New approaches in music generation from tonal and modal perspectives

María Navarro-Cáceres

Madrid 15th December 2017

University of Salamanca (Spain)

BISITE
RESEARCH GROUP

VNiVERSiDAD D SALAMANCA
CAMPUS DE EXCELENCIA INTERNACIONAL

Contents

Universidad de Salamanca (1 of 2)

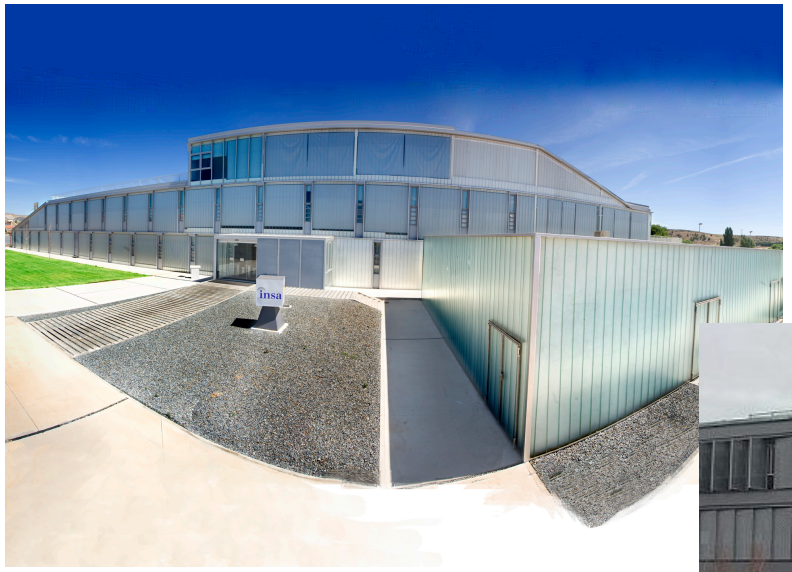
(Universitas Studii Salmanticensis, latín)

Web page: **http://www.usal.es**

- Located in Salamanca (Spain)
- Founded in **1218**. In 2018, it will celeb
  its VIII centenary.
- **8 centuries** creating knowledge.
- **Spain's oldest university.**
- One of the four oldest in Europe.
- Actually, the University has over:
  - **30.000** students
  - **25** Faculties
  - **66** Departments
  - **16** Research institutes
  - **106** research groups

Universidad de Salamanca (2 of 2)

Web page: **http://www.usal.es**



IBM / INSA Center in Salamanca

The University of Salamanca has a new **Scientific Park** and business partnerships with important Innovation Enterprises like **IBM**.

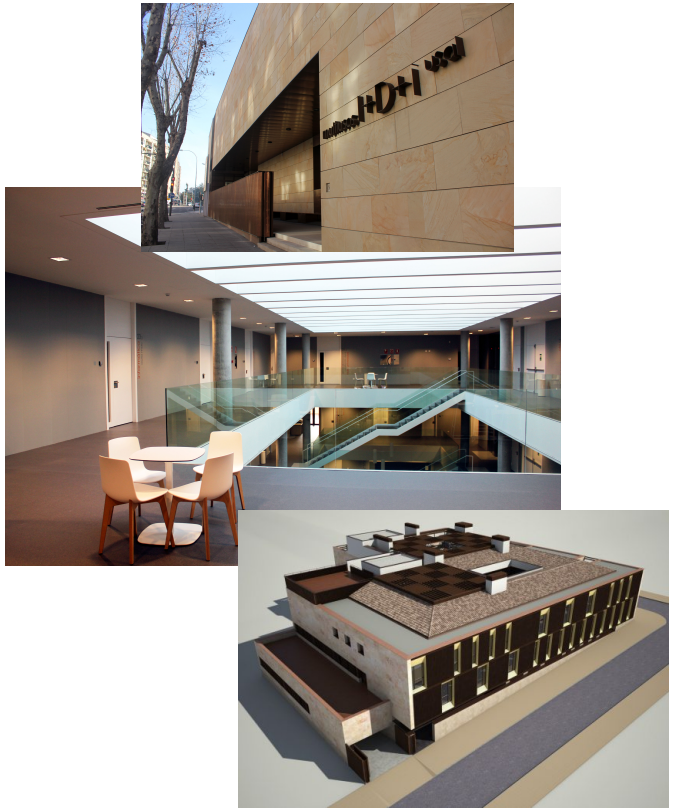
University of Salamanca's Scientific Park

BISITE Research Group

BISITE is a multidisciplinary group interested in Artificial Intelligent distributed models. The group works in areas such as ambient intelligent, technology enhanced learning, bioinformatics, sensors, robotics, multiagents systems, etc.

Members:

- Researcher: Juan M. Corchado
- PhD Members: 21
- PhD Students: 8
- Engineers: 21
- Collaborators (Universities, groups or research centres): 11



Research lines

- Security and monitoring
- Smart Cities
- Energy Efficiency
- Media and Comunication
- Health and Dependence
- Industry and Control Process
- Security and Monitoring
- Education
- Administration
- Logistics, Transport and Guidance
- Business Inteligence
- Robotics
- Bioinformatics
- Creativity

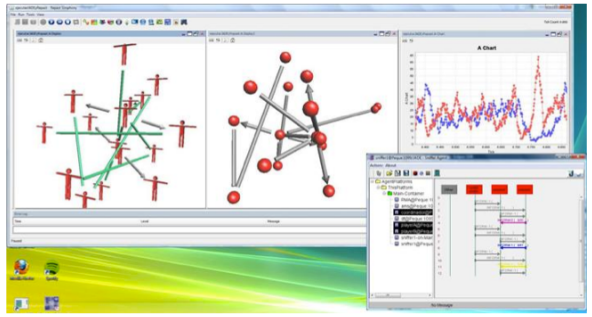
Technologies

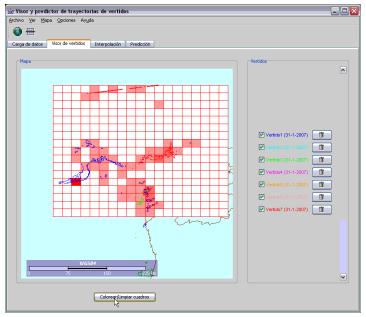
- Artificial Intelligence and Computer Sciences
- Distributed AI
- Case-Based Reasoning Systems
- Ambient Intelligence / Ambient Assisted Living / e-Health / e-Inclusion
- Agents Technology
- Mobility and Wireless Sensor Networks.
- Technology Enhanced Learning
- Bioinformatics
- Web 3D and Digital Animation
- Cloud Computing
- Distributed Intelligent Control
- Intelligent Webs
- Creativity

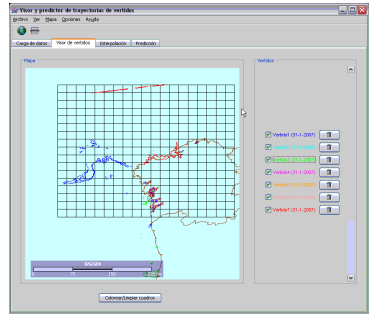
Technologies

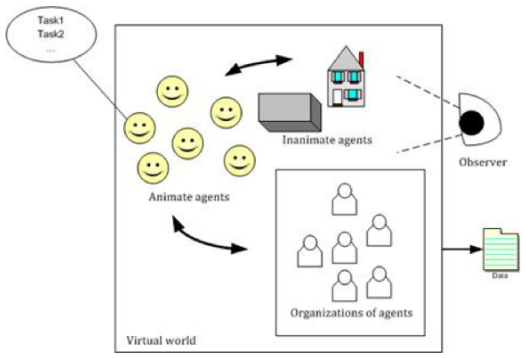
Agents Technology and Multi-Agent Systems

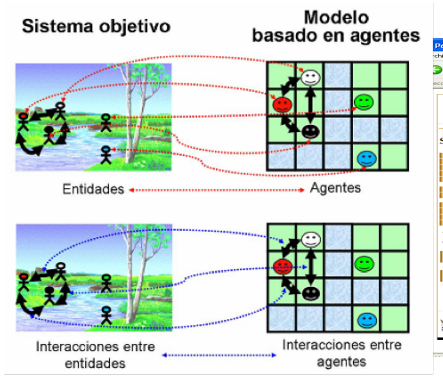
New models for smart agents. New architectures for advanced open multi-agent systems. Methodologies, tools and mechanisms for multi-agent systems

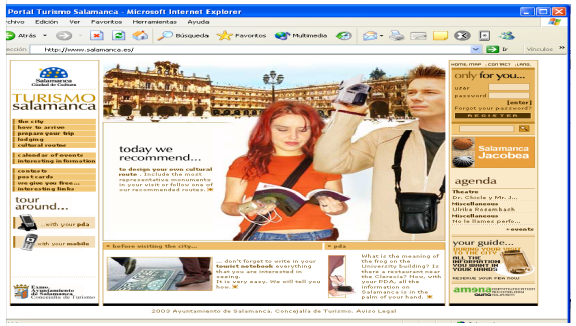








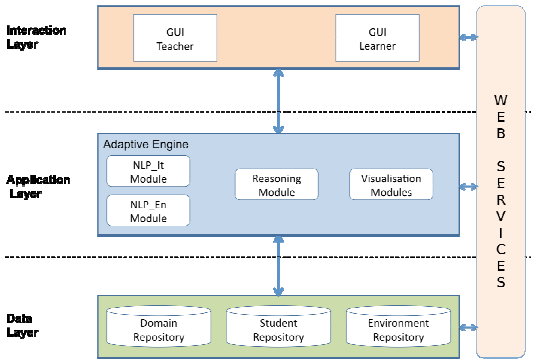


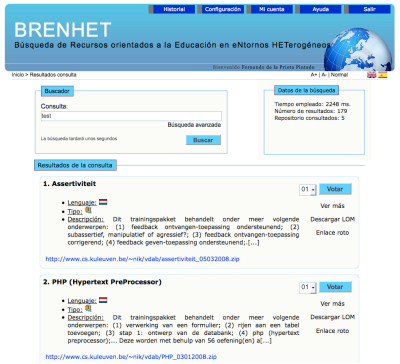


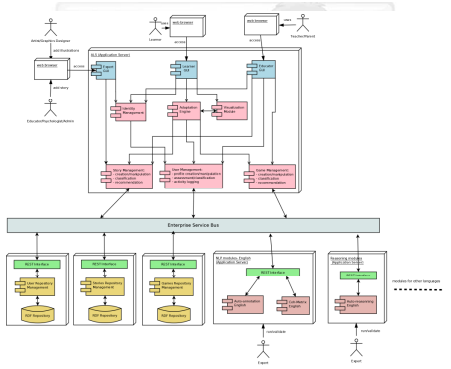
Technologies

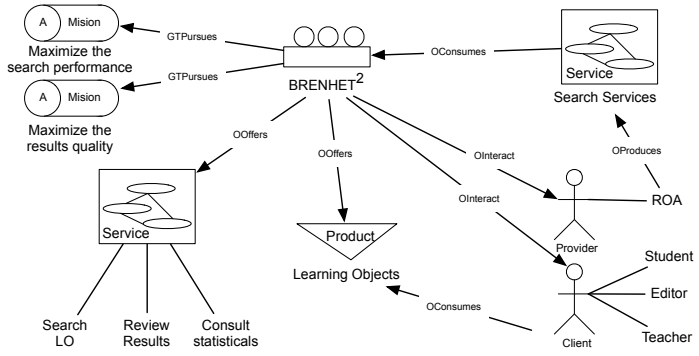
Technology Enhanced Learning

Computational and Artificial Intelligence techniques in the field of e-learning





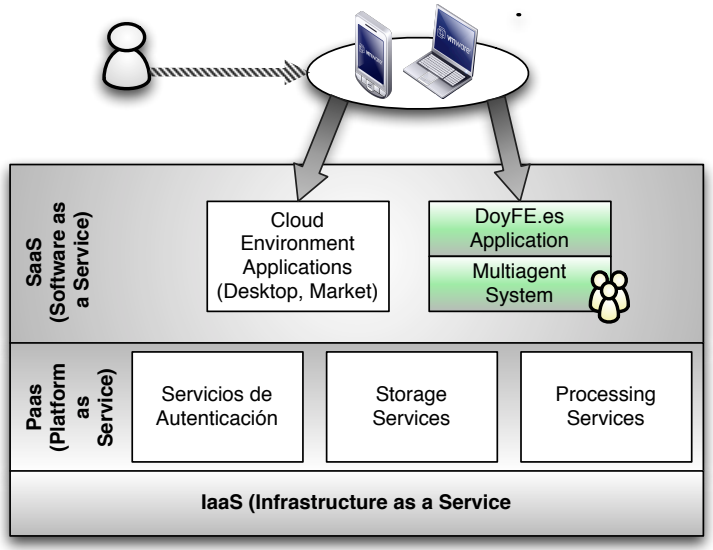


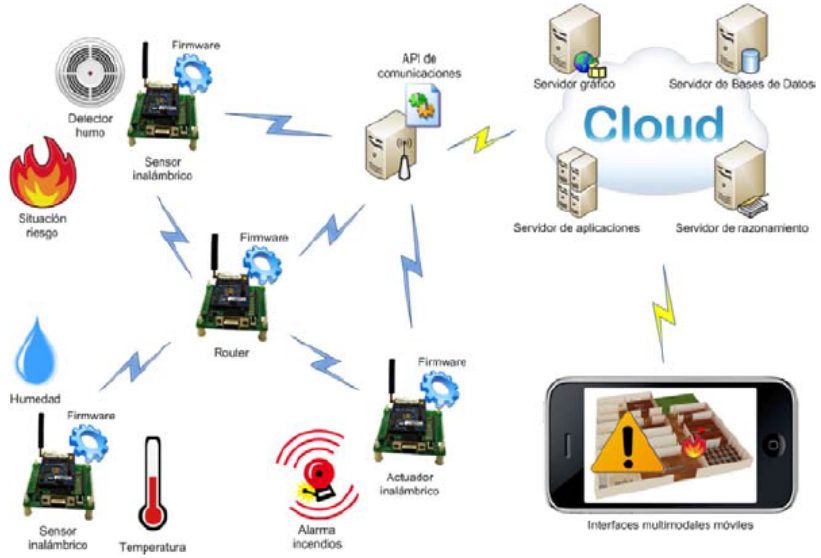


Technologies

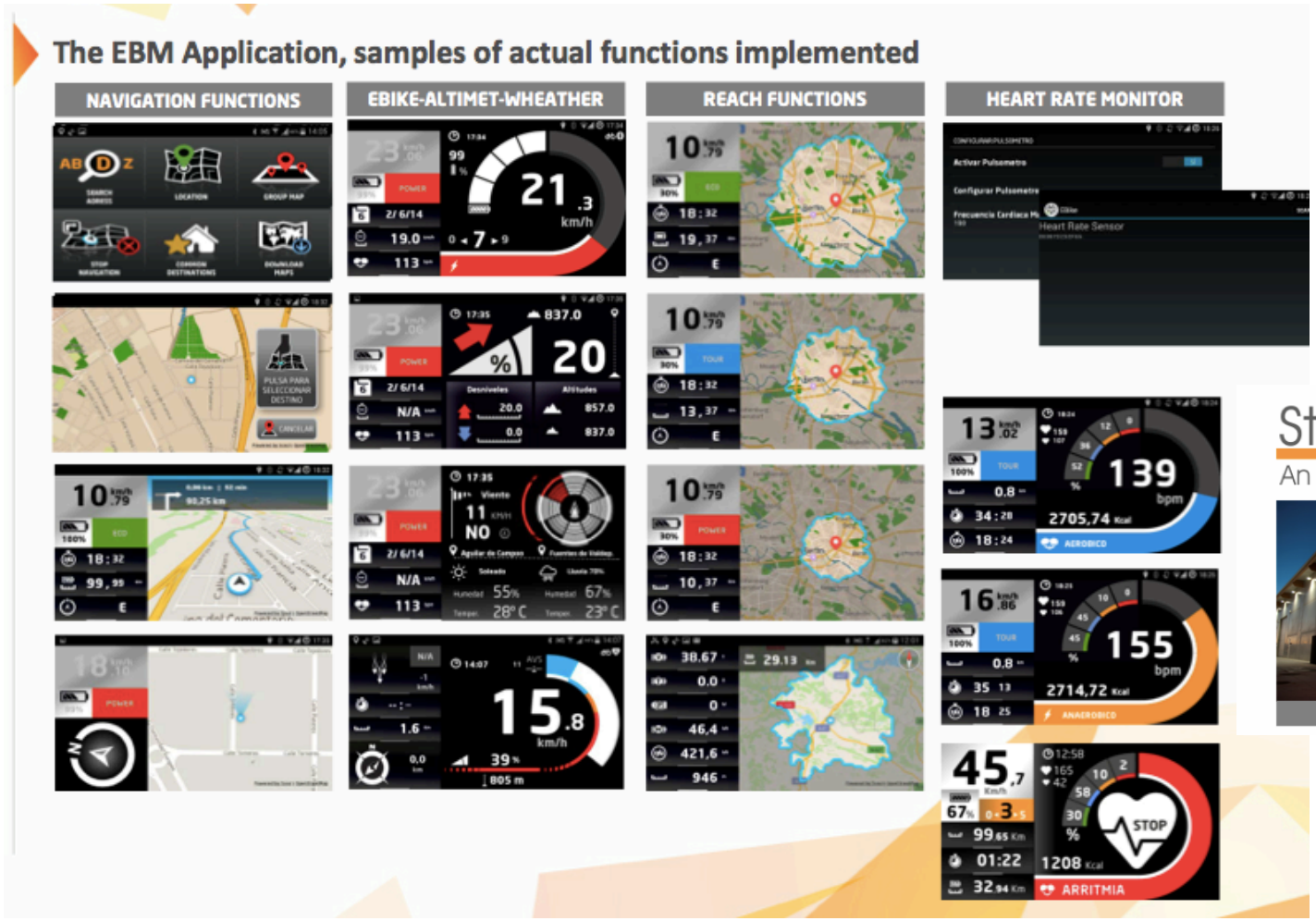
Cloud Computing, Distributed systems

The three fundamental points at the core of the group's research are: Multiagent Systems, Distributed Resolution of Problems, and cloud computing systems. The basic problems studied within DAI. In line with this study, the team has worked on research projects in collaboration with companies such as INSA-IBM, among others.

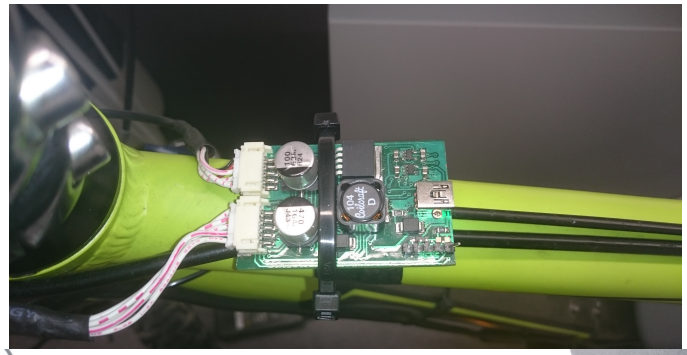




Electric Bikes



Electric Bi

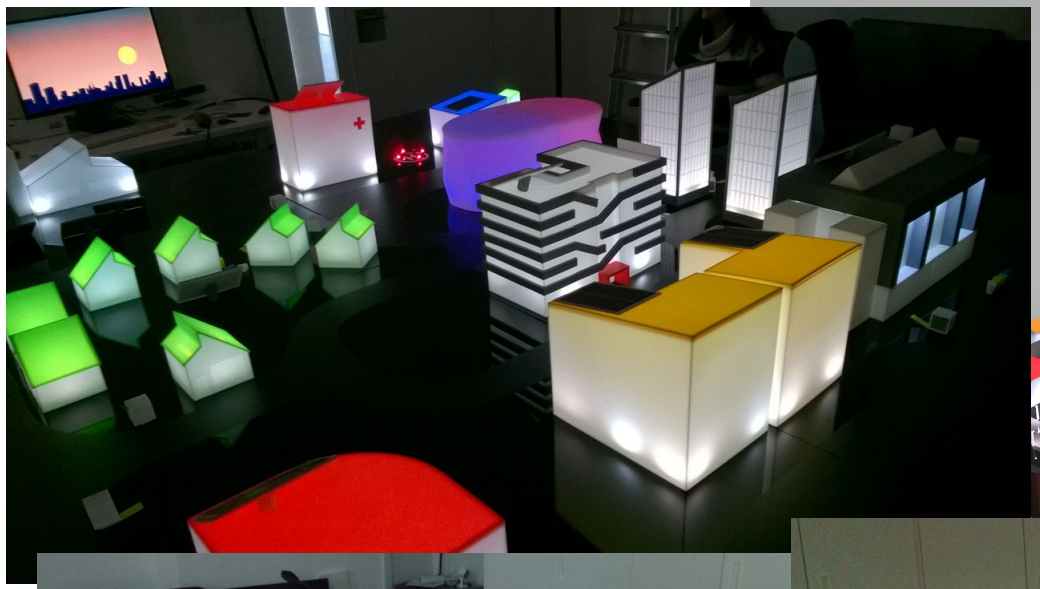


BISITELamp

- **Smart Lighting System**
- Public lighting management system that aims to cut the costs of street lighting in order to save money for both public administrations and private entities

BISITE LAMP

Model of smart city



R&D Projects

INTERNATIONAL PROJECTS (some of our latest projects are):

- **EKRUCAmI**
- **TERENCE: An Adaptive Learning System for Reasoning about Stories with Poor Stories Comprehenders and their Educators**
- **IOTEC**
- Train and Customer Prediction
- **DREAM-GO**

Publications

Our activities in the last 15 years

JCR	No JCR	Books	Chapters	Conference
122	55	133	27	422

Main topics of our research papers:

- **Artificial Intelligence and Computer Sciences**
  - **Distributed AI**
  - **Case-Based Reasoning Systems Ambient Intelligence / Ambient Assisted Living / e-Health / e-Inclusion**
  - **Technology Enhanced Learning**
  - **Agents Technology**
  - **Creativity**

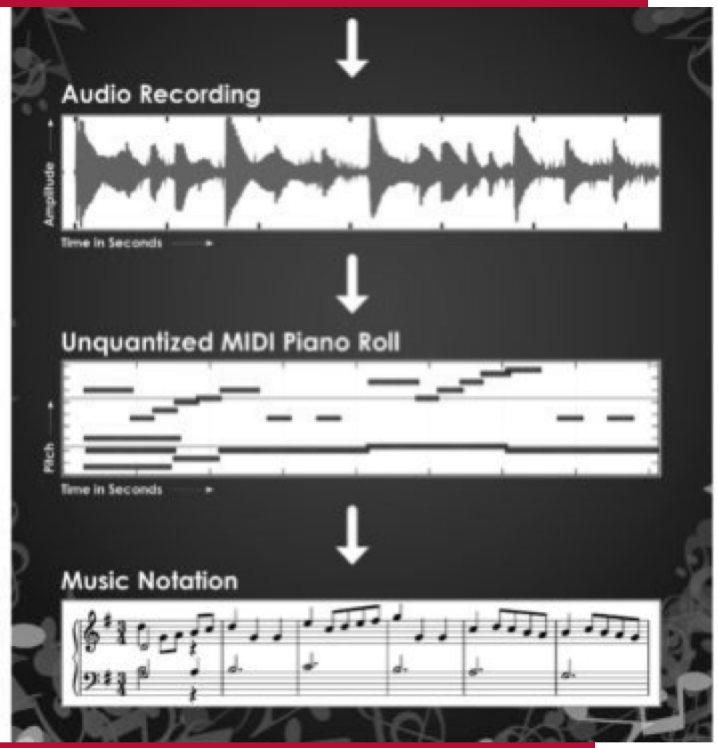
Partnerships

Creativity Projects: Chord Generator

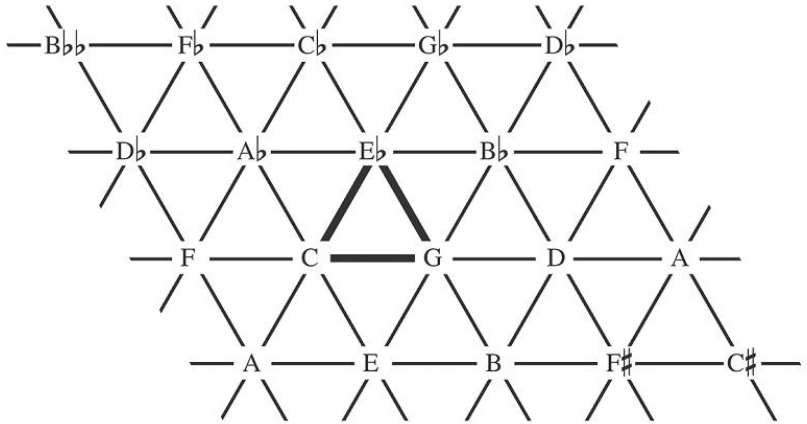
Introduction

- In the area of music, there are some interesting proposals about collaboration between humans and machines
  - VirtualBand
  - FlowMachines
  - MotionComposer

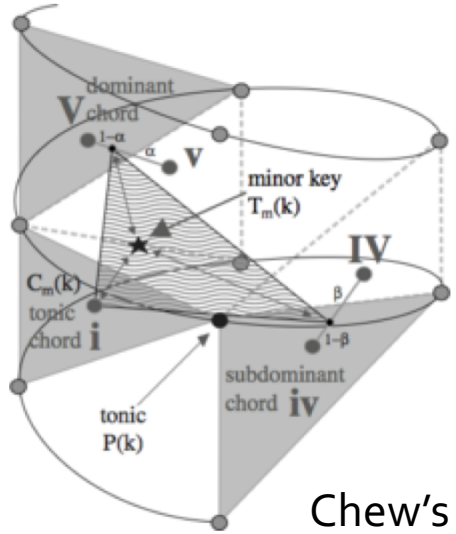
Codification of Pitch Configurations



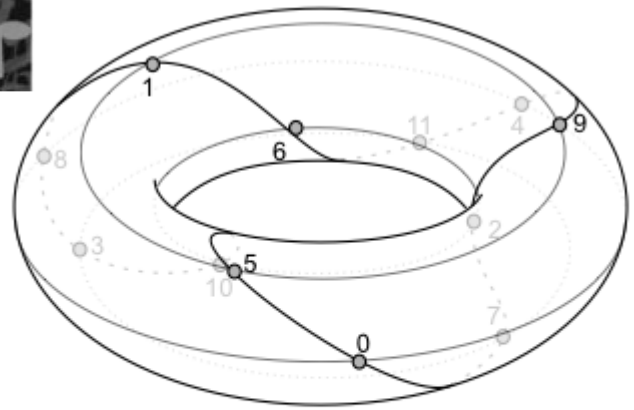
MIDI

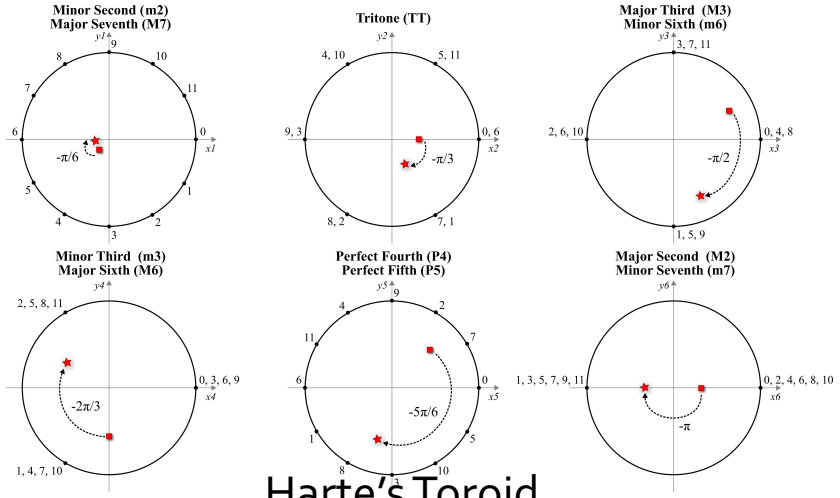


Tonnetz



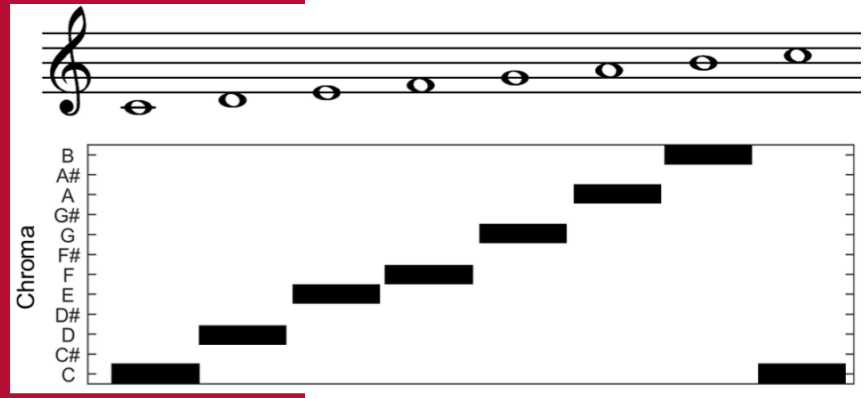
Chew's Spiral





Harte's Toroid

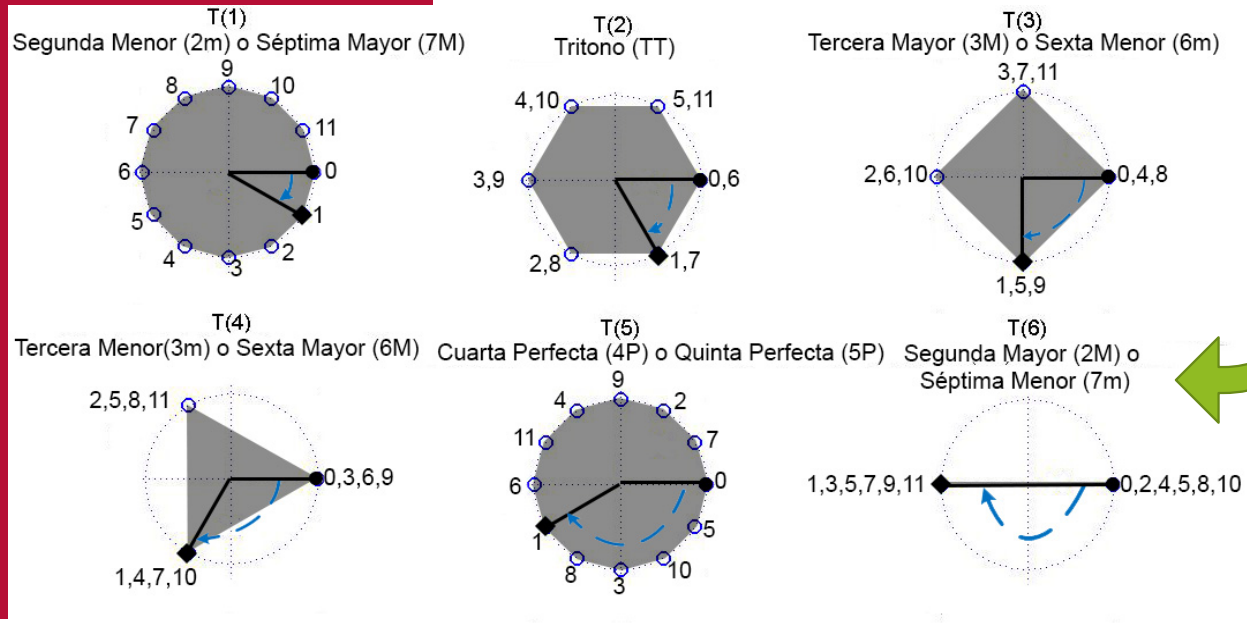
Tonal Interval Space



[1 0 1 0 1 1 0 1 0 1 0 1]

$$T(k) = W(k) \sum_{n=0}^{N-1} \bar{C}(n)\, e^{\frac{-j2\pi}{N}kn}, \quad k \in \mathbb{Z}$$

Transformada Discreta de Fourier (DFT)



Chord construction of an objective function

Dissonance

$$\xi\left(T_i\right) = 1 - \frac{\left\| T_i\left(k\right) \right\|}{\sum_{k=1}^{M=6} W\left(k\right)}$$

- Euclidean distance to the center of the TIS

Perceptual Relationship

$$\delta\left(T_i, T_{i-1}\right) = \sqrt{\sum_{k=1}^{M=6} \left|T_i\left(k\right) - T_{i-1}\left(k\right)\right|^2}$$

- Euclidean distance between two pitch configurations

Scale Relationship

$$\lambda\left(T_i, T_l\right) = 1 - \cos\theta = 1 - \frac{T_i \cdot T_l}{\|T_i\| \|T_l\|}$$

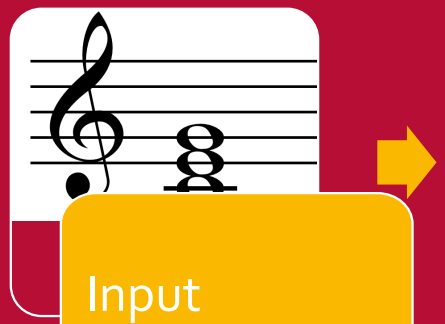
- Scalar product between the pitch configuration vector and the key vector

Harmonic Function relationship

$$\phi\left(T_i, T_l, T_f\right) = 1 - \cos\Phi = 1 - \frac{\left(T_i - T_l\right) \cdot T_f}{\left\| \left(T_i - T_l\right) \right\| \|T_f\|}$$

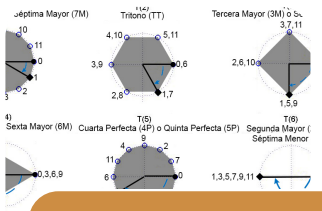
- Producto escalar de la configuración tonal y el vector función armónica, con respecto a la codificación de la escala

Generating a Chord Progression

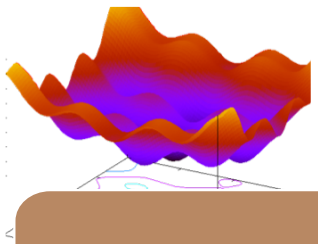


Input
- By the user
- Last iteration

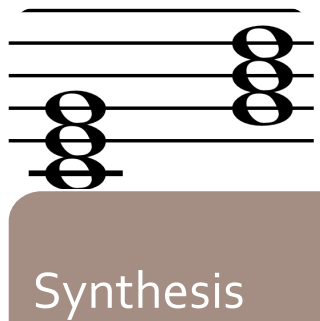
Chroma Vector
- 12 elements
- Binary



DFT
- 6 components



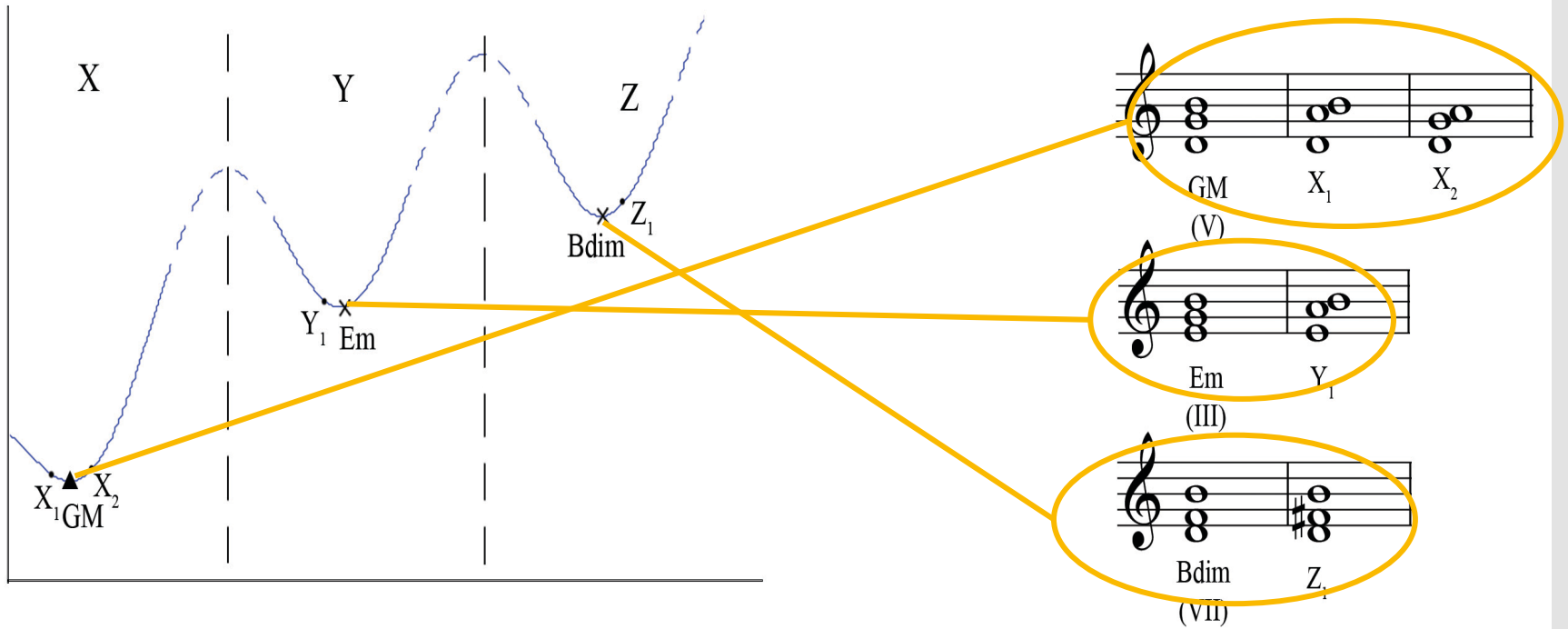
AIS (opt-Ainet)
- Objective Function
- Optimization



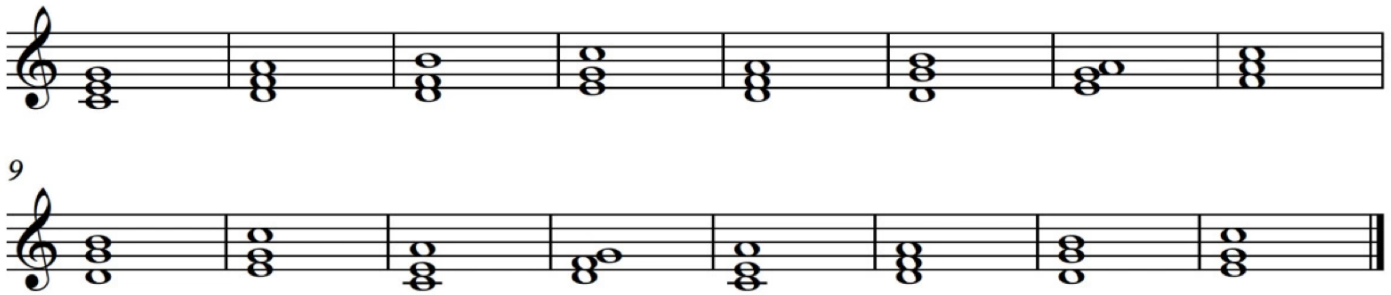
Synthesis
- Several options
- Similar quality

$$P(\delta, \xi, \lambda, \phi) = D\delta + X\xi + L\lambda + F\phi$$

AIS Properties

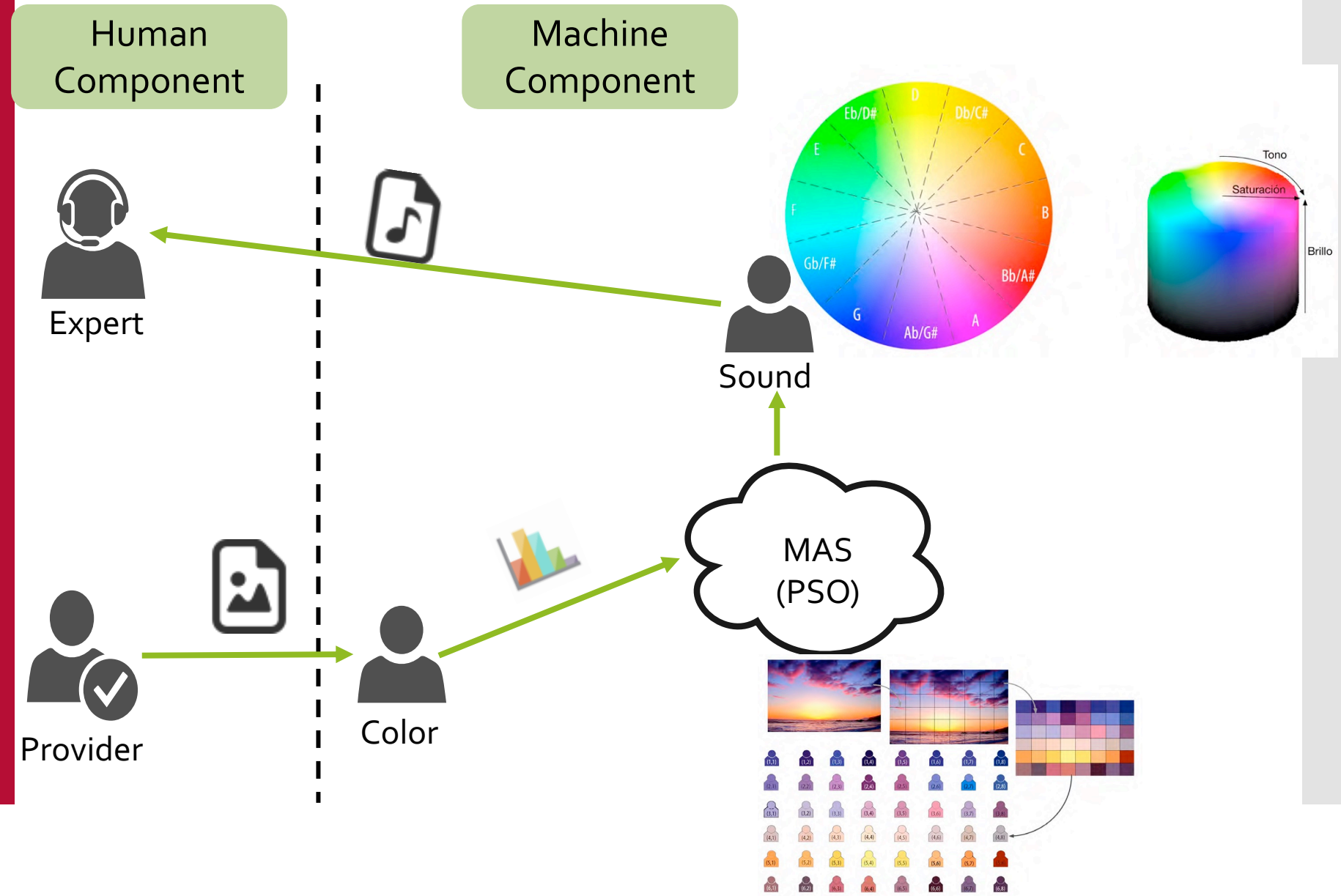


Audios



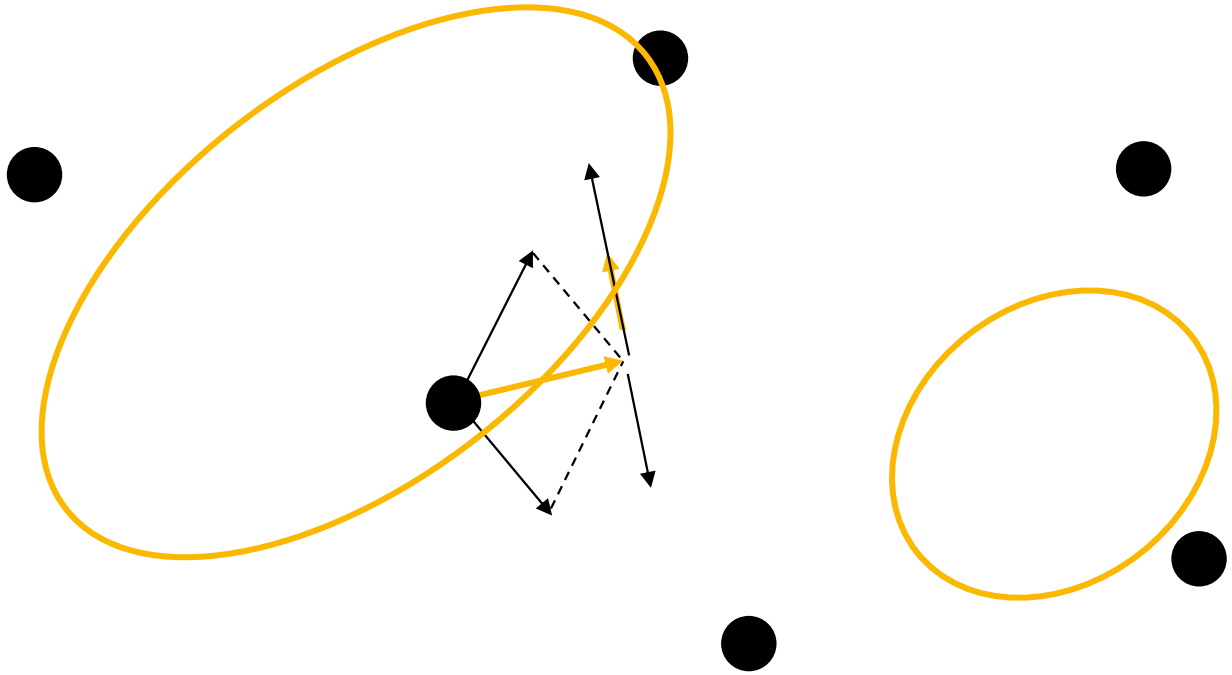
Creativity Projects: Synesthetic Generation of Melodies

Synesthesia System

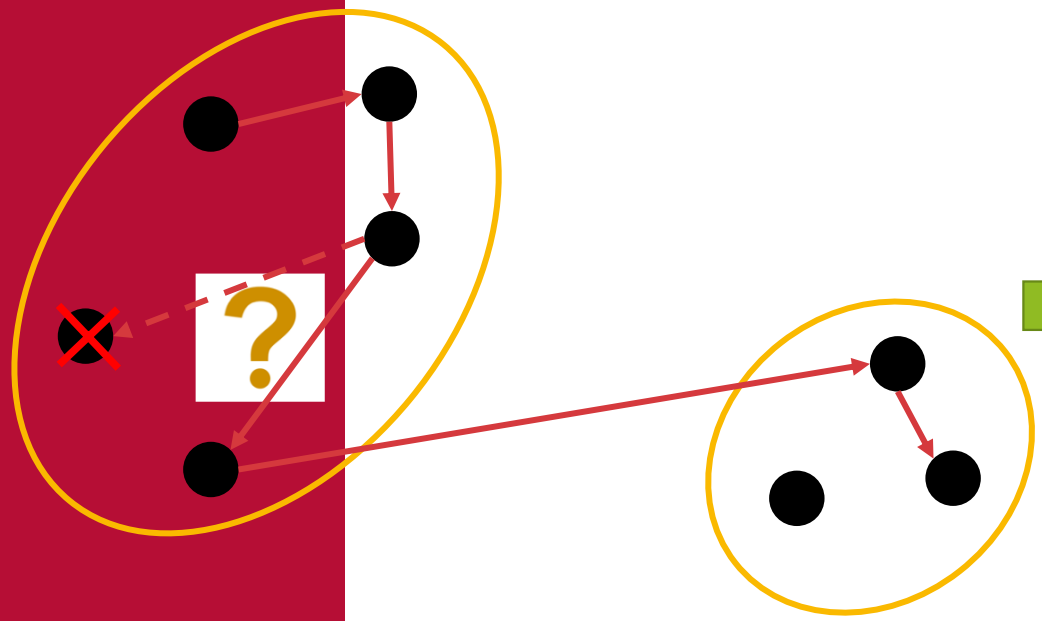


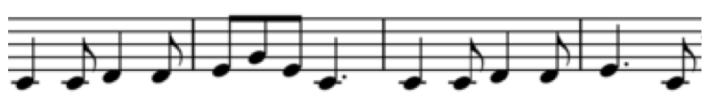
PSO

$$F(n_a, n) = \sum_{i=0}^{M} (W_c \cdot C(n_a) W_d \cdot D(n_a, n_i) + W_l \cdot L(n_a, n_i))$$



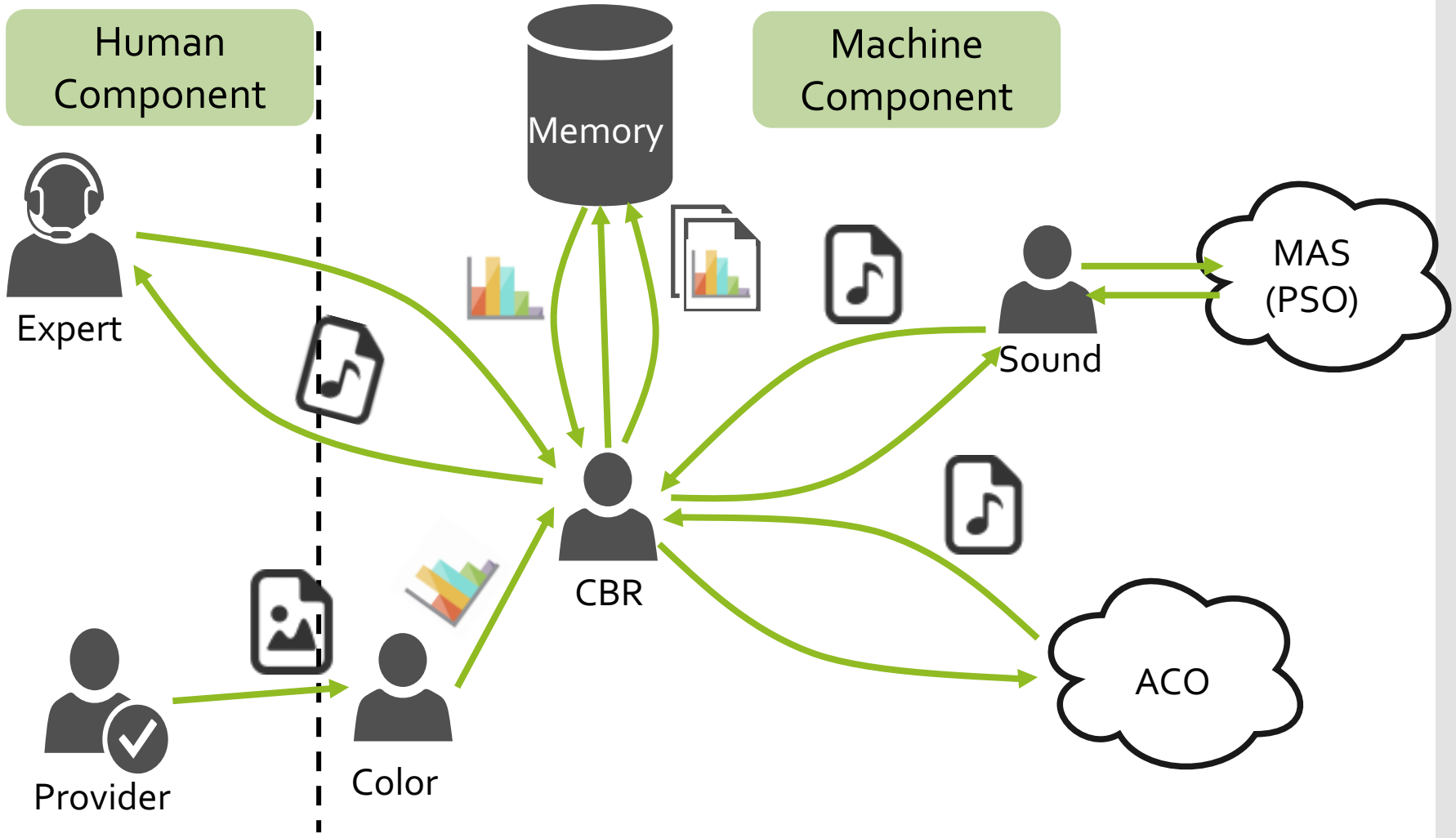
Ordering Notes



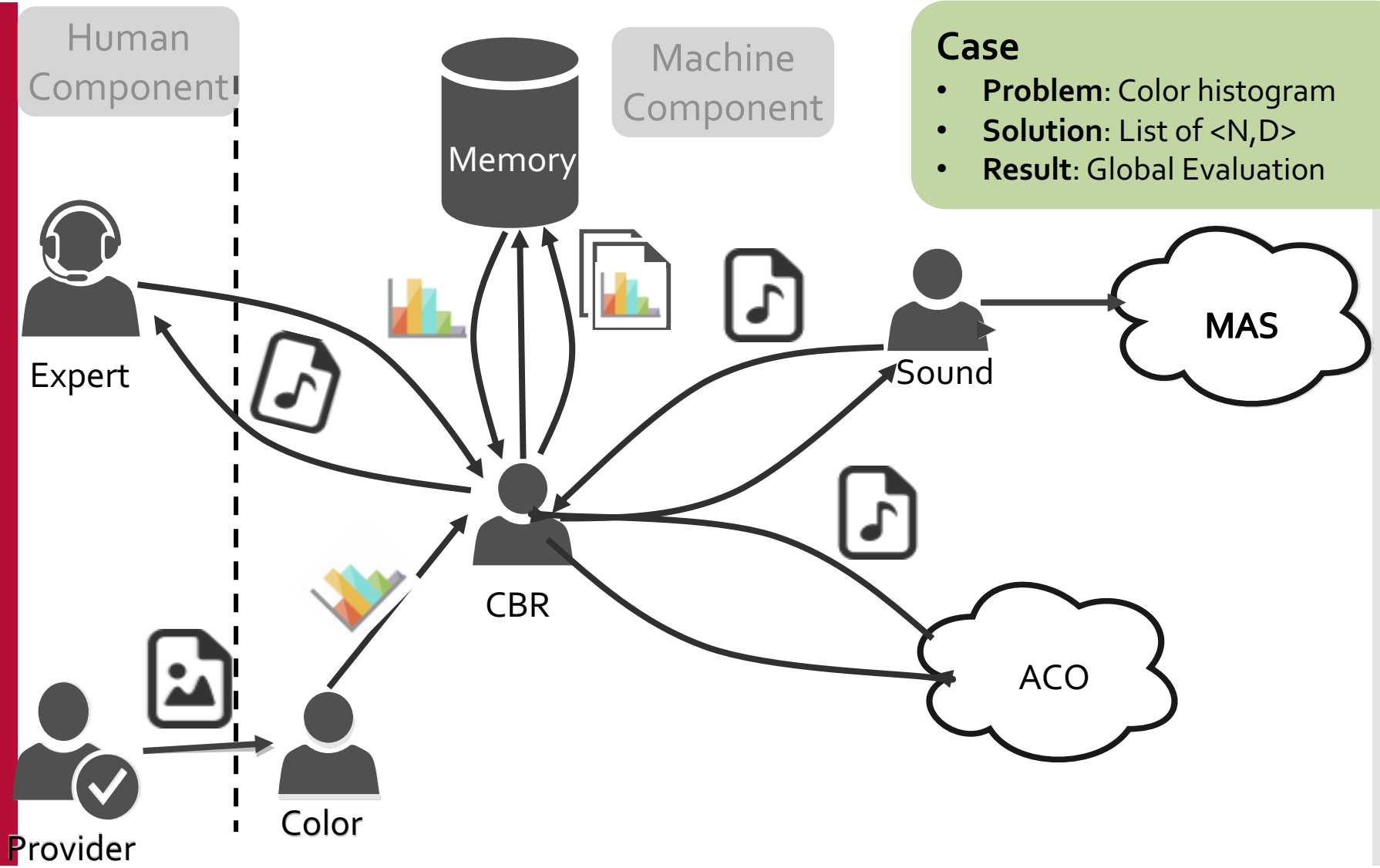


$$\kappa(n_i, n_{i-1}, n_l) = \Theta(n_i, n_l) + W_{at} \cdot A(n_{i-1}, n_i) + W_c \cdot F(n_{i-1}, n_i)$$

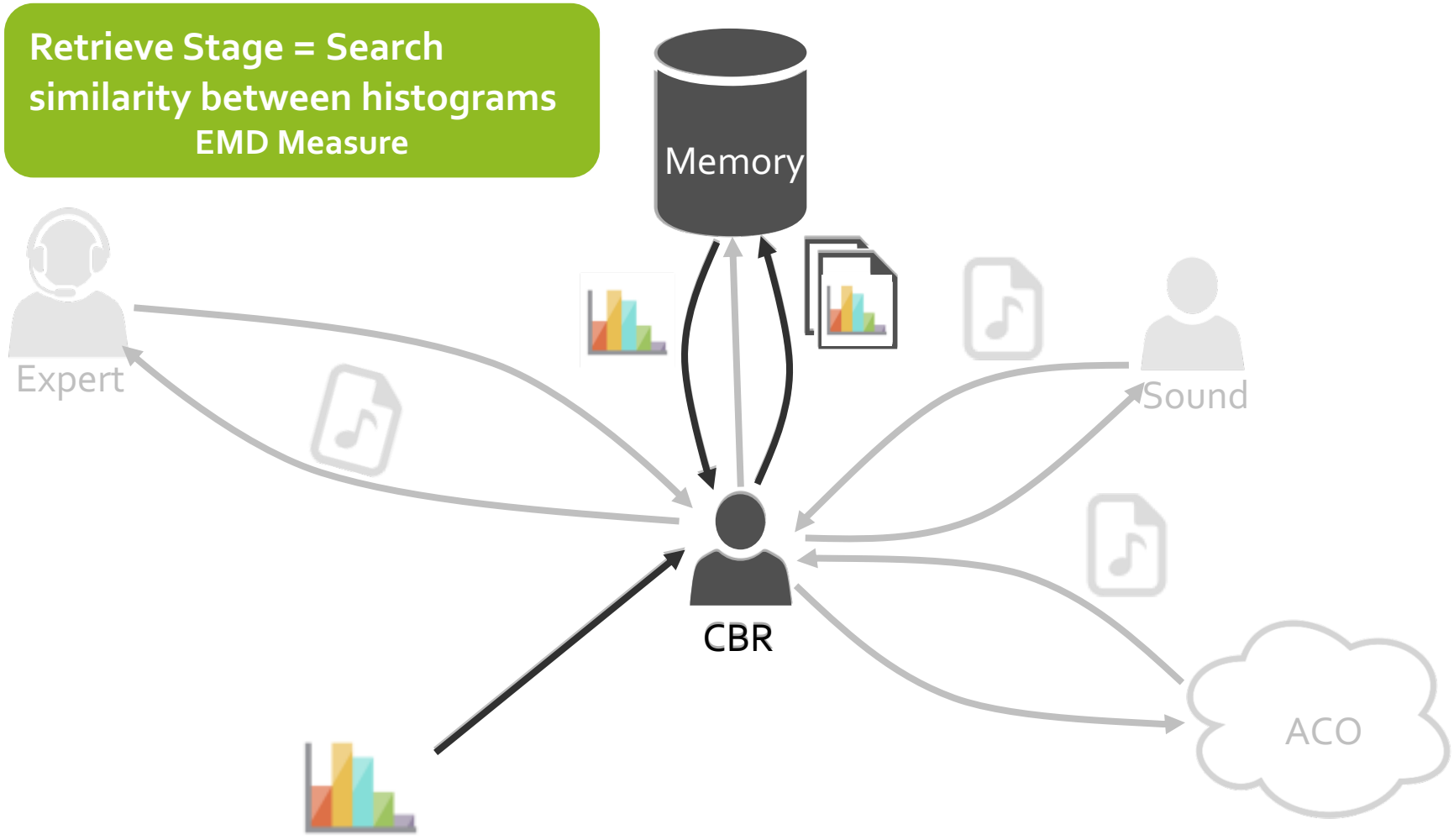
Total System



Total System

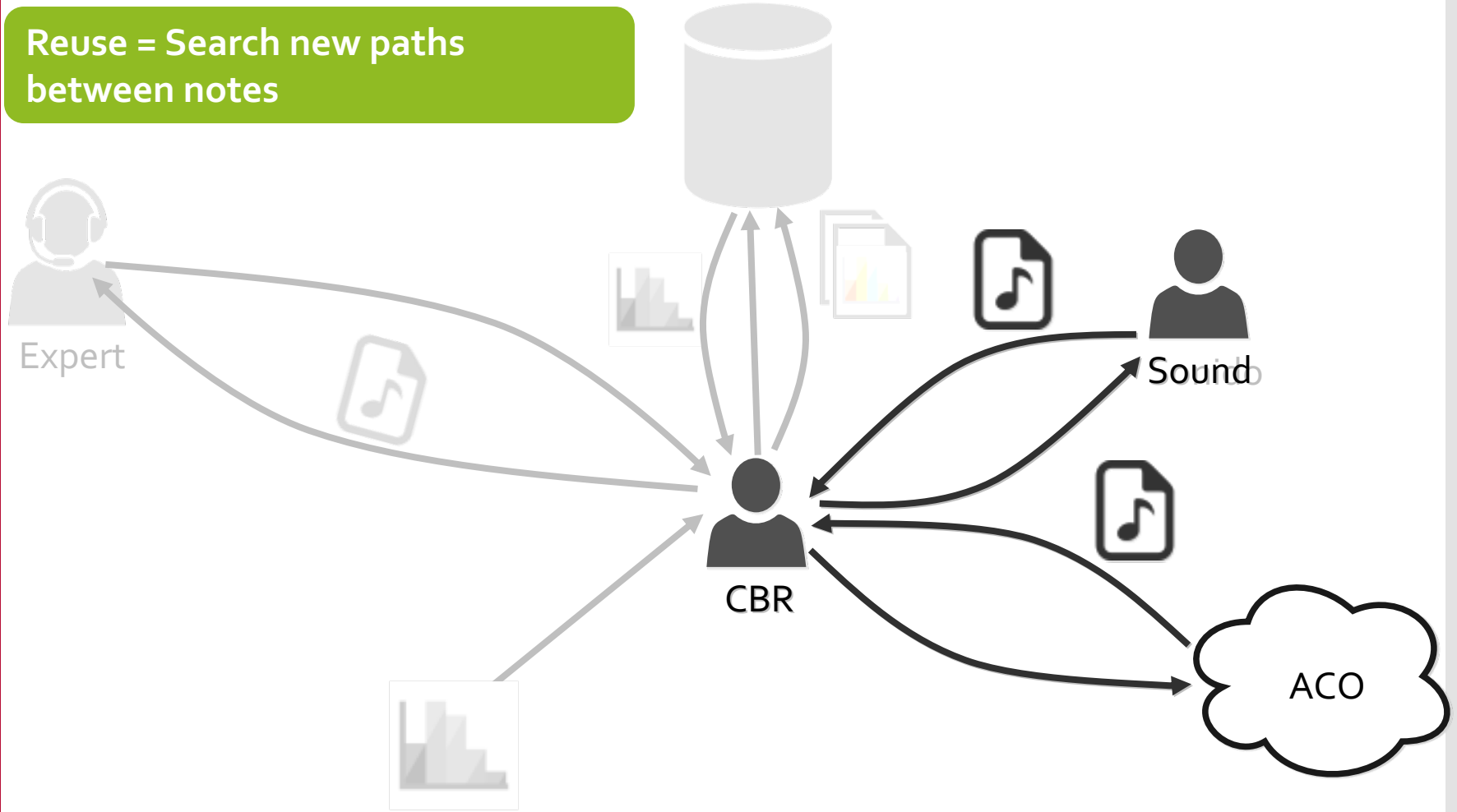


Retrieve Stage

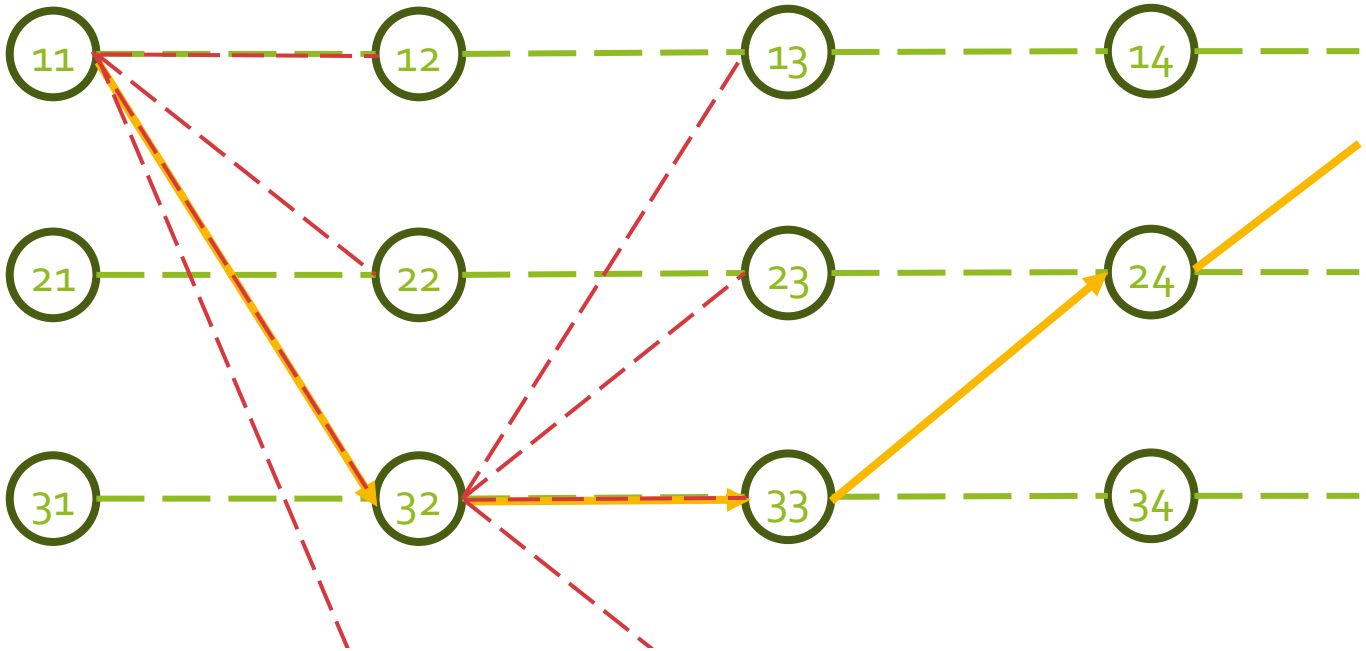


Reuse Stage

Reuse = Search new paths between notes



Reuse Stage

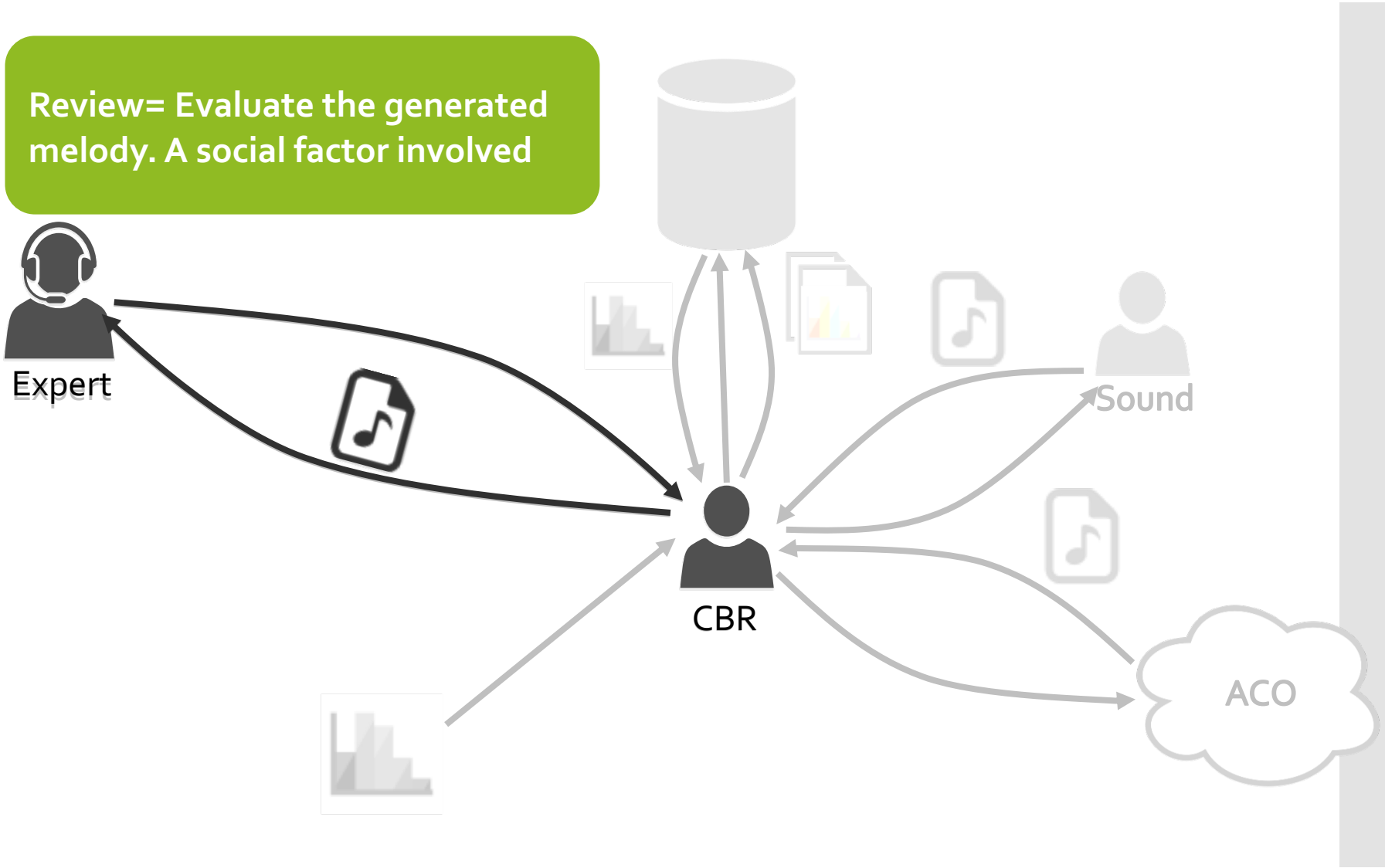


$$f(s,t) = \sum_{i=1,j=1}^{N} \Delta \cdot u(n_i, n_j) + (1-\Delta) \cdot \kappa(n_i, n_j, n_l)$$

Cost Function

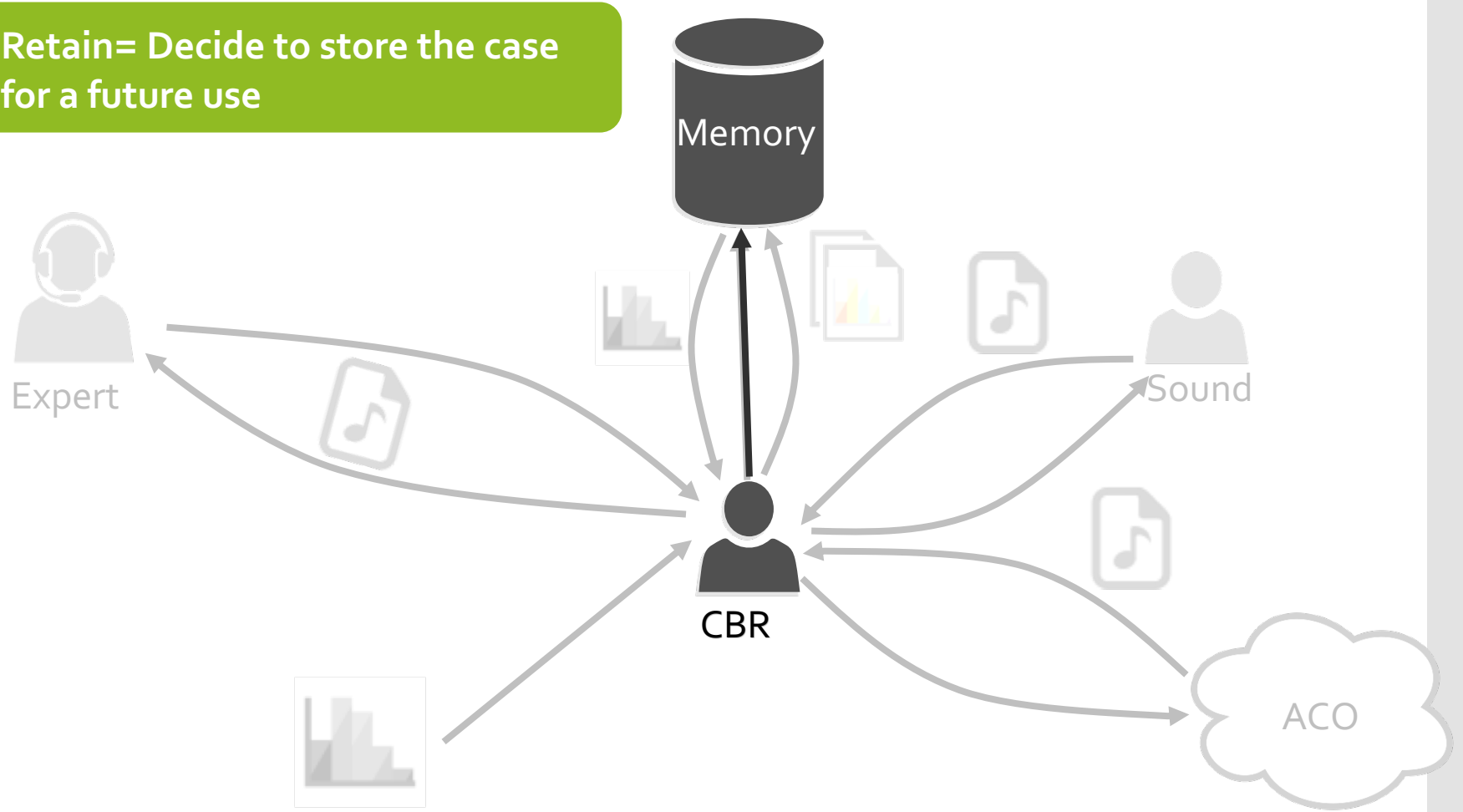
- Quality of transition between two notes, based on TIS measures
- Difference of the global scores of previous musical compositions

Review Stage



Retain Stage

Retain= Decide to store the case for a future use



Audios

Introducing Modality in the Generation Process

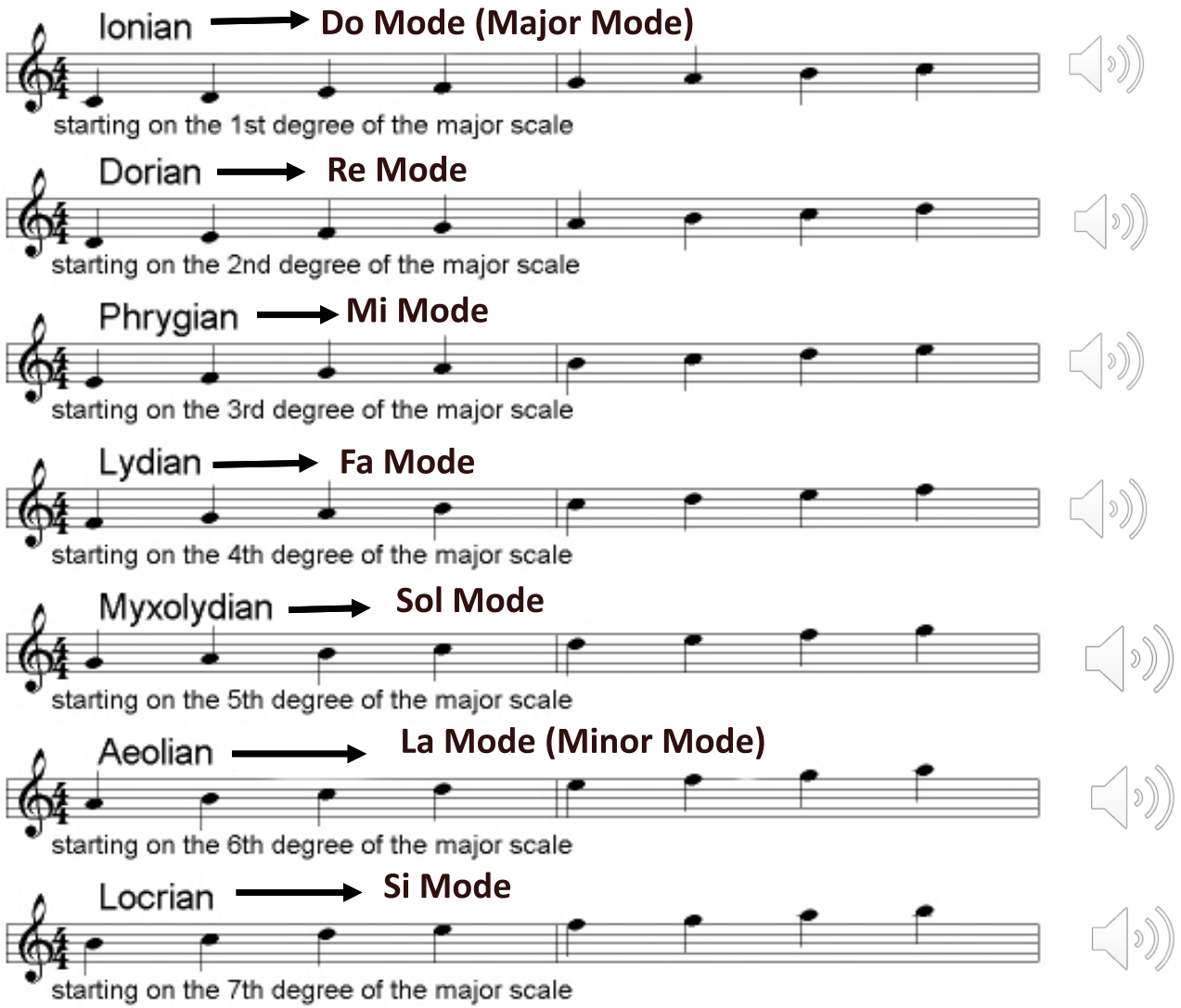
Introduction

- This work proposes an intelligent system to generate melodies based on user guidelines and previous melodies.
- The user can guide the generation of melodies by moving a connected mechanical device.

Introduction

- A CBR is integrated to learn from previous melodies generated by the user.
- The final results are also influenced by the users' preferences

Modality


Ionian → Do Mode (Major Mode)
starting on the 1st degree of the major scale
Dorian → Re Mode
starting on the 2nd degree of the major scale
Phrygian → Mi Mode
starting on the 3rd degree of the major scale
Lydian → Fa Mode
starting on the 4th degree of the major scale
Myxolydian → Sol Mode
starting on the 5th degree of the major scale
Aeolian → La Mode (Minor Mode)
starting on the 6th degree of the major scale
Locrian → Si Mode
starting on the 7th degree of the major scale

Popular Music

Tonality	Modality
Melody is very rich, with a high registry	Melody has a low registry, with signs of archaism such as repeated notes
Harmony is always present	Harmony does not have to be present
There are some harmonic rules which should be followed	The harmony does not follow any special rule, it depends on the text
It exists a hierarchy that depends on the chords	It exists a hierarchy which depends on the text or the action (work, nanny, etc.)
The music can be very long (sonata, symphony)	The music is not usually very long.
The instrumentation can be very complex	The instrumentation can be simple, i.e. only consisting on voice and a rattle.

Popular Music

- With features like those:
  - it becomes harder to use tools like grammars or optimization functions to generate popular songs.
  - It becomse harder to teach students to learn this kind of music
- Learning approaches are the most suitable tools:
  - Markov Models

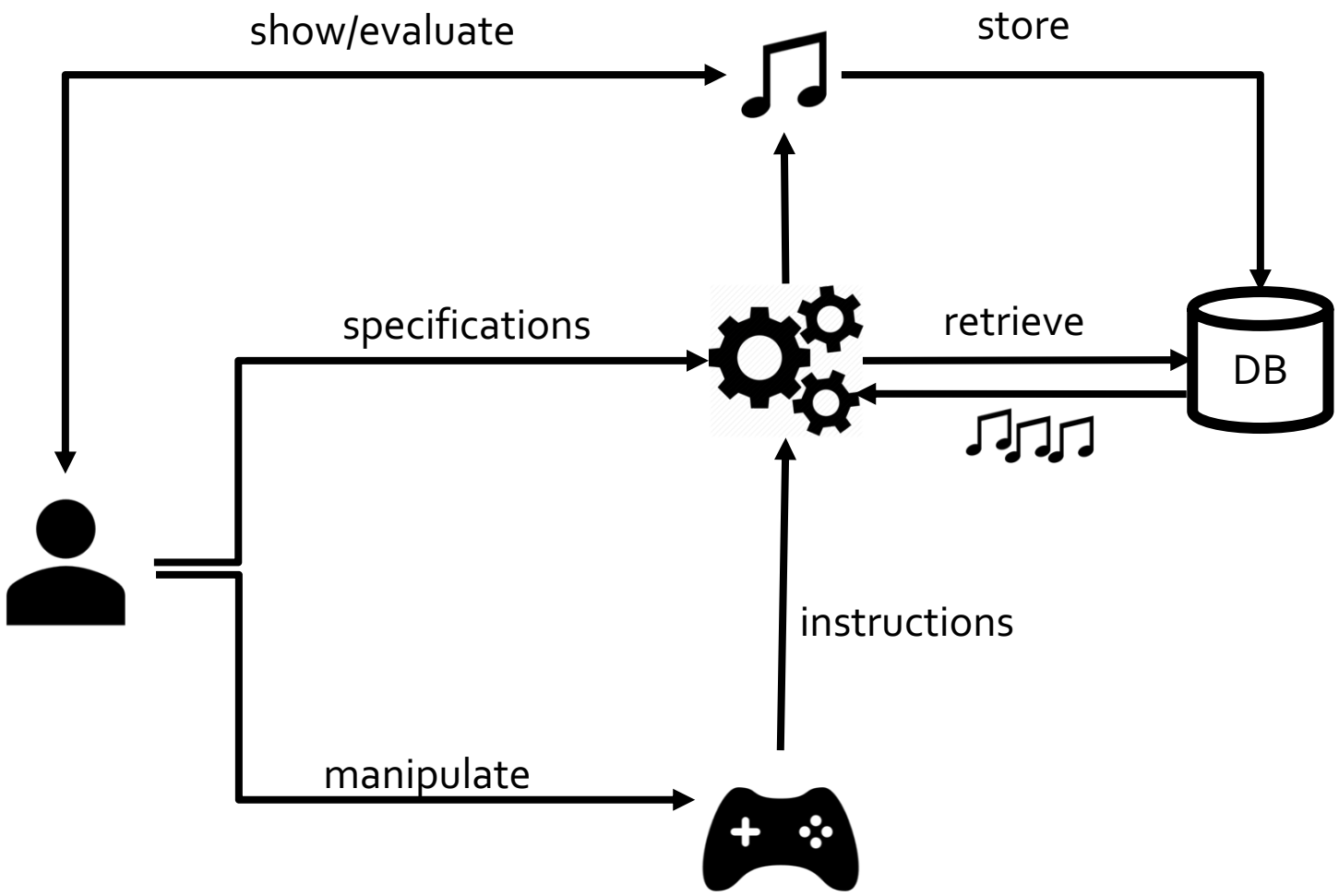
The Corpus

- There are many ways to train the models:
  - By genre
  - **By instruments → Melodies with one instrument or vocal**
  - **By sonority → Modality**
- We use the most common modes in the musical literature (in Spain):
  - La mode: https://www.youtube.com/watch?v=iTpShVBIoVY&list=RDmXJm1drcJIE&index=11
  - Mi mode: https://www.youtube.com/watch?v=AfjGFBHEGts

The Corpus

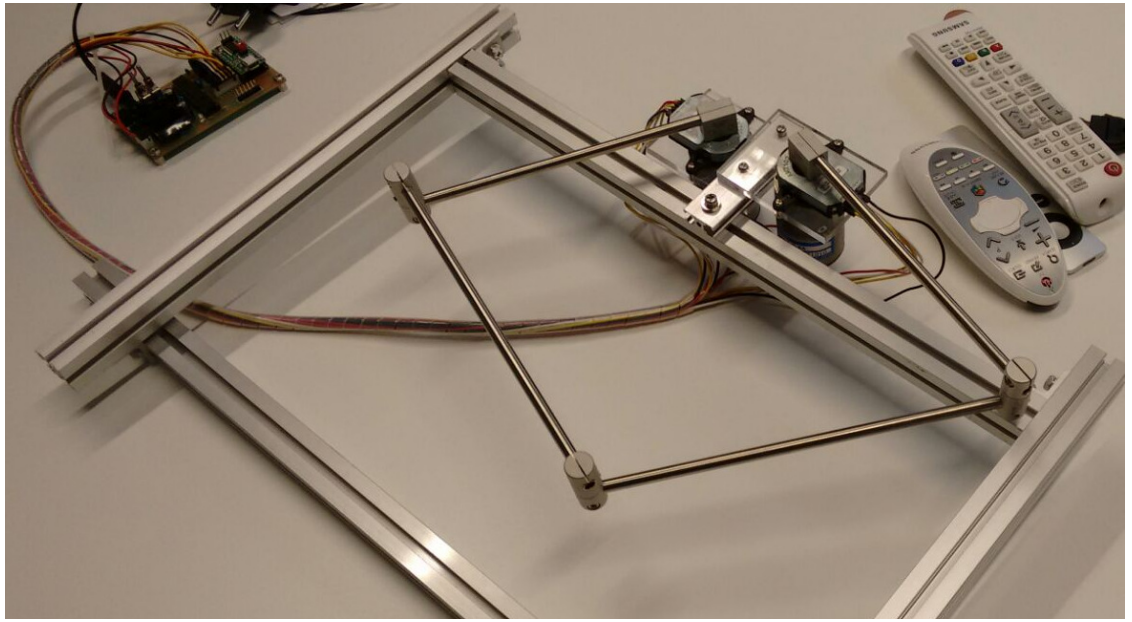
- Select some popular songs according to their sonority
- Transcribe to MIDI
- Get data from the midi:
  - Pitch
  - Duration
  - Position in the scale
  - Position in the bar
  - Key signature
  - Time Signature
  - Position in a musical phrase

Introduction

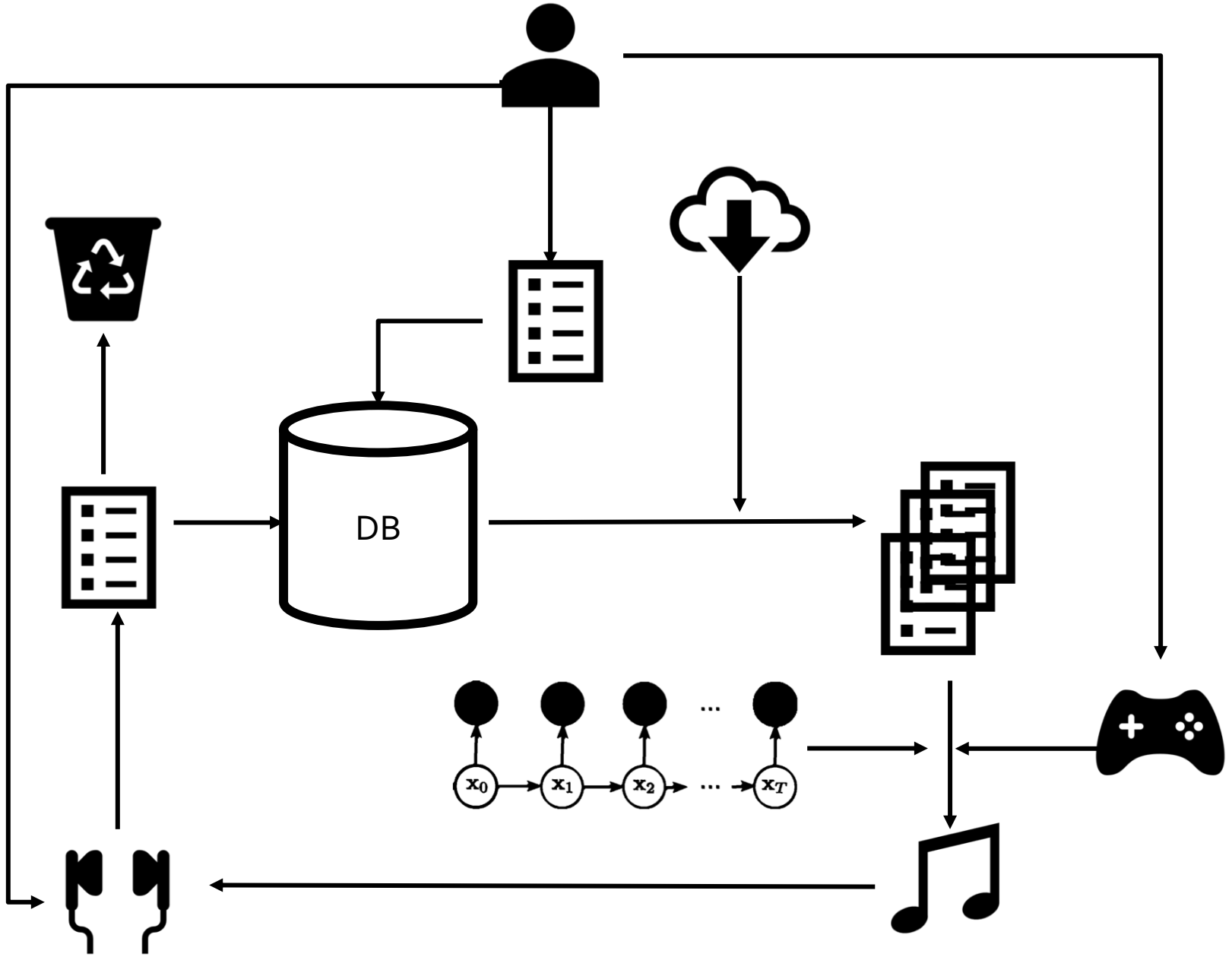


The Device

- This device consists of an articulated arm with 4 rigid segments and 3 joints, connected at both ends to two motors anchored in an aluminum frame.
- The user can manipulate the position of the central articulation to place it in any interior point of the rectangle that delimits the frame.
- The arm translates the position of that point at the angles of the motors



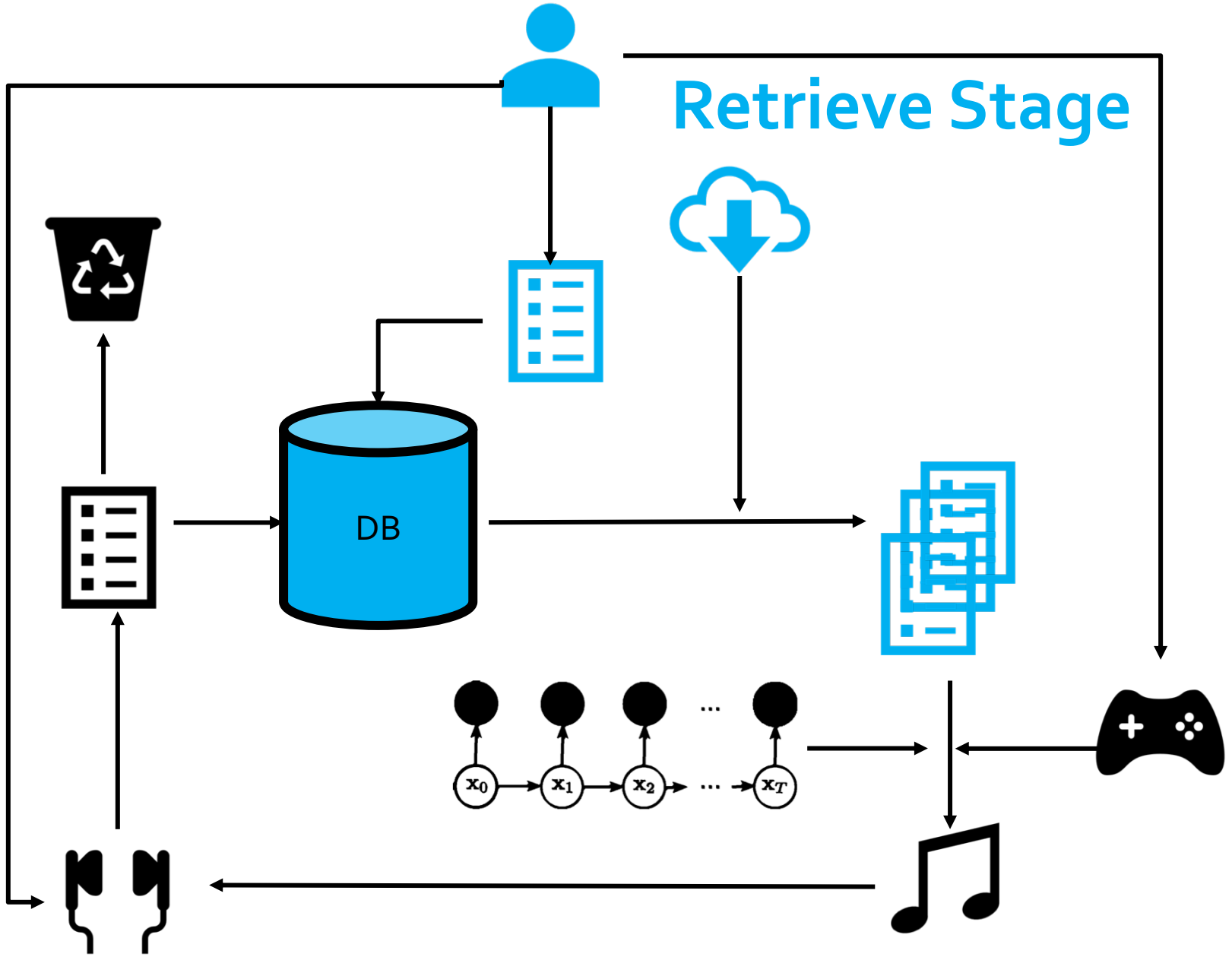
Main Architecture



Main Architecture

- The proposal is divided into several stages:
  - Initially, the user submits a description of the case
  - The system starts composing a new melody following two constraints: the probabilities calculated by the markov model and the device position.
  - The user should rate the result
  - The system decides whether the melody is good enough to be stored.

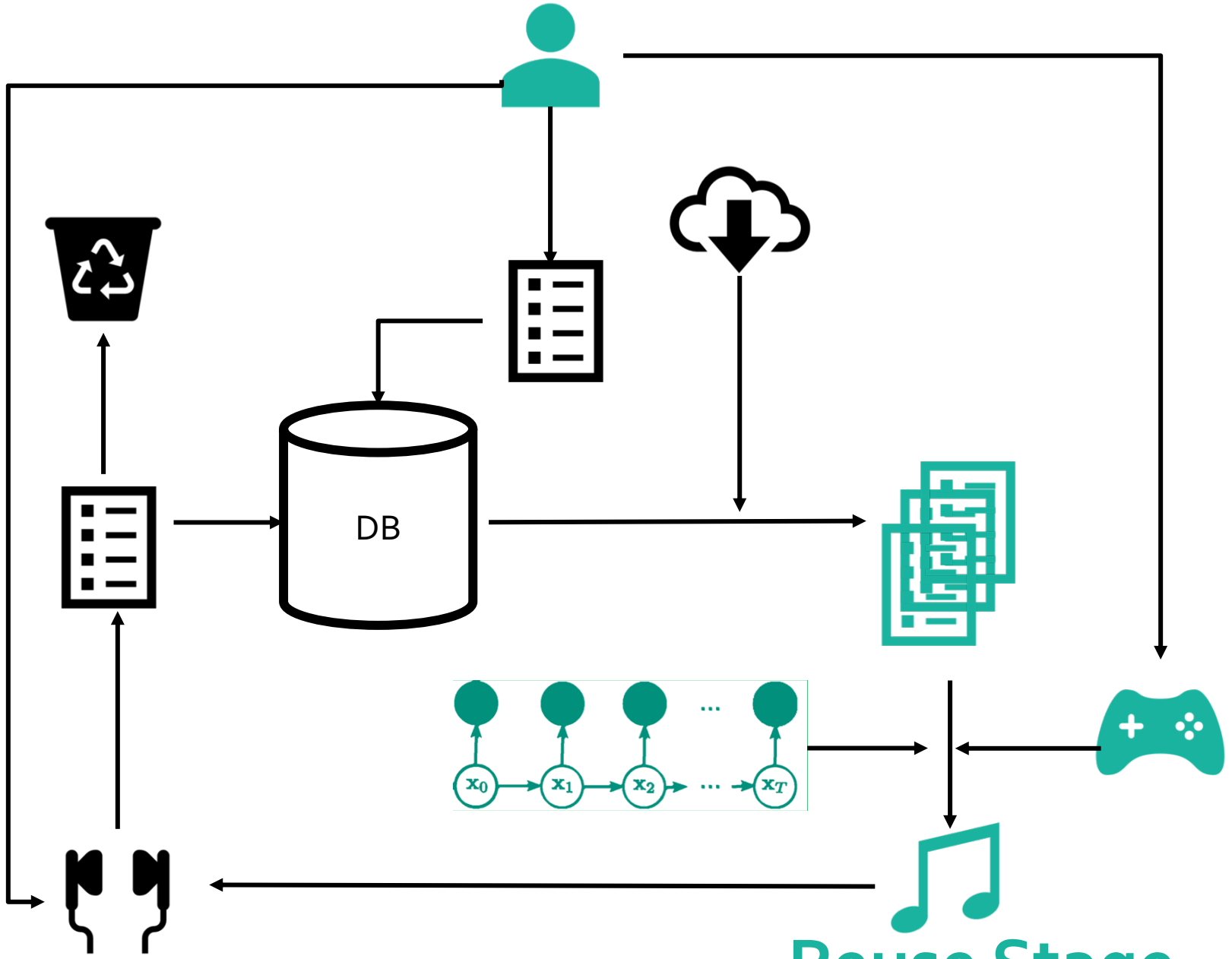
Main Architecture



Retrieve Stage

- The cases C=<P,S,R> are stored in our database. P is a list of labels with the style and author features and/or the main tonality of the composition. The system searches for solutions in our data base (MIDI files)
- We have to locate the MIDI events corresponding to "Note Change" to extract information related to pitch and rhythm.

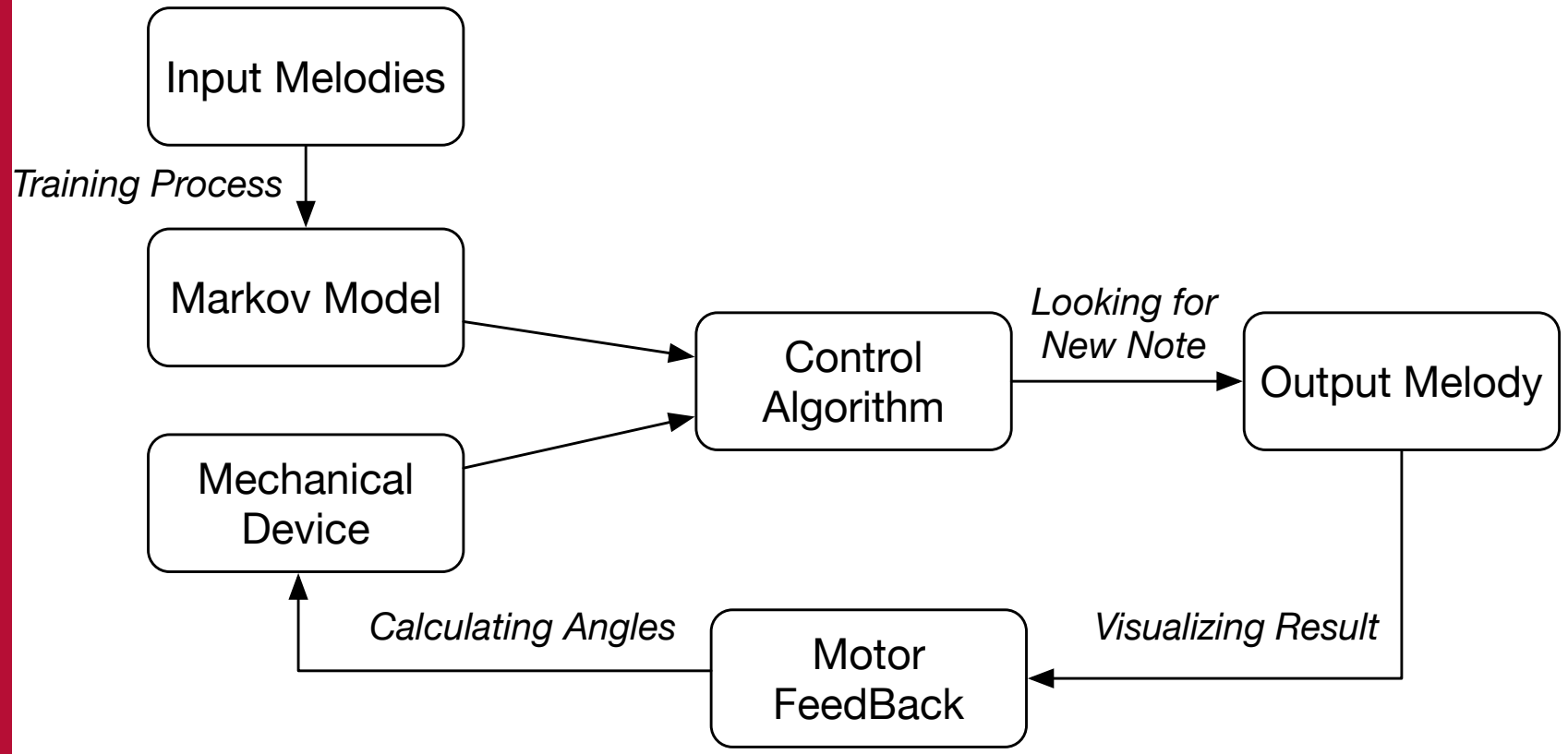
Main Architecture



Reuse Stage

- With these dataset, we trained the MM
- The selection of the notes are always influenced by the position of the mechanical device.
- After the generation of each note, visual feedback is given

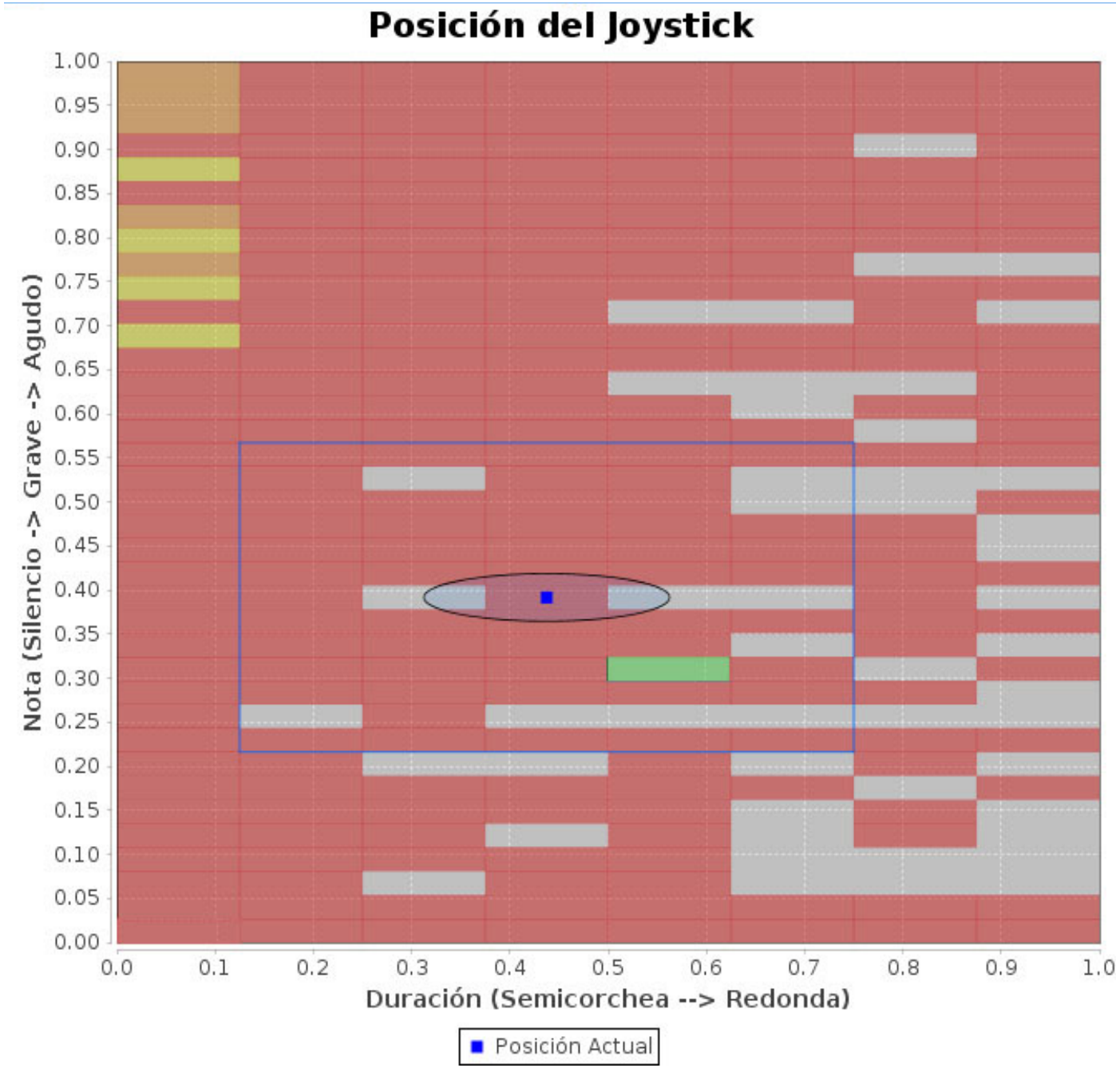
Reuse Stage



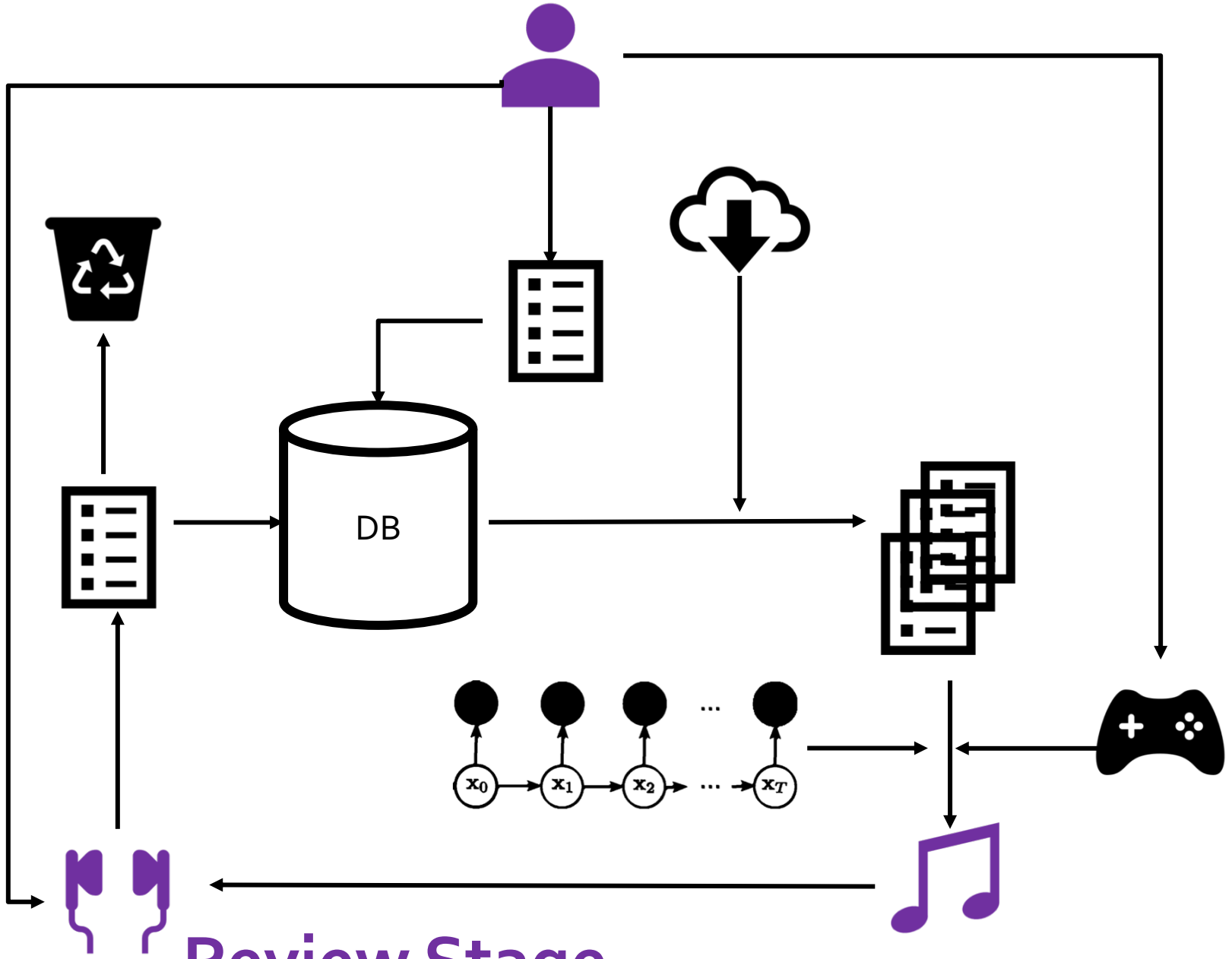
Reuse Stage

- The user can partially control the melody.
  - The position corresponds to a "reference" note t_r
- We aim to modify the probabilities of the different possible transitions t_i of the Markov model according to the device.
  - We calculate $P_D(t)$ as a function of the distance between each transition t_i and the reference transition t_r

Reuse Stage


Posición del Joystick
Nota (Silencio -> Grave -> Agudo)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Duración (Semicorchea --> Redonda)
Posición Actual

Review Stage

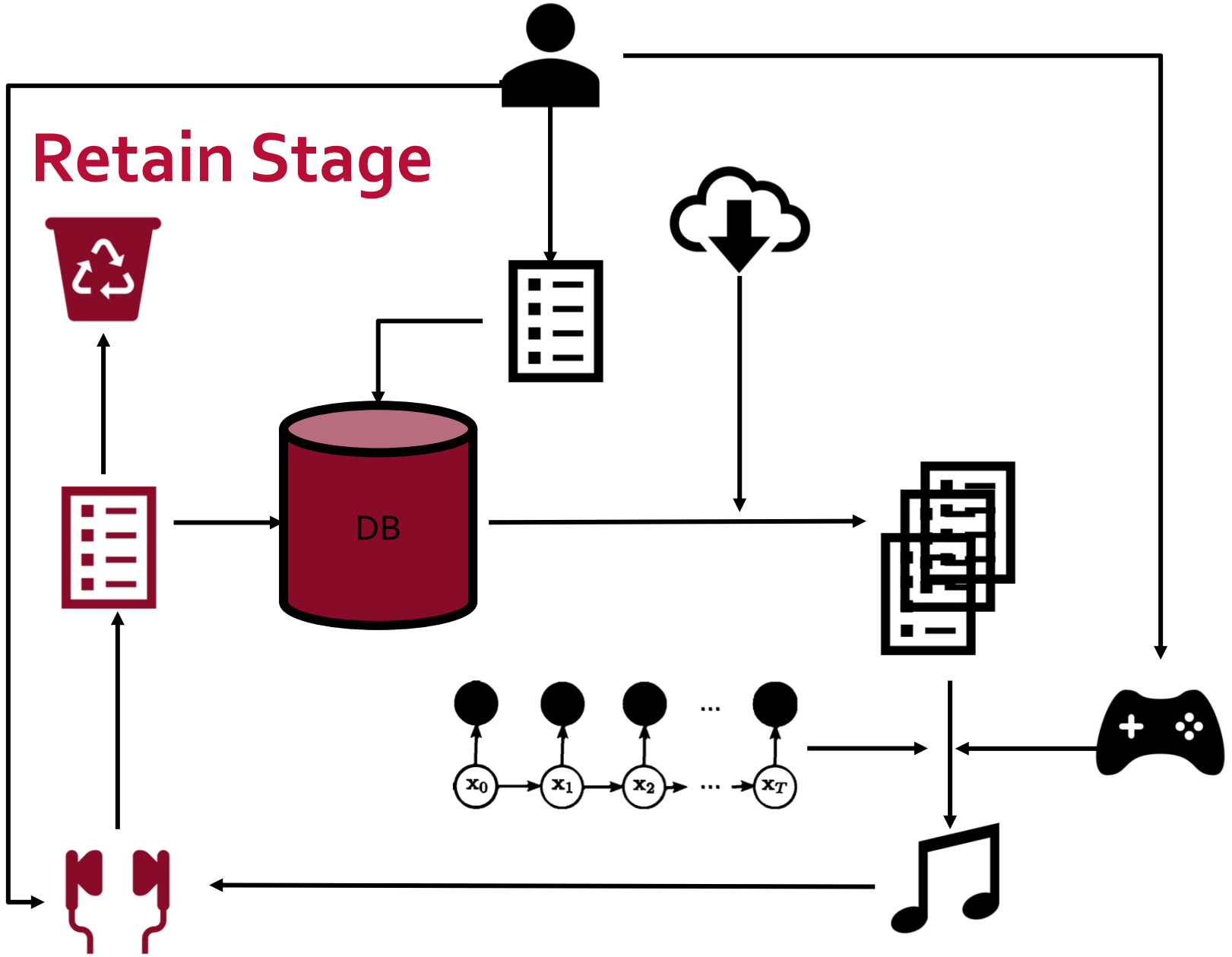


Review Stage

Review Stage

- The musical result is presented to the user. They are asked for their degree of satisfaction with the final result.
- Musical evaluations always depend on personal preferences.

Retain Stage



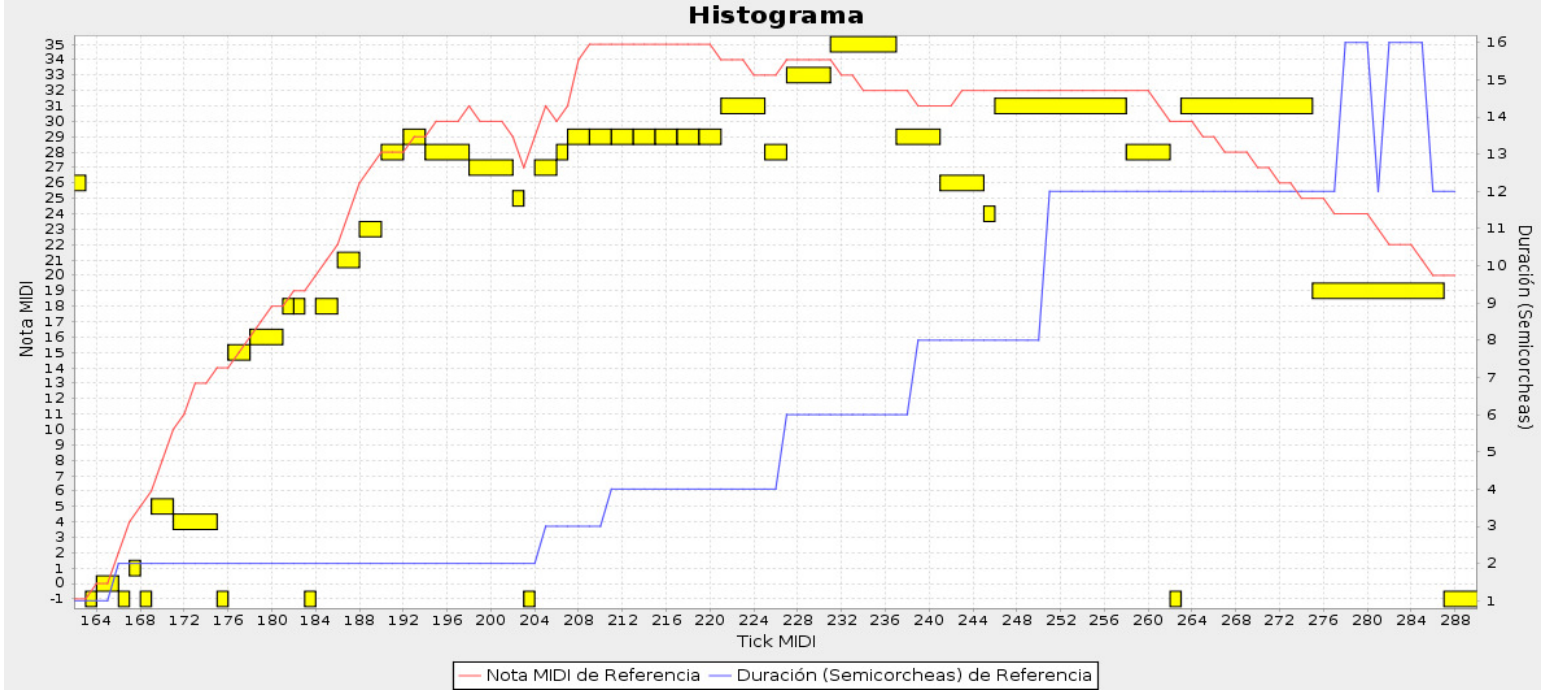
Retain Stage

- The system should decide whether the case is stored for a future use.
- It dynamically establishes a threshold which depends on the previously stored cases.

Overall System

- The user has to log in the system.
- Once they have logged in, they can select if they want to generate a melody based on a general musical style or a specific author.
- The system then starts to create music. The user can guide this melody generation by moving the mechanical device

Interface


Histograma
Nota MIDI
Duración (Semicorcheas)
Tick MIDI
Nota MIDI de Referencia
Duración (Semicorcheas) de Referencia

Some Excerpts

Conclusions and Future Work

Conclusions

- Intelligent system to compose melodies using a mechanical device to control the duration and the pitch.
- The melodies adapt to user preferences by applying a CBR architecture
- The system implemented with the CBR architecture shows an overall tendency to improve their results as the number of melodies for a specific use increases.

Future Work

- We want to implement this system in a web platform.
- We want to improve the rhythm patterns in the melodies.
- We are studying to generate lyrics to the melodies

Thank you

RESEARCH GROUP BISITE .usal.es

VNiVERSiDAD D SALAMANCA
CAMPUS DE EXCELENCIA INTERNACIONAL

Know more at

w bisite.usal.es

fb.com/bisite

@bisite_usal

Contact

bisite@usal.es