2)
  | n <  1    = emptyMusic
  | n == 1    = m1
  | otherwise = m1 :+: takeNotes (n - 1) m2

instance FromJSON Node where
  parseJSON = withObject "Node" $ \v ->
    Node <$> v .: "id" <*> (Prim <$> v .: "music")

lookupNode :: Text -> [Object] -> Parser Node
lookupNode id nodes = do
```

```
  matches <- filterM (fmap (== id) . (.: "id")) nodes
  case matches of
    [node] -> parseJSON (Object node)
    _ -> fail "Couldn't match node by id"

buildMap :: [Object] -> [Object] -> Graph -> Parser Graph
buildMap _ [] m = pure m
buildMap nodes (e:es) m = do
  toId <- e .: "to"
  fromId <- e .: "from"
  edge <- Edge <$> lookupNode toId nodes <*> e .: "prob"
  from <- lookupNode fromId nodes
  buildMap nodes es $ insertEdge from edge m

instance FromJSON Graph where
  parseJSON = withObject "Graph" $ \v -> do
    edges <- v .: "edges"
    nodes <- v .: "nodes"
    buildMap nodes edges $ Graph mempty

instance FromJSON (Primitive Pitch) where
  parseJSON = withObject "Primitive" $ \v -> do
    -- TODO Ratio _Integer_ is easy DOSable
    -- RAM consumption
    duration <- v .: "dur"
    octave <- v .: "octave"
    pitchClass <- v .: "pitch"
    case pitchClass of
      "Rest" -> pure $ Rest duration
      p -> pure $ Note duration (read pitchClass, octave)
```

**Backend**

**backend/Api.hs**

```
{-# LANGUAGE OverloadedStrings #-}
{-# LANGUAGE FlexibleInstances #-}
{-# LANGUAGE DataKinds         #-}
{-# LANGUAGE TypeOperators     #-}
module Api where

import Data.Aeson
import Data.ByteString.Lazy (ByteString ())
import Data.Monoid ((<>))
import Data.Ratio
import Data.Text (Text ())
import GHC.Generics
import Servant.API
import Sound.Likely
```

```
type LikelyApi = "interpretation" :> Capture "format" OutputFormat
                                  :> ReqBody '[JSON] GraphWithParams
                                  :> Post '[OctetStream] ByteString
            :<|> "seed" :> Get '[JSON] Int
            :<|> Raw

data OutputFormat = Midi | Wav
  deriving (Show, Eq, Ord)

instance FromHttpApiData OutputFormat where
  parseUrlPiece "mid" = Right Midi
  parseUrlPiece "wav" = Right Wav
  parseUrlPiece x     = Left $ "Couldn't match " <> x <> " with {mid, wav}"

data GraphWithParams
  = GraphWithParams
  { gpParams :: Params
  , gpGraph  :: Graph
  } deriving (Show, Eq, Ord)

instance FromJSON GraphWithParams where
  parseJSON = withObject "GraphWithParams" $ \v ->
    GraphWithParams <$> v .: "params"
                    <*> v .: "graph"

data Params
  = Params
  { pMaxHops      :: Int
  , pStartingNode :: Node
  , pSeed         :: Int
  } deriving (Show, Eq, Ord)

instance FromJSON Params where
  parseJSON = withObject "Params" $ \v ->
    Params <$> v .: "maxhops"
           <*> v .: "starting_node"
           <*> v .: "seed"
```

**backend/Main.hs**

```
{-# LANGUAGE OverloadedStrings #-}
module Main where

import Api

import Codec.Midi (buildMidi)
import Codec.ByteString.Builder
import Control.Monad.IO.Class
import Data.ByteString.Lazy (ByteString ())
import qualified Data.ByteString.Lazy as B
import Euterpea hiding (app)
```

```
import GHC.IO.Handle
import Network.Wai
import Network.Wai.Handler.Warp
import Servant
import Sound.Likely
import System.Directory
import System.Exit
import System.Environment
import System.FilePath.Posix
import System.IO
import System.Process
import System.Random

api :: Proxy LikelyApi
api = Proxy

midiString :: ToMusic1 a => Music a -> ByteString
midiString = toLazyByteString . buildMidi . toMidi . perform

server :: Server LikelyApi
server = genInterpretation :<|> randomSeed :<|> serveDirectoryWebApp "web/
    dist"

randomSeed :: Handler Int
randomSeed = liftIO newStdGen >>= return . fst . random

genInterpretation :: OutputFormat -> GraphWithParams -> Handler ByteString
genInterpretation Midi g = do
  let params       = gpParams g
      maxHops      = fromIntegral . pMaxHops $ params
      randomGen    = mkStdGen $ pSeed params
      song         = interpretation randomGen (gpGraph g) (pStartingNode
          params)
  return . midiString $ takeNotes maxHops song
genInterpretation Wav g = genInterpretation Midi g >>= synthWav

synthWav :: ByteString -> Handler ByteString
synthWav midi = do
  inName <- tempFile "mid"
  liftIO $ B.writeFile inName midi
  outName <- tempFile "wav"
  (_, _, _, ph) <- liftIO $
    createProcess_ "fluidsynth"
      (proc "fluidsynth"
        [ "-a", "file"
        , "-F", outName
        , "-i"
--        , "/usr/share/sounds/sf2/FluidR3_GM.sf2"
        , "/nix/store/591834mz365ccwyj3ah2d66ncsqvp8w9-Fluid-3/share/
            soundfonts/FluidR3_GM2-2.sf2"
```

```
        , inName ])
        { std_in = CreatePipe }
  code <- liftIO $ waitForProcess ph
  case code of
    ExitFailure _ -> throwError err500 { errBody = "fluidsynth failed" }
    ExitSuccess -> do
      out <- liftIO $ B.readFile outName
      liftIO $ removePathForcibly outName
      return out

tempFile :: String -> Handler FilePath
tempFile ext = try 0
  where maxtries = 100
        try :: Integer -> Handler FilePath
        try n
          | n < maxtries = do
            progName <- liftIO $ getProgName
            let path = "/tmp" </> addExtension (makeValid progName ++ "-"
               ++ show n) ext
            exists <- liftIO $ doesFileExist path
            if exists
              then try (n + 1)
              else pure path
          | otherwise = throwError err500
app :: Application
app = serve api server

main :: IO ()
main = newStdGen >> run 8081 app
```

**Web**

**web/source/index.html**

```
<!doctype html>
<html>
    <head>
        <meta charset="utf-8">
        <meta http-equiv="x-ua-compatible" content="ie=edge" />
        <meta name="viewport" content="width=device-width, initial-scale=1"
            />
        <title>likely music</title>
        <link rel="stylesheet" type="text/css" href="custom.css">
        <link rel="stylesheet" type="text/css" href="vis.min.css">
        <script src="main.js"></script>
    </head>
    <body>
        <div id="network"></div>
        <div id="sidebar">
            <h1>likely music</h1>
```

```
    <h2>General Settings</h2>
    <button id="set-starting-node">Set starting node</button>
    <button id="show-starting-node">Show starting node</button>
    <h2>Generate an interpretation</h2>
    <div class="multi-inputs">
        <label for="seed">Seed:</label>
        <input type="number" id="seed">
        <button id="random-seed">&amp;#8634;</button>
    </div>
    <div class="multi-inputs">
        <label for="hop-count">Length:</label>
        <input type="number" min="0" id="hop-count" placeholder="
            Max. note count">
    </div>
    <div id="player-container">
        <button id="reload-player">&amp;#8634;</button>
        <audio id="player" controls></audio>
    </div>
    <div class="multi-inputs">
        <button id="download-audio">Download</button>
        <label for="format">
            as
        </label>
        <select id="format">
            <option value="mid">MIDI</option>
            <option value="wav">WAV</option>
        </select>
    </div>
    <h2>Load or Save Work</h2>
    <button id="gen-score" class="save">Save</button>
    <label for="upload-score" class="custom-file">
        <input type="file" id="upload-score" >
        <span>Load</span>
    </label>
    <button id="clear-score" class="cancel">Clear</button>
</div>
<div id="edge-overlay" class="hidden dialog">
    <h2><span id="edge-operation"></span> edge</h2>
    <div class="multi-inputs">
        <label for="prob">Probability:</label>
        <input id="prob" type="number" min="0.0" max="100">
        <span>%</span>
    </div>
    <div class="multi-inputs">
        <button class="save" id="edge-save">Save</button>
        <button class="cancel" id="edge-cancel">Cancel</button>
    </div>
</div>
<div id="node-overlay" class="hidden dialog">
    <h2><span id="node-operation"></span> node</h2>
```

```
            <div class="multi-inputs">
                <label for="pitch">Pitch:</label>
                <select id="pitch"></select>
            </div>
            <div class="multi-inputs">
                <label for="octave">Octave:</label>
                <input id="octave" type="number" step="1">
            </div>
            <div class="multi-inputs">
                <label>Duration:</label>
                <input min="0" id="numerator" type="number" step="1">
                <span>/</span>
                <input min="0" id="denominator" type="number" step="1">
            </div>
            <div class="multi-inputs">
                <button class="save" id="node-save">Save</button>
                <button class="cancel" id="node-cancel">Cancel</button>
            </div>
        </div>
    </body>
</html>
```

**web/source/custom.css**

```
body {
    font-size:1em;
    font-family: sans-serif;
    margin: 0px;
    background-color: black;
}

#network {
    width: 79%;
    float:left;
    height: 100vh;
}

#sidebar {
    width: 20%;
    float:right;
    color: white;
    background-color: black;
    box-shadow: 0px 0px 20px #111;
    font-size: 1.2rem;
}

#sidebar > * {
    width: 100%;
    border-top: 1px solid #232200;
    color: white;
    padding-left: 0px;
```

```
    padding-right: 0px;
    margin: 0;
}

#sidebar button:hover, #sidebar input:hover,
#sidebar .custom-file:hover, #sidebar select:hover {
    background-color: #563d7c;
}

#sidebar button, #sidebar input, #sidebar .custom-file, #sidebar select {
  background-color: #000;
}

#sidebar h1 {
    font-size: 1.5rem;
    padding-top: 0.75rem;
    padding-bottom: 0.75rem;
    text-align: center;
    background-color: #111;
}

#sidebar h2 {
    font-size: 1.2rem;
    padding-top: 0.9rem;
    padding-bottom: 0.9rem;
    text-align: center;
    background-color: #222;
}

#sidebar select {
  color: white;
  border: none;
  padding: 0.75rem;
  font-size: 1.2rem;
  width: auto;
}

button {
    border: none;
    color: white;
    background-color:black;
    font-size: 1.2rem;
    margin:0;
    padding:0.75rem;
}

input[type="number"] {
    background-color: #333;
    color: white;
    border: none;
```

```
    text-align: center;
    font-size: 1.2rem;
    padding:0.75rem;
}

.custom-file {
    top:0;
    right:0;
    position: relative;
    display: inline-block;
    height: 3rem;
}

.custom-file input[type="file"] {
    position: relative;
    top:0;
    left:0;
    right:0;
    z-index:0;
    opacity: 0;
    width: 100%;
    height: 100% !important;
    margin:0;
    padding:0;
}

.custom-file span {
    text-align: center;
    position: absolute;
    top: 0;
    left: 0;
    right: 0;
    z-index: 1;
    width: 100%;
    height: 3rem;
    pointer-events: none;
    background-color: transparent !important;
    font-size: 1.2rem;
    line-height: 1.5rem;
    padding-top: 0.75rem;
    padding-bottom: 0.75rem;
}

.dialog {
    position: absolute;
    top: 10%;
    left: 25%;
    width: 30%;
    min-width:500px;
    padding: 10px;
```

```
    background-color: black;
    color: white;
    box-shadow: 0px 0px 10px #111;
}

.dialog > div {
    height: 3rem;
}

.hidden {
    visibility:hidden;
}

.dialog > div {
  width: 100%;
}

.dialog button {
    padding: 0.75rem;
    font-size: 1.5rem;
}

button.cancel {
    background-color: #a23a30;
}

button.save {
    background-color: #0ea92f;
}

.dialog .multi-inputs {
  font-size: 1.5rem;
}

.multi-inputs {
  display: inline-flex;
  flex-direction: row;
  flex-wrap: nowrap;
  justify-content: flex-start;
  align-items: baseline;
  width: 100%;
}

.multi-inputs > * {
  flex-grow: 1;
  flex-basis: auto;
  transition: width 0.7s ease-out;
  max-height: 100%;
  text-align: center;
}
```

```
.multi-inputs :nth-child(1) {
  text-align: left;
}

.multi-inputs label {
  display: inline-block;
  background-color: #333;
  padding: 0.75rem;
}

.multi-inputs input {
  display: inline-block;
  color: white;
  background-color: #111;
  padding: 0.75rem;
  border: none;
  min-width: 0px;
}

.multi-inputs span {
  display: inline-block;
  padding: 0.75rem;
  background-color: #222;
}

.multi-inputs button {
    padding: 0.75rem;
}

#player-container {
  display: inline-flex;
  align-items: center;
}

#player-container > * {
  flex: auto;
}
```

**web/source/main.js**

```
import vis from 'vis';
import { Map } from 'immutable';
// types / internals

const valid_pitches = [
    'Rest',
    'Cff', 'Cf', 'C',
    'Dff', 'Cs', 'Df',
    'Css', 'D', 'Eff',
    'Ds', 'Ef', 'Fff',
```

```
    'Dss', 'E', 'Ff',
    'Es', 'F', 'Gff',
    'Ess', 'Fs', 'Gf',
    'Fss', 'G', 'Aff',
    'Gs', 'Af', 'Gss',
    'A', 'Bff', 'As',
    'Bf', 'Ass', 'B',
    'Bs', 'Bss'
];

const display_pitches = [
    'Rest',
    ' C', 'C', 'C',
    ' D', 'C', 'D',
    'C', 'D', ' E',
    'D', 'E', ' F',
    'D', 'E', 'F',
    'E', 'F', 'Gff',
    'E', 'F', 'G',
    'F', 'G', ' A',
    'G', 'A', 'G',
    'A', ' B', 'A',
    'B', 'A', 'B',
    'B', 'B'
];

function displayPitch(pitch) {
    var i = valid_pitches.indexOf(pitch);
    if(i === -1) {
        throw 'Invalid pitch';
    } else {
        return display_pitches[i];
    }
}

function standard_rests(dur) {
    if(dur.numerator === 1) {
        switch(dur.denominator) {
            case 1:
                return '';
                break;
            case 2:
                return '';
                break;
            case 4:
                return '';
                break;
            case 8:
                return '';
                break;
```

```
            case 16:
                return '';
                break;
            case 32:
                return '';
                break;
            case 64:
                return ''
                break;
            case 128:
                return ''
                break;
            default:
                return null;
                break;
        }
    } else {
        return null;
    }
}

function standard_notes(dur) {
    if(dur.numerator === 1) {
        switch(dur.denominator) {
            case 1:
                return '';
                break;
            case 2:
                return '';
                break;
            case 4:
                return '';
                break;
            case 8:
                return '';
                break;
            case 16:
                return '';
                break;
            case 32:
                return '';
                break;
            case 64:
                return ''
                break;
            case 128:
                return ''
                break;
            default:
                return null;
```

```
                break;
        }
    } else if(dur.numerator === 2 && dur.denominator === 1) {
        return ''
    } else {
        return null;
    }
}

function musical_symbol(lookup, dur) {
    const dot = ' ';
    var standard_symbol = lookup(dur);
    if(standard_symbol !== null) {
        return standard_symbol;
    } else {
        return dur.toString();
    }
}

class Music {
    constructor(dur, pitch_class, octave) {
        this.dur = dur;
        if(valid_pitches.indexOf(pitch_class) !== -1) {
            this.pitch = pitch_class;
        } else {
            throw `Invalid pitch class '${pitch_class}'`;
        }
        this.octave = octave;
    }

    toString() {
        if(this.pitch === 'Rest') {
            return `${displayPitch(this.pitch)} for ${this.dur.toString()
                }`;
        } else {
            return `${displayPitch(this.pitch)}${this.octave} for ${this.
                dur.toString()}`;
        }
    }

    nodeText() {
        if(this.pitch === 'Rest') {
            // alignment using a space! #justvisjsthings
            return ` ${musical_symbol(standard_rests, this.dur)}`;
        } else {
            return `${musical_symbol(standard_notes, this.dur)}   ${
                displayPitch(this.pitch)}${this.octave}`
        }
    }
```

```
    static fromObject(obj) {
        return new Music(Rational.fromObject(obj.dur), obj.pitch, Number(
            obj.octave));
    }
}

class Rational {
    constructor(a, b) {
        this.numerator = a;
        this.denominator = b;
        this.reduce();
    }

    reduce() {
        let gcd = (a, b) => !b ? a : gcd(b, a % b);
        let div = function(a, b) {
            if(b === 0) {
                throw 'Divide by zero';
            } else {
                return Math.floor(a / b);
            }
        };

        var d = gcd(this.numerator, this.denominator);
        this.numerator = div(this.numerator, d);
        this.denominator = div(this.denominator, d);
    }

    toString() {
        return `${this.numerator}/${this.denominator}`;
    }

    static fromObject(obj) {
        return new Rational(obj.numerator, obj.denominator);
    }
}

function collectGraphData(nodeDate, edgeData) {
    return {
        nodes: [... nodeData.values()].map(x => ({
            id: x.nodeData.id,
            music: x.music
        })),
        edges: [... edgeData.values()].map(x => ({
            id: x.edgeData.id,
            from: x.edgeData.from,
            to: x.edgeData.to,
            prob: x.prob
        }))
```

```
    };
}

function importGraphData(g) {
    nodeData = new Map();
    edgeData = new Map();
    var nodeSet = new vis.DataSet({});
    var edgeSet = new vis.DataSet({});
    for(let node of g.nodes) {
        var music = Music.fromObject(node.music);
        var data = { id: node.id, label: music.nodeText() };
        nodeData = nodeData.set(node.id, { nodeData: data, music: node.
            music });
        nodeSet.add(data);
    }

    for(let edge of g.edges) {
        var data = {
            id: edge.id,
            from: edge.from,
            to: edge.to,
            label: `${edge.prob * 100}%`
        };
        edgeData = edgeData.set(edge.id, { edgeData: data, prob: edge.prob
            });
        edgeSet.add(data);
    }

    network.setData({ nodes: nodeSet, edges: edgeSet });
}

// helper

function download(url, filename) {
    var link = document.createElement('a');
    link.setAttribute('href', url);
    link.setAttribute('download', filename);
    link.style.display = 'none';
    document.body.appendChild(link);
    link.click();
    document.body.removeChild(link);
}

function downloadFile(content_type, filename, content) {
    var data = `data:${content_type},${encodeURIComponent(content)}`;
    download(data, filename);
}


// graph code
```

```
var nodeData = Map();
var edgeData = Map();
var network = null;
var starting_node_id = null;


function showOverlay(id) {
    document.getElementById(id).classList.remove('hidden');
}

function genericEditNode(data, callback) {
    function clearOverlay() {
        document.getElementById('node-save').onclick = null;
        document.getElementById('node-cancel').onclick = null;
        hideOverlay('node-overlay');
    }

    function saveNode(data, callback) {
        var duration = new Rational(document.getElementById('numerator').
            value,
            document.getElementById('denominator').value);
        var music = new Music(duration, document.getElementById('pitch').
            value,
            Number(document.getElementById('octave').value));
        data.label = music.nodeText();
        clearOverlay();
        callback(data);
        nodeData = nodeData.set(data.id, { music: music, nodeData: data });
    }

    function discardNode(callback) {
        clearOverlay();
        callback(null);
    }

    showOverlay('node-overlay');
    var node = nodeData.get(data.id);
    if(node !== undefined) {
        var music = node.music;
        document.getElementById('pitch').value = music.pitch;
        document.getElementById('octave').value = music.octave;
        document.getElementById('numerator').value = music.dur.numerator;
        document.getElementById('denominator').value = music.dur.
            denominator;
    }
    document.getElementById('node-save').onclick = saveNode.bind(this, data
        , callback);
    document.getElementById('node-cancel').onclick = discardNode.bind(this,
         callback);
```

```
}

function genericEditEdge(data, callback) {
    function clearOverlay() {
        document.getElementById('edge-save').onclick = saveEdge.bind(this,
            data, callback);
        document.getElementById('edge-cancel').onclick = discardEdge.bind(
            this, callback);
        hideOverlay('edge-overlay');
    }

    function saveEdge(data, callback) {
        // for some reason, editWithoutDrag
        // sets from & to to the node respective
        // node objects, which results in the edge
        // disappearing.
        if (typeof data.to === 'object')
            data.to = data.to.id
        if (typeof data.from === 'object')
            data.from = data.from.id

        var prob = document.getElementById('prob').value / 100;
        data.label = `${prob * 100}%`;
        clearOverlay();
        callback(data);
        edgeData = edgeData.set(data.id, { prob: prob, edgeData: data } );
    }

    function discardEdge(callback) {
        clearOverlay();
        callback(null);
    }

    showOverlay('edge-overlay');
    var edge = edgeData.get(data.id);
    if(edge !== undefined) {
        document.getElementById('prob').value = edge.prob * 100;
    }
    document.getElementById('edge-save').onclick = saveEdge.bind(this, data
        , callback);
    document.getElementById('edge-cancel').onclick = discardEdge.bind(this,
         callback);
}

function deleteFromMap(data, callback) {
    for(let node of data.nodes) {
        nodeData = nodeData.delete(node);
    }

    for(let edge of data.edges) {
```

```
        edgeData = edgeData.delete(edge);
    }

    callback(data);
}


function hideOverlay(id) {
    document.getElementById(id).classList.add('hidden');
}

function handleImport() {
    var files = document.getElementById('upload-score').files;
    if(files.length === 0) {
        alert('Select a file first!');
    } else {
        var file = files[0];
        var reader = new FileReader();
        reader.addEventListener('loadend', function() {
            var parsed = JSON.parse(this.result);
            if(parsed === undefined) {
                alert('Could not parse likely score');
            } else {
                var confirmation = window.confirm('Proceeding will
                    overwrite the current graph. Are you sure?');
                if(confirmation) {
                    try {
                        importGraphData(parsed);
                    } catch(e) {
                        alert(`Could not import likely score, probably the
                            file was malformed. Error: ${e}`);
                    }
                }
            }
        });
        reader.readAsText(file);
    }
}

function saveDataToLocalStorage() {
    const json = JSON.stringify(collectGraphData(nodeData, edgeData));
    const params = JSON.stringify(gatherParams());
    localStorage.setItem("score", json)
    localStorage.setItem("params", params)
}

function showStartingNode() {
    if(typeof starting_node_id === 'string') {
        network.selectNodes([starting_node_id], false);
    } else {
```

```
        alert('No starting node selected yet!');
    }
}

function setStartingNode() {
    var selected = network.getSelectedNodes();
    if(selected.length > 1) {
        alert('Only select one node!');
    } else if(selected.length === 0) {
        alert('Select a node first!');
    } else {
        starting_node_id = selected[0];
    }
}

function fetchInterpretation(params, format) {
    var jsonRequest = JSON.stringify({
        graph: collectGraphData(nodeData, edgeData),
        params: params
    });

    var myHeaders = new Headers();
    myHeaders.set('Content-Type', 'application/json');

    var myInit = {
        method: 'POST',
        headers: myHeaders,
        mode: 'cors',
        body: jsonRequest
    };

    var myRequest = new Request(`http://localhost:8081/interpretation/${
       format}`, myInit);

    return fetch(myRequest).then(res => res.blob());
}

function gatherParams() {
    var starting_node_entry = nodeData.get(starting_node_id);
    if(starting_node_entry !== undefined && starting_node_entry !== null) {
        var starting_node = {
            id: starting_node_entry.nodeData.id,
            music: starting_node_entry.music
        };
    } else {
        var starting_node = null
    }

    var maxhops = document.getElementById('hop-count').value;
    if(maxhops === "" || Number(maxhops) === NaN) {
```

```
        maxhops = null;
    } else {
        maxhops = Number(maxhops);
    }

    var seed = document.getElementById('seed').value;
    if(seed === "" || Number(seed) === NaN) {
        seed = null;
    } else {
        seed = Number(seed);
    }

    return {
        maxhops:  maxhops,
        starting_node: starting_node,
        seed: seed
    };
}

function completeGatherParams() {
    var p = gatherParams();
    if(p.starting_node === null) {
        alert('Set a starting node first!');
        return null;
    }

    if(p.maxhops === null) {
        alert('Set the maximum amount of hops to a valid number');
        return null;
    }

    if(p.seed === null) {
        // TODO auto generate a random one, let the user confirm before
        alert('Set the seed to a valid number!');
        return null;
    }

    return p;
}

function importParams(p) {
    if(p.starting_node !== null) {
        starting_node_id = p.starting_node.id;
    }
    if(p.seed !== null) {
        document.getElementById('seed').value = p.seed;
    }
    if(p.maxhops !== null) {
        document.getElementById('hop-count').value = p.maxhops;
    }
```

```
}

function randomSeed() {
    if(window.crypto) {
        var array = new Int32Array(1);
        window.crypto.getRandomValues(array);
        document.getElementById('seed').value = array[0];
    }
}

function downloadInterpretation(format) {
    var params = completeGatherParams();
    if(params != null) {
        try {
            fetchInterpretation(params, format).then(file => {
                var url = URL.createObjectURL(file);
                download(url, `export.${format}`);
            });
        } catch(e) {
            alert('An error occured while contacting the API: ' + e);
        }
    }
}

function reloadPlayer() {
    var params = completeGatherParams();
    if(params !== null) {
        document.getElementById('player').src = null;
        try {
            fetchInterpretation(params, 'wav').then(file => {
                var url = URL.createObjectURL(file);
                document.getElementById('player').src = url;
            });
        } catch(e) {
            alert('An error occured while contacting the API: ' + e);
        }
    }
}

function init() {
    var container = document.getElementById('network');

    var options = {
        manipulation: {
            addNode: function(nodeData, callback) {
                document.getElementById('node-operation').innerHTML = 'Add
                    ';
                genericEditNode(nodeData, callback);
            },
            addEdge: function(edgeData, callback) {
```

```
            document.getElementById('edge-operation').innerHTML = 'Add
                ';
            genericEditEdge(edgeData, callback);
        },
        editNode: function(nodeData, callback) {
            document.getElementById('node-operation').innerHTML = 'Edit
                ';
            genericEditNode(nodeData, callback);
        },
        editEdge: {
            editWithoutDrag: function(edgeData, callback) {
                document.getElementById('edge-operation').innerHTML = '
                    Edit';
                genericEditEdge(edgeData, callback);
            }
        },
        deleteNode: deleteFromMap,
        deleteEdge: deleteFromMap,
        controlNodeStyle: {
        }
    },
    nodes: {
        borderWidth: 0,
        color: {
            background: '#563d7c',
            hover: {
                background: '#8f14ff'
            },
            highlight: {
                background: '#8f14ff'
            }
        },
        chosen: true,
        font: {
            color: 'white',
            size: 20,
            align: 'center'
        },
        shape: 'circle',
    },
    edges: {
        arrows: {
            to: { enabled: true }
        },
        color: {
            color: '#563d7c',
            hover: '#563d7c',
            highlight: '#563d7c',
        },
        font: {
```

```
            color: '#ffffff',
            strokeWidth: 0
        }
    }
};

network = new vis.Network(container, {}, options);

try {
    const score = localStorage.getItem('score');
    if(score !== null) {
        importGraphData(JSON.parse(score));
    }
} catch(e) {
    localStorage.removeItem('score');
}

try {
    const params = localStorage.getItem('params')
    if(params !== null) {
        importParams(JSON.parse(params));
    }
} catch(e) {
    localStorage.removeItem('params');
}

const pitch_selector = valid_pitches.map((p, i) =>
    `<option value="${p}">${display_pitches[i]}</option>`)
    .reduce((acc, v) =>
        acc + v, '');
document.getElementById('pitch').innerHTML = pitch_selector;

/* event handling, order as in sidebar */
document.getElementById('set-starting-node').onclick = setStartingNode;
document.getElementById('show-starting-node').onclick =
    showStartingNode;

document.getElementById('random-seed').onclick = randomSeed;

document.getElementById('reload-player').onclick = reloadPlayer;
document.getElementById('download-audio').onclick = () => {
    var format = document.getElementById('format').value;
    downloadInterpretation(format);
};

document.getElementById('gen-score').onclick = () =>
    downloadFile('application/json', 'score.likely.json',
        JSON.stringify(collectGraphData(nodeData, edgeData)));
document.getElementById('upload-score').addEventListener('change',
    handleImport);
```

```
    document.getElementById('clear-score').onclick = () =>
        importGraphData({ nodes: [], edges: []});

    window.setInterval(saveDataToLocalStorage, 5000);
}

document.addEventListener('DOMContentLoaded', () => init());
```

## Lizenz

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