likely music

Probabilistische Musiknotation

Lukas Epple

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Zusammenfassung

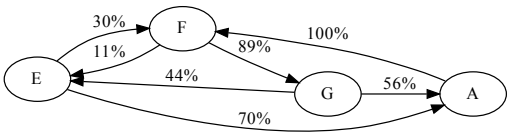
likely music ist eine Software, um probabilistiche Musik zu notieren und abzupsielen. Probabilistische Musik heißt in diesem Falle, dass die Interpretation der vorliegenden Notation deutlich freier ist als bei herkömmlicher Musik und auch die Reihenfolge der Noten betrifft. Um dies zu erreichen wird 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

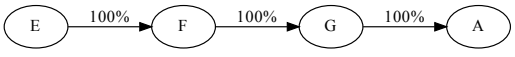
Der eigentlichen Idee ging ein mehr oder minder gescheitertes Projekt für diesen Wettbewerb vorraus. Im Frühjahr diesen Jahres entschied ich mich dieses, eine Demo [1], abzubrechen, einfach weil ich befürchtete, es nicht bis zur Frist fertigstellen zu können. Die Motivation für dieses Projekt speiste 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:



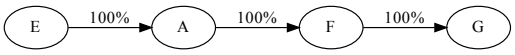
In diesem konkreten Graphen sind die Noten E, F, G und A als Knoten vertreten (der Einfachheit halber sind die Notenlängen weggelassen). Beispielsweise vom E führen zwei Kanten weg, eine zum F mit dreißigprozentiger Wahrscheinlichkeit und eine zum A mit siebzigprozentiger Wahrscheinlichkeit, d. h. nach 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

Gleich zu Beginn war klar, dass Haskell die Programmiersprache der Wahl werden sollte. Sie ist die Sprache, die ich in den letzten Jahren am aktivsten verwendet habe und mir einiges bietet, statische Typisierung, um Fehler vorzubeugen, ein expressives Typsystem, das es erlaubt, Daten besser zu strukturieren, und funktionale Programmierparadigmen, die mir persönlich sehr gut taugen, um mal einige zu nennen.

Zunächst konzentrierte ich mich darauf, den Graphen und den Interpretationsalgorithmus als Bibliothek zu implementieren. In der ersten Iteration dieser Bibliothek, noch *probable music* genannt, begann ich auch einen eigenen Softwaresynthesizer zu implementieren, der flexibel auf verschiedenen Plattformen und zu verschiedenen Zwecken verwendet werden kann. Der Synthesizer konnte – gegeben ein Algorithmus dafür – jegliche Daten in Töne umwandeln, was interessante Möglichkeiten ergab, sich außerhalb des Zwölftonsystems zu bewegen. Die Tonerzeugung basierte dann auf einer freien Monade [2], die die Instruktionen ›Warten‹ und ›Abspielen‹ kannte. Indem man diese Instruktionen für verschiedene Audiosystem, wie SDL [4], Jack [3] oder auch Audiodateien wie WAV [5], implementierte, konnte man verschiedene Plattformen unterstützen. Allerdings gestaltete es sich schwierig, einen gut klingenden Synthesizer zu schreiben schwierig, denn die Messlatte ist im Vergleich zu realen Instrumenten hoch. Hinzu kamen noch einige Performance-Probleme mit meinem macschinennahem Audio-Code.

Also entschied ich mich, die Library vor allem auf den Graphen und die dazugehörigen Algorithmen zu fokusieren und zur Tonerzeugung eine geeignete Abstraktion zu verwenden, die diese zu vereinfachern. Ich habe hierfür MIDI gewählt, eine Technologie, die schon lang in allen Arten von Software und Hardware zur Musikproduktion verwendet wird, entschieden. MIDI basiert auf einer Abfolge von zeitlich abgestimmten Nachrichten, wie zum Beispiel ›Note C an‹ oder ›Note C aus‹. Aufgrund dieser Nachrichten kann man die Erzeugung und das Abspielen von Musik zwischen mehreren Programmen aufteilen, außerdem erlaubt es die bereits existierende Infrastruktur für MIDI-Verarbeitung zu verwenden, die sehr beachtlich ist. Für MIDI verwendet *likely music* die Open-Source-Bibliothek Euterpea[1] [8], die unter anderem eine kleine Abstraktion über MIDI enthält. Sie erlaubt es, in einem internen Format Musik zu konstruieren und anschließend als MIDI zu exportieren bzw. an ein anderes Programm zur Weiterverarbeitung zu schicken.

Bei der Darstellung des Graphen habe ich mich vor allem darauf konzentriert, dass der Interpretationsalgorithmus, also das (zufällige) Ablaufen des Graphen, möglichst effizient zu machen. Da es sich um einen gerichten Graphen handelt, ist es besonders wichtig zu wissen, wohin man von einem gegebenen Knoten aus gelangen kann bzw. welche Kanten von einem Knoten weggehen. So gelangt man in unserem Beispiel aus dem vorherigen Kapitel vom Knoten mit dem E zu den Knoten mit F und A. Es

[1] Ich musste allerdings aufgrund von Inkompatibilitäten mit den aktuellen Haskell-Paketen diese selbst beheben [9]. Diese Änderung wartet [10] aktuell (Stand 23.09.2017) darauf vom Hauptentwickler in den Code von Euterpea übernommen zu werden.

muss also möglichst effizient sein, die Kanten nachzuschlagen, die von einem Knoten *wegführen*. Mit der Datenstruktur *Map* [11] (im deutschen Sprachgebrauch typischerweise *assoziative Datenfeld* bzw. *assoziatives Array*) kann man genau das sehr leicht realisieren, indem man die Knoten als Schlüssel und eine Liste von Kanten, die vom Schlüssel weggehen, als Elemente verwendet. Wenn der Algorithmus nun einen Knoten nachschlägt, erhält er direkt die Kanten, die von diesem Knoten weggehen und somit auch die nächsten möglichen Knoten. Dies ist die einzige Information, die in jedem Schritt benötigt wird. Die Operation des Nachschlagen hat in einem *Map* die Komplexität $O(\log n)$ [12], d. h. die Zeit, die benötigt wird, um ein Element nachzuschlagen, steigt mit dem Wachsen der Datenstruktur logarithmisch (d. h. weniger starkes Wachstum als linear!), wodurch auch das Interpretieren großer Graphen ziemlich schnell bleibt. Der Code für die Datenstruktur findet sich im Abschnitt Library, Zeile 30 bis 43.

Der Interpretationsalgorithmus selbst ist rekursiv [15] gestaltet und findet sich in der Funktion `interpretation`, siehe Abschnitt Library, Zeile 52 bis 60. Diese Funktion benötigt einen intialisierten Pseudozufallszahlengenerator [13, 14], den zu interpretierenden Graphen in der eben besprochenen Datenstruktur und einen Startknoten und gibt die resultierende Interpretation im MIDI-Format von Euterpea [8] zurück. Zunächst wird der Startknoten im Graphen nachgeschlagen, so werden die Kanten bzw. die nächsten möglichen Knoten erhalten. Nun gibt es zwei Möglichkeiten für den weiteren Verlauf:

1. Es gibt keine Kanten, die von diesem Knoten ausgehen. Also wird die bisher generierte Interpretation einfach zurückgegeben, die Funktion terminiert.

2. Wenn es eine oder mehr Kanten vom Knoten aus gibt, wird eine (reelle) Zufallszahl zwischen 0 und 1 berechnet und mittels der Hilfsfunktion `edgeForRoll` (siehe Abschnitt Library, Zeile 62 - 67) die Kante erhalten, die gemäß des zufälligen Ergebnis als nächstes abgelaufen werden soll. Nun ergibt sich das gleiche Problem wie zu Beginn der Interpretation: Man kennt einen Knoten und will wissen wie es weitergeht. Also wird nach der Ermittlung des zweiten Knotens die MIDI-Nachrichten aus dem Startknoten extrahiert und dann der Interpretationsalgorithmus nochmal bzw. rekursiv aufgerufen – nur mit dem Folgeknoten als Startknoten – dessen Ergebnis wird an die aktuellen MIDI-Nachrichten angehängt, was jener Aufruf auch seinerseits wieder macht. So entsteht rekursiv eine (potentiell unendliche) Verkettung von MIDI-Nachrichten, die letztlich die finale Interpretation ergeben.

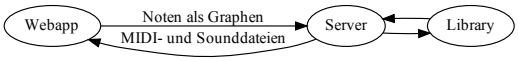
Da die meisten Graphen vermutlich vollständig untereinander verbunden sein werden wie zum Beispiel der Beispielgraph im ersten Abschnitt, entstehen unendlich lange Interpretationen. Diese zu erstellen benötigt natürgemäß natürlich auch unendlich viel Zeit – der Interpretationsalgorithmus terminiert also nicht. Die einfache Antwort auf dieses Problem ist die Begrenzung der Länge der Interpretation auf eine gewisse Anzahl von Noten, was sich dank eines Sprachfeatures von Haskell – Lazy Evaluation [16] – leicht umsetzen lässt. Denn mit Lazy Evaluation wird nur das berechnet, was im Moment benötigt wird. Somit werden zum Beispiel nur die ersten vier benötigten Noten berechnet und nicht die unendlich vielen die eigentlich noch darauf folgen würden – genau dies wird durch die Funktion `takeNotes` (siehe Abschnitt Library, Zeile 79 - 86) realisiert.

Nun können wir probabilistische Musik in Graphen darstellen, diese automatisch interpretieren und dank Euterpea nach MIDI exportieren. Was fehlt, ist eine angenehme Benutzerschnittstelle.

Zur Technologie für die Benutzerschnittstelle gab es für mich folgende Überlegungen: Zum einen sollte es leicht portabel bzw. auf jedem System laufen sowie außerdem einen begrenzten Entwicklungsaufwand mit sich bringen, sodass es bis zur Abgabe auch fertig sein würde. Ich selbst entwickle meine Software auf GNU/Linux, aber zur Abgabe müsste es auf macOS und / oder Windows laufen. Alle größeren Frameworks für Graphische Interfaces für GNU/Linux, wie zum Beispiel Qt [21] oder GTK [22], laufen auch auf den anderen großer Betriebssystemen. Allerdings bin ich nicht besonders vertraut mit irgendeinem dieser Frameworks, außerdem war ich mir nicht sicher, wie stressfrei die Verwendung dieser von Haskell aus sein würde (denn klassischerweise verwendet man C oder C++). Also entschied ich mich *likely music* als Webapplikation, die einfach in gängigen Browsern läuft zu

implementieren. Das hat einige Vorteile für mich, unter anderem, dass es leicht zu testen ist, weil die Browser eigentlich überall gleich sind, und, dass ich schon einige Erfahrung in Webentwicklung hatte.

Allerdings hatte ich die Library schon in Haskell implementiert, in Browsern läuft aber nur JavaScript (ohne größeren Aufwand zumindest). Also musste also ein Zwischenstück her um die Kommunikation zwischen der Library und der Webapplikation zu realisieren. Ich entschied mich für eine Client-Server-Architektur [17], also einen Server, der die Interpretation und den Export von Sounddateien für den Client, also die Webapplikation, übernimmt. Der Client wiederum müsste sich ausschließlich um ein ansprechendes Interface kümmern. Die ungefähre Gesamtarchitektur sieht also nun so aus:



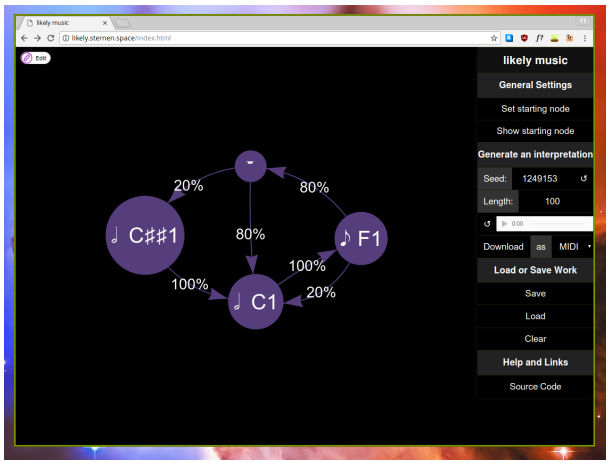
Der Server basiert auf den Libraries servant [18] als Webframework. Wie im Abschnitt **??** zu sehen, besteht das Serverbackend aus zwei Dateien Quelltext: In `Api.hs` wird die Struktur der REST-API [19] definiert, mittels der die Webapplikation mit dem Server kommuniziert. Der Server bietet folgende Funktionalität an:

- `/interpretation/mid` An diesen Endpunkt schickt die Webapplikation einen Graphen plus einiger Parameter in Form von JSON [20] und erhält eine Interpretation auf Basis des Algorithmus als MIDI-Datei zurück.
- `/interpretation/wav` Gleich wie der obige Endpunkt, allerdings wird vorher noch das MIDI mittels eines MIDI-Synthesizers, fluidsynth [**?**], in eine WAV-Datei konvertiert, sodass man es direkt anhören kann.
- Außerdem liefert er die statischen Dateien der Webapplikation, wie das nötige HTML, JavaScript und CSS.

Die erwähnten Parameter sind nur folgende drei:

- Der Anfangsknoten der Interpretation im Graphen, den der Algorithmus benötigt (wie oben besprochen).
- Die Länge der Interpretation als die maximale Anzahl an Noten in der Interpretation.
- Der Startwert für den Pseudozufallszahlengenerator [14], der für die Interpretation verwendet werden soll. Da derselbe Startwert in die selbe Interpretation resultiert, erlaubt dies sich interessante Interpretationen zu merken und zum Beispiel zu einer Interpretation noch die MIDI-Version zusätzlich herunterzuladen.

Dies ist auch schon alles, was das Serverbackend tut, denn es ist nur als minimaler Aufsatz auf die Library konzipiert. Das meiste für Benutzer relevante passiert in der Webapplikation, die folgendermaßen aussieht:



Lizenzierung

Benutzung

Zukünftige Weiterentwicklung

Links

- Der gesamte Quelltext `https://github.com/sternenseemann/likely-music`
- Eine laufende Instanz von *likely music* `https://likely.sternen.space`

Literatur

[1] `https://de.wikipedia.org/wiki/Demoszene`

[2] http://www.haskellforall.com/2012/07/purify-code-using-free-monads.html

[3] http://www.jackaudio.org/

[4] https://www.libsdl.org/index.php

[5] https://de.wikipedia.org/wiki/RIFF_WAVE

[6] https://www.midi.org/

[7] https://de.wikipedia.org/wiki/Musical_Instrument_Digital_Interface

[8] https://hackage.haskell.org/package/Euterpea

[9] https://github.com/sternenseemann/Euterpea2

[10] https://github.com/Euterpea/Euterpea2/issues/16

[11] https://hackage.haskell.org/package/containers-0.5.10.2/docs/Data-Map-Lazy.html#t:Map

[12] https://hackage.haskell.org/package/containers-0.5.10.2/docs/Data-Map-Lazy.html#v:lookup

[13] https://hackage.haskell.org/package/random-1.1/docs/System-Random.html#t:RandomGen

[14] https://en.wikipedia.org/wiki/Pseudorandom_number_generator

[15] https://de.wikipedia.org/wiki/Rekursion

[16] https://de.wikipedia.org/wiki/Lazy_Evaluation

[17] https://en.wikipedia.org/wiki/Client%E2%80%93server_model

[18] https://hackage.haskell.org/package/servant

[19] https://de.wikipedia.org/wiki/Representational_State_Transfer

[20] http://json.org/

[21] https://www.qt.io/

[22] https://www.gtk.org/

Anhang

Quelltext

Library

lib/Sound/Likely.hs

```
1  {-# LANGUAGE OverloadedStrings #-}
2  {-# LANGUAGE FlexibleInstances #-}
3  module Sound.Likely
4    ( Probability
5    , ID
6    , Node (..)
7    , Edge (..)
8    , Graph (..)
9    , insertNode
10   , insertEdge
11   , interpretation
12   , takeNotes
13   , emptyMusic
14   , exampleGraph
15   ) where
16
17 import Control.Monad
18 import Data.Aeson
19 import Data.Aeson.Types (Parser ())
20 import Data.Maybe
21 import Data.Text (Text ())
22 import Euterpea
23 import System.Random
24 import qualified Data.Map as M
25 import qualified Data.Set as S
26
27 type Probability = Double
28 type ID = Text
29
30 data Node
31   = Node
32   { nId :: ID
33   , nMusic :: Music Pitch
34   } deriving (Show, Eq, Ord)
35
36 data Edge
37   = Edge
38   { eTo    :: Node
39   , eProb :: Probability
40   } deriving (Show, Eq, Ord)
41
42 newtype Graph = Graph { unGraph :: M.Map Node (S.Set Edge) }
43   deriving (Show, Eq, Ord)
```

```
44
45 insertNode :: Node -> Graph -> Graph
46 insertNode t = Graph . M.insertWith S.union t S.empty . unGraph
47
48 insertEdge :: Node -> Edge -> Graph -> Graph
49 insertEdge n e =
50   insertNode n . Graph . M.insertWith S.union n (S.singleton e) . unGraph
51
52 interpretation :: RandomGen g => g -> Graph -> Node -> Music Pitch
53 interpretation gen graph n = (nMusic n) :+:
54   recurse (fromMaybe S.empty (M.lookup n (unGraph graph)))
55   where (prob, gen') = randomR (0.0, 1.0) gen
56         recurse edges =
57           if S.null edges
58             then emptyMusic
59             else interpretation gen' graph
60                  . eTo . edgeForRoll prob $ edges
61
62 edgeForRoll :: Probability -> S.Set Edge -> Edge
63 edgeForRoll prob set =
64   let curr = S.elemAt 0 set
65     in if prob <= eProb curr
66          then curr
67          else edgeForRoll (prob - eProb curr) (S.delete curr set)
68
69 emptyMusic :: Music a
70 emptyMusic = Prim (Rest 0)
71
72 exampleGraph :: Graph
73 exampleGraph = Graph $ M.fromList
74   [ (Node "bla" (c 4 qn), S.fromList [ Edge (Node "blub" (d 4 qn)) 1 ] )
75   , (Node "blub" (d 4 qn), S.fromList [ ])
76   ]
77
78 -- | Take the first @n@ notes of a 'Music'
79 takeNotes :: Integer -> Music a -> Music a
80 takeNotes _ m@(Prim _) = m
81 takeNotes n (Modify c m) = Modify c $ takeNotes n m
82 takeNotes _ m@(_ :=: _) = m
83 takeNotes n (m1 :+: m2)
84   | n <  1    = emptyMusic
85   | n == 1    = m1
86   | otherwise = m1 :+: takeNotes (n - 1) m2
87
88 instance FromJSON Node where
89   parseJSON = withObject "Node" $ \v ->
90     Node <$> v .: "id" <*> (Prim <$> v .: "music")
91
92 lookupNode :: Text -> [Object] -> Parser Node
93 lookupNode id nodes = do
```

```
94    matches <- filterM (fmap (== id) . (.: "id")) nodes
95    case matches of
96      [node] -> parseJSON (Object node)
97      _ -> fail "Couldn't match node by id"
98
99  buildMap :: [Object] -> [Object] -> Graph -> Parser Graph
100 buildMap _ [] m = pure m
101 buildMap nodes (e:es) m = do
102   toId <- e .: "to"
103   fromId <- e .: "from"
104   edge <- Edge <$> lookupNode toId nodes <*> e .: "prob"
105   from <- lookupNode fromId nodes
106   buildMap nodes es $ insertEdge from edge m
107
108 instance FromJSON Graph where
109   parseJSON = withObject "Graph" $ \v -> do
110     edges <- v .: "edges"
111     nodes <- v .: "nodes"
112     buildMap nodes edges $ Graph mempty
113
114 instance FromJSON (Primitive Pitch) where
115   parseJSON = withObject "Primitive" $ \v -> do
116     -- TODO Ratio _Integer_ is easy DOSable
117     -- RAM consumption
118     duration <- v .: "dur"
119     octave <- v .: "octave"
120     pitchClass <- v .: "pitch"
121     case pitchClass of
122       "Rest" -> pure $ Rest duration
123       p -> pure $ Note duration (read pitchClass, octave)
```

Backend

backend/Api.hs

```haskell
{-# 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)

```

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

backend/Main.hs

```
1  {-# LANGUAGE OverloadedStrings #-}
2  module Main where
3
4  import Api
5
6  import Codec.Midi (buildMidi)
7  import Codec.ByteString.Builder
8  import Control.Monad.IO.Class
9  import Data.ByteString.Lazy (ByteString ())
10 import qualified Data.ByteString.Lazy as B
11 import Euterpea hiding (app)
12 import GHC.IO.Handle
13 import Network.Wai
14 import Network.Wai.Handler.Warp
15 import Servant
16 import Sound.Likely
17 import System.Directory
18 import System.Exit
19 import System.Environment
20 import System.FilePath.Posix
21 import System.IO
22 import System.Process
23 import System.Random
24
25 api :: Proxy LikelyApi
26 api = Proxy
27
28 midiString :: ToMusic1 a => Music a -> ByteString
29 midiString = toLazyByteString . buildMidi . toMidi . perform
30
31 server :: Server LikelyApi
32 server = genInterpretation :<|> randomSeed :<|> serveDirectoryWebApp "web/
       dist"
33
34 randomSeed :: Handler Int
35 randomSeed = liftIO newStdGen >>= return . fst . random
36
37 genInterpretation :: OutputFormat -> GraphWithParams -> Handler ByteString
38 genInterpretation Midi g = do
39   let params       = gpParams g
40       maxHops      = fromIntegral . pMaxHops $ params
```

```
41        randomGen     = mkStdGen $ pSeed params
42        song          = interpretation randomGen (gpGraph g) (pStartingNode
              params)
43    return . midiString $ takeNotes maxHops song
44  genInterpretation Wav g = genInterpretation Midi g >>= synthWav
45
46  synthWav :: ByteString -> Handler ByteString
47  synthWav midi = do
48    inName <- tempFile "mid"
49    liftIO $ B.writeFile inName midi
50    outName <- tempFile "wav"
51    (_, _, _, ph) <- liftIO $
52      createProcess_ "fluidsynth"
53        (proc "fluidsynth"
54          [ "-a", "file"
55          , "-F", outName
56          , "-i"
57  --          , "/usr/share/soundfonts/FluidR3_GM.sf2"
58          , "/nix/store/591834mz365ccwyj3ah2d66ncsqvp8w9-Fluid-3/share/
                soundfonts/FluidR3_GM2-2.sf2"
59          , inName ])
60          { std_in = CreatePipe }
61    code <- liftIO $ waitForProcess ph
62    case code of
63      ExitFailure _ -> throwError err500 { errBody = "fluidsynth failed" }
64      ExitSuccess -> do
65        out <- liftIO $ B.readFile outName
66        liftIO $ removePathForcibly outName
67        return out
68
69  tempFile :: String -> Handler FilePath
70  tempFile ext = try 0
71    where maxtries = 100
72          try :: Integer -> Handler FilePath
73          try n
74            | n < maxtries = do
75              progName <- liftIO $ getProgName
76              let path = "/tmp" </> addExtension (makeValid progName ++ "-"
                      ++ show n) ext
77              exists <- liftIO $ doesFileExist path
78              if exists
79                then try (n + 1)
80                else pure path
81            | otherwise = throwError err500
82  app :: Application
83  app = serve api server
84
85  main :: IO ()
86  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">
```

```
46                  <input type="file" id="upload-score" >
47                  <span>Load</span>
48              </label>
49              <button id="clear-score" class="cancel">Clear</button>
50              <h2>Help and Links</h2>
51              <a href="https://github.com/sternenseemann/likely-music">Source
                    Code</a>
52          </div>
53          <div id="edge-overlay" class="hidden dialog">
54              <h2><span id="edge-operation"></span> edge</h2>
55              <div class="multi-inputs">
56                  <label for="prob">Probability:</label>
57                  <input id="prob" type="number" min="0.0" max="100">
58                  <span>%</span>
59              </div>
60              <div class="multi-inputs">
61                  <button class="save" id="edge-save">Save</button>
62                  <button class="cancel" id="edge-cancel">Cancel</button>
63              </div>
64          </div>
65          <div id="node-overlay" class="hidden dialog">
66              <h2><span id="node-operation"></span> node</h2>
67              <div class="multi-inputs">
68                  <label for="pitch">Pitch:</label>
69                  <select id="pitch"></select>
70              </div>
71              <div class="multi-inputs">
72                  <label for="octave">Octave:</label>
73                  <input id="octave" type="number" step="1">
74              </div>
75              <div class="multi-inputs">
76                  <label>Duration:</label>
77                  <input min="0" id="numerator" type="number" step="1">
78                  <span>/</span>
79                  <input min="0" id="denominator" type="number" step="1">
80              </div>
81              <div class="multi-inputs">
82                  <button class="save" id="node-save">Save</button>
83                  <button class="cancel" id="node-cancel">Cancel</button>
84              </div>
85          </div>
86      </body>
87  </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, #sidebar a:hover {
    background-color: #563d7c;
}

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

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

```
48
49 #sidebar h2 {
50     font-size: 1.2rem;
51     padding-top: 0.9rem;
52     padding-bottom: 0.9rem;
53     text-align: center;
54     background-color: #222;
55 }
56
57 #sidebar select {
58   color: white;
59   border: none;
60   padding: 0.75rem;
61   font-size: 1.2rem;
62   width: auto;
63 }
64
65 #sidebar a {
66   padding: 0.75rem;
67   display: inline-block;
68   text-decoration: none;
69   color: white;
70   text-align: center;
71 }
72
73 button {
74     border: none;
75     color: white;
76     background-color:black;
77     font-size: 1.2rem;
78     margin:0;
79     padding:0.75rem;
80 }
81
82 input[type="number"] {
83     background-color: #333;
84     color: white;
85     border: none;
86     text-align: center;
87     font-size: 1.2rem;
88     padding:0.75rem;
89 }
90
91 .custom-file {
92     top:0;
93     right:0;
94     position: relative;
95     display: inline-block;
96     height: 3rem;
97 }
```

```
98
99  .custom-file input[type="file"] {
100     position: relative;
101     top:0;
102     left:0;
103     right:0;
104     z-index:0;
105     opacity: 0;
106     width: 100%;
107     height: 100% !important;
108     margin:0;
109     padding:0;
110 }
111
112 .custom-file span {
113     text-align: center;
114     position: absolute;
115     top: 0;
116     left: 0;
117     right: 0;
118     z-index: 1;
119     width: 100%;
120     height: 3rem;
121     pointer-events: none;
122     background-color: transparent !important;
123     font-size: 1.2rem;
124     line-height: 1.5rem;
125     padding-top: 0.75rem;
126     padding-bottom: 0.75rem;
127 }
128
129 .dialog {
130     position: absolute;
131     top: 10%;
132     left: 25%;
133     width: 30%;
134     min-width:500px;
135     padding: 10px;
136     background-color: black;
137     color: white;
138     box-shadow: 0px 0px 10px #111;
139 }
140
141 .dialog > div {
142     height: 3rem;
143 }
144
145 .hidden {
146     visibility:hidden;
147 }
```

```
148
149 .dialog > div {
150   width: 100%;
151 }
152
153 .dialog button {
154     padding: 0.75rem;
155     font-size: 1.5rem;
156 }
157
158 button.cancel {
159     background-color: #a23a30;
160 }
161
162 button.save {
163     background-color: #0ea92f;
164 }
165
166 .dialog .multi-inputs {
167   font-size: 1.5rem;
168 }
169
170 .multi-inputs {
171   display: inline-flex;
172   flex-direction: row;
173   flex-wrap: nowrap;
174   justify-content: flex-start;
175   align-items: baseline;
176   width: 100%;
177 }
178
179 .multi-inputs > * {
180   flex-grow: 1;
181   flex-basis: auto;
182   transition: width 0.7s ease-out;
183   max-height: 100%;
184   text-align: center;
185 }
186
187 .multi-inputs :nth-child(1) {
188   text-align: left;
189 }
190
191 .multi-inputs label {
192   display: inline-block;
193   background-color: #333;
194   padding: 0.75rem;
195 }
196
197 .multi-inputs input {
```

```
198     display: inline-block;
199     color: white;
200     background-color: #111;
201     padding: 0.75rem;
202     border: none;
203     min-width: 0px;
204   }
205
206   .multi-inputs span {
207     display: inline-block;
208     padding: 0.75rem;
209     background-color: #222;
210   }
211
212   .multi-inputs button {
213       padding: 0.75rem;
214   }
215
216   #player-container {
217     display: inline-flex;
218     align-items: center;
219   }
220
221   #player-container > * {
222     flex: auto;
223   }
```

web/source/main.js

```
1  import vis from 'vis';
2  import { Map } from 'immutable';
3  // types / internals
4
5  const valid_pitches = [
6      'Rest',
7      'Cff', 'Cf', 'C',
8      'Dff', 'Cs', 'Df',
9      'Css', 'D', 'Eff',
10     'Ds', 'Ef', 'Fff',
11     'Dss', 'E', 'Ff',
12     'Es', 'F', 'Gff',
13     'Ess', 'Fs', 'Gf',
14     'Fss', 'G', 'Aff',
15     'Gs', 'Af', 'Gss',
16     'A', 'Bff', 'As',
17     'Bf', 'Ass', 'B',
18     'Bs', 'Bss'
19 ];
20
21 const display_pitches = [
22     'Rest',
23     ' C', 'C', 'C',
24     ' D', 'C', 'D',
25     'C', 'D', ' E',
26     'D', 'E', ' F',
27     'D', 'E', 'F',
28     'E', 'F', 'Gff',
29     'E', 'F', 'G',
30     'F', 'G', ' A',
31     'G', 'A', 'G',
32     'A', ' B', 'A',
33     'B', 'A', 'B',
34     'B', 'B'
35 ];
36
37 function displayPitch(pitch) {
38     var i = valid_pitches.indexOf(pitch);
39     if(i === -1) {
40         throw 'Invalid pitch';
41     } else {
42         return display_pitches[i];
43     }
44 }
45
46 function standard_rests(dur) {
47     if(dur.numerator === 1) {
48         switch(dur.denominator) {
```

```
49              case 1:
50                  return  '';
51                  break;
52              case 2:
53                  return  '';
54                  break;
55              case 4:
56                  return  '';
57                  break;
58              case 8:
59                  return  '';
60                  break;
61              case 16:
62                  return  '';
63                  break;
64              case 32:
65                  return  '';
66                  break;
67              case 64:
68                  return  ''
69                  break;
70              case 128:
71                  return  ''
72                  break;
73              default:
74                  return null;
75                  break;
76          }
77      } else {
78          return null;
79      }
80  }
81
82  function standard_notes(dur) {
83      if(dur.numerator === 1) {
84          switch(dur.denominator) {
85              case 1:
86                  return  '';
87                  break;
88              case 2:
89                  return  '';
90                  break;
91              case 4:
92                  return  '';
93                  break;
94              case 8:
95                  return  '';
96                  break;
97              case 16:
98                  return  '';
```

```
99                  break;
100             case 32:
101                 return  '';
102                 break;
103             case 64:
104                 return  ''
105                 break;
106             case 128:
107                 return  ''
108                 break;
109             default:
110                 return null;
111                 break;
112         }
113     } else if(dur.numerator === 2 && dur.denominator === 1) {
114         return  ''
115     } else {
116         return null;
117     }
118 }
119
120 function compute_dot_times(dur, denominator) {
121     let baseLog = (b, x) => Math.log(x) / Math.log(b);
122     let term = (dur.numerator * Math.pow(2, denominator)) / dur.denominator
        ;
123     return [ denominator, baseLog(1.5, term)];
124 }
125
126 function musical_symbol(lookup, dur) {
127     const dot =  ' ';
128     let isNat = n => {
129         if (typeof n !== 'number')
130             return false;
131         return (n >= 0.0) && (Math.floor(n) === n) && n !== Infinity;
132     };
133     var standard_symbol = lookup(dur);
134     var bla = [0, 1, 2, 3, 4, 5, 6, 7 ].map(compute_dot_times.bind(dur));
135     console.log(bla);
136     var dots = bla.filter(([den, dots]) => isNat(dots));
137
138     console.log(dots);
139
140     if(standard_symbol !== null) {
141         return standard_symbol;
142     } else if (dots.length !== 0) {
143         var symbol = lookup(new Rational(1, dots[0][0]));
144         for(var i = dots[0]; i > 0; i--) {
145             symbol = symbol + dot;
146         }
147         return symbol;
```

```
148     } else {
149         return dur.toString();
150     }
151 }
152
153 class Music {
154     constructor(dur, pitch_class, octave) {
155         this.dur = dur;
156         if(valid_pitches.indexOf(pitch_class) !== -1) {
157             this.pitch = pitch_class;
158         } else {
159             throw `Invalid pitch class '${pitch_class}'`;
160         }
161         this.octave = octave;
162     }
163
164     toString() {
165         if(this.pitch === 'Rest') {
166             return `${displayPitch(this.pitch)} for ${this.dur.toString()
                    }`;
167         } else {
168             return `${displayPitch(this.pitch)}${this.octave} for ${this.
                    dur.toString()}`;
169         }
170     }
171
172     nodeText() {
173         if(this.pitch === 'Rest') {
174             // alignment using a space! #justvisjsthings
175             return ` ${musical_symbol(standard_rests, this.dur)}`;
176         } else {
177             return `${musical_symbol(standard_notes, this.dur)}   ${
                    displayPitch(this.pitch)}${this.octave}`
178         }
179     }
180
181
182     static fromObject(obj) {
183         return new Music(Rational.fromObject(obj.dur), obj.pitch, Number(
                obj.octave));
184     }
185 }
186
187 class Rational {
188     constructor(a, b) {
189         this.numerator = a;
190         this.denominator = b;
191         this.reduce();
192     }
193
```

```
194     reduce() {
195         let gcd = (a, b) => !b ? a : gcd(b, a % b);
196         let div = function(a, b) {
197             if(b === 0) {
198                 throw 'Divide by zero';
199             } else {
200                 return Math.floor(a / b);
201             }
202         };
203 
204         var d = gcd(this.numerator, this.denominator);
205         this.numerator = div(this.numerator, d);
206         this.denominator = div(this.denominator, d);
207     }
208 
209     toString() {
210         return `${this.numerator}/${this.denominator}`;
211     }
212 
213     static fromObject(obj) {
214         return new Rational(obj.numerator, obj.denominator);
215     }
216 }
217 
218 function collectGraphData(nodeDate, edgeData) {
219     return {
220         nodes: [... nodeData.values()].map(x => ({
221             id: x.nodeData.id,
222             music: x.music
223         })),
224         edges: [... edgeData.values()].map(x => ({
225             id: x.edgeData.id,
226             from: x.edgeData.from,
227             to: x.edgeData.to,
228             prob: x.prob
229         }))
230     };
231 }
232 
233 function importGraphData(g) {
234     nodeData = new Map();
235     edgeData = new Map();
236     var nodeSet = new vis.DataSet({});
237     var edgeSet = new vis.DataSet({});
238     for(let node of g.nodes) {
239         var music = Music.fromObject(node.music);
240         var data = { id: node.id, label: music.nodeText() };
241         nodeData = nodeData.set(node.id, { nodeData: data, music: node.
                music });
242         nodeSet.add(data);
```

```
243     }
244
245     for(let edge of g.edges) {
246         var data = {
247             id: edge.id,
248             from: edge.from,
249             to: edge.to,
250             label: `${edge.prob * 100}%`
251         };
252         edgeData = edgeData.set(edge.id, { edgeData: data, prob: edge.prob
                });
253         edgeSet.add(data);
254     }
255
256     network.setData({ nodes: nodeSet, edges: edgeSet });
257 }
258
259 // helper
260
261 function download(url, filename) {
262     var link = document.createElement('a');
263     link.setAttribute('href', url);
264     link.setAttribute('download', filename);
265     link.style.display = 'none';
266     document.body.appendChild(link);
267     link.click();
268     document.body.removeChild(link);
269 }
270
271 function downloadFile(content_type, filename, content) {
272     var data = `data:${content_type},${encodeURIComponent(content)}`;
273     download(data, filename);
274 }
275
276
277 // graph code
278
279 var nodeData = Map();
280 var edgeData = Map();
281 var network = null;
282 var starting_node_id = null;
283
284
285 function showOverlay(id) {
286     document.getElementById(id).classList.remove('hidden');
287 }
288
289 function genericEditNode(data, callback) {
290     function clearOverlay() {
291         document.getElementById('node-save').onclick = null;
```

```
292         document.getElementById('node-cancel').onclick = null;
293         hideOverlay('node-overlay');
294     }
295
296     function saveNode(data, callback) {
297         var duration = new Rational(document.getElementById('numerator').
                value,
298             document.getElementById('denominator').value);
299         var music = new Music(duration, document.getElementById('pitch').
                value,
300             Number(document.getElementById('octave').value));
301         data.label = music.nodeText();
302         clearOverlay();
303         callback(data);
304         nodeData = nodeData.set(data.id, { music: music, nodeData: data });
305     }
306
307     function discardNode(callback) {
308         clearOverlay();
309         callback(null);
310     }
311
312     showOverlay('node-overlay');
313     var node = nodeData.get(data.id);
314     if(node !== undefined) {
315         var music = node.music;
316         document.getElementById('pitch').value = music.pitch;
317         document.getElementById('octave').value = music.octave;
318         document.getElementById('numerator').value = music.dur.numerator;
319         document.getElementById('denominator').value = music.dur.
                denominator;
320     }
321     document.getElementById('node-save').onclick = saveNode.bind(this, data
            , callback);
322     document.getElementById('node-cancel').onclick = discardNode.bind(this,
             callback);
323 }
324
325 function genericEditEdge(data, callback) {
326     function clearOverlay() {
327         document.getElementById('edge-save').onclick = saveEdge.bind(this,
                data, callback);
328         document.getElementById('edge-cancel').onclick = discardEdge.bind(
                this, callback);
329         hideOverlay('edge-overlay');
330     }
331
332     function saveEdge(data, callback) {
333         // for some reason, editWithoutDrag
334         // sets from & to to the node respective
```

```
335         // node objects, which results in the edge
336         // disappearing.
337         if (typeof data.to === 'object')
338             data.to = data.to.id
339         if (typeof data.from === 'object')
340             data.from = data.from.id
341 
342         var prob = document.getElementById('prob').value / 100;
343         data.label = `${prob * 100}%`;
344         clearOverlay();
345         callback(data);
346         edgeData = edgeData.set(data.id, { prob: prob, edgeData: data } );
347     }
348 
349     function discardEdge(callback) {
350         clearOverlay();
351         callback(null);
352     }
353 
354     showOverlay('edge-overlay');
355     var edge = edgeData.get(data.id);
356     if(edge !== undefined) {
357         document.getElementById('prob').value = edge.prob * 100;
358     }
359     document.getElementById('edge-save').onclick = saveEdge.bind(this, data
        , callback);
360     document.getElementById('edge-cancel').onclick = discardEdge.bind(this,
         callback);
361 }
362 
363 function deleteFromMap(data, callback) {
364     for(let node of data.nodes) {
365         nodeData = nodeData.delete(node);
366     }
367 
368     for(let edge of data.edges) {
369         edgeData = edgeData.delete(edge);
370     }
371 
372     callback(data);
373 }
374 
375 
376 function hideOverlay(id) {
377     document.getElementById(id).classList.add('hidden');
378 }
379 
380 function handleImport() {
381     var files = document.getElementById('upload-score').files;
382     if(files.length === 0) {
```

```
383         alert('Select a file first!');
384     } else {
385         var file = files[0];
386         var reader = new FileReader();
387         reader.addEventListener('loadend', function() {
388             var parsed = JSON.parse(this.result);
389             if(parsed === undefined) {
390                 alert('Could not parse likely score');
391             } else {
392                 var confirmation = window.confirm('Proceeding will
                        overwrite the current graph. Are you sure?');
393                 if(confirmation) {
394                     try {
395                         importGraphData(parsed);
396                     } catch(e) {
397                         alert(`Could not import likely score, probably the
                            file was malformed. Error: ${e}`);
398                     }
399                 }
400             }
401         });
402         reader.readAsText(file);
403     }
404 }
405
406 function saveDataToLocalStorage() {
407     const json = JSON.stringify(collectGraphData(nodeData, edgeData));
408     const params = JSON.stringify(gatherParams());
409     localStorage.setItem("score", json)
410     localStorage.setItem("params", params)
411 }
412
413 function showStartingNode() {
414     if(typeof starting_node_id === 'string') {
415         network.selectNodes([starting_node_id], false);
416     } else {
417         alert('No starting node selected yet!');
418     }
419 }
420
421 function setStartingNode() {
422     var selected = network.getSelectedNodes();
423     if(selected.length > 1) {
424         alert('Only select one node!');
425     } else if(selected.length === 0) {
426         alert('Select a node first!');
427     } else {
428         starting_node_id = selected[0];
429     }
430 }
```

```
431
432 function fetchInterpretation(params, format) {
433     var jsonRequest = JSON.stringify({
434         graph: collectGraphData(nodeData, edgeData),
435         params: params
436     });
437
438     var myHeaders = new Headers();
439     myHeaders.set('Content-Type', 'application/json');
440
441     var myInit = {
442         method: 'POST',
443         headers: myHeaders,
444         mode: 'cors',
445         body: jsonRequest
446     };
447
448     var myRequest = new Request(`/interpretation/${format}`, myInit);
449
450     return fetch(myRequest).then(res => res.blob());
451 }
452
453 function gatherParams() {
454     var starting_node_entry = nodeData.get(starting_node_id);
455     if(starting_node_entry !== undefined && starting_node_entry !== null) {
456         var starting_node = {
457             id: starting_node_entry.nodeData.id,
458             music: starting_node_entry.music
459         };
460     } else {
461         var starting_node = null
462     }
463
464     var maxhops = document.getElementById('hop-count').value;
465     if(maxhops === "" || Number(maxhops) === NaN) {
466         maxhops = null;
467     } else {
468         maxhops = Number(maxhops);
469     }
470
471     var seed = document.getElementById('seed').value;
472     if(seed === "" || Number(seed) === NaN) {
473         seed = null;
474     } else {
475         seed = Number(seed);
476     }
477
478     return {
479         maxhops:  maxhops,
480         starting_node: starting_node,
```

```
481             seed: seed
482         };
483     }
484
485     function completeGatherParams() {
486         var p = gatherParams();
487         if(p.starting_node === null) {
488             alert('Set a starting node first!');
489             return null;
490         }
491
492         if(p.maxhops === null) {
493             alert('Set the maximum amount of hops to a valid number');
494             return null;
495         }
496
497         if(p.seed === null) {
498             // TODO auto generate a random one, let the user confirm before
499             alert('Set the seed to a valid number!');
500             return null;
501         }
502
503         return p;
504     }
505
506     function importParams(p) {
507         if(p.starting_node !== null) {
508             starting_node_id = p.starting_node.id;
509         }
510         if(p.seed !== null) {
511             document.getElementById('seed').value = p.seed;
512         }
513         if(p.maxhops !== null) {
514             document.getElementById('hop-count').value = p.maxhops;
515         }
516     }
517
518     function randomSeed() {
519         if(window.crypto) {
520             var array = new Int32Array(1);
521             window.crypto.getRandomValues(array);
522             document.getElementById('seed').value = array[0];
523         }
524     }
525
526     function downloadInterpretation(format) {
527         var params = completeGatherParams();
528         if(params != null) {
529             try {
530                 fetchInterpretation(params, format).then(file => {
```

```
531                 var url = URL.createObjectURL(file);
532                 download(url, `export.${format}`);
533             });
534         } catch(e) {
535             alert('An error occured while contacting the API: ' + e);
536         }
537     }
538 }
539
540 function reloadPlayer() {
541     var params = completeGatherParams();
542     if(params !== null) {
543         document.getElementById('player').src = null;
544         try {
545             fetchInterpretation(params, 'wav').then(file => {
546                 var url = URL.createObjectURL(file);
547                 document.getElementById('player').src = url;
548             });
549         } catch(e) {
550             alert('An error occured while contacting the API: ' + e);
551         }
552     }
553 }
554
555 function init() {
556     var container = document.getElementById('network');
557
558     var options = {
559         manipulation: {
560             addNode: function(nodeData, callback) {
561                 document.getElementById('node-operation').innerHTML = 'Add
                        ';
562                 genericEditNode(nodeData, callback);
563             },
564             addEdge: function(edgeData, callback) {
565                 document.getElementById('edge-operation').innerHTML = 'Add
                        ';
566                 genericEditEdge(edgeData, callback);
567             },
568             editNode: function(nodeData, callback) {
569                 document.getElementById('node-operation').innerHTML = 'Edit
                        ';
570                 genericEditNode(nodeData, callback);
571             },
572             editEdge: {
573                 editWithoutDrag: function(edgeData, callback) {
574                     document.getElementById('edge-operation').innerHTML = '
                            Edit';
575                     genericEditEdge(edgeData, callback);
576                 }
```

```
577             },
578             deleteNode: deleteFromMap,
579             deleteEdge: deleteFromMap,
580             controlNodeStyle: {
581             }
582         },
583         nodes: {
584             borderWidth: 0,
585             color: {
586                 background: '#563d7c',
587                 hover: {
588                     background: '#8f14ff'
589                 },
590                 highlight: {
591                     background: '#8f14ff'
592                 }
593             },
594             chosen: true,
595             font: {
596                 color: 'white',
597                 size: 20,
598                 align: 'center'
599             },
600             shape: 'circle',
601         },
602         edges: {
603             arrows: {
604                 to: { enabled: true }
605             },
606             color: {
607                 color: '#563d7c',
608                 hover: '#563d7c',
609                 highlight: '#563d7c',
610             },
611             font: {
612                 color: '#ffffff',
613                 strokeWidth: 0
614             }
615         }
616     };
617
618     network = new vis.Network(container, {}, options);
619
620     try {
621         const score = localStorage.getItem('score');
622         if(score !== null) {
623             importGraphData(JSON.parse(score));
624         }
625     } catch(e) {
626         localStorage.removeItem('score');
```

```
627     }
628
629     try {
630         const params = localStorage.getItem('params')
631         if(params !== null) {
632             importParams(JSON.parse(params));
633         }
634     } catch(e) {
635         localStorage.removeItem('params');
636     }
637
638     const pitch_selector = valid_pitches.map((p, i) =>
639         `<option value="${p}">${display_pitches[i]}</option>`)
640         .reduce((acc, v) =>
641             acc + v, '');
642     document.getElementById('pitch').innerHTML = pitch_selector;
643
644     /* event handling, order as in sidebar */
645     document.getElementById('set-starting-node').onclick = setStartingNode;
646     document.getElementById('show-starting-node').onclick =
        showStartingNode;
647
648     document.getElementById('random-seed').onclick = randomSeed;
649
650     document.getElementById('reload-player').onclick = reloadPlayer;
651     document.getElementById('download-audio').onclick = () => {
652         var format = document.getElementById('format').value;
653         downloadInterpretation(format);
654     };
655
656     document.getElementById('gen-score').onclick = () =>
657         downloadFile('application/json', 'score.likely.json',
658             JSON.stringify(collectGraphData(nodeData, edgeData)));
659     document.getElementById('upload-score').addEventListener('change',
        handleImport);
660     document.getElementById('clear-score').onclick = () =>
661         importGraphData({ nodes: [], edges: []});
662
663     window.setInterval(saveDataToLocalStorage, 5000);
664 }
665
666 document.addEventListener('DOMContentLoaded', () => init());
```

Lizenz

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