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Laban Movement Analysis: Towards Behavior Patterns

Probayes
Mastering Uncertainty

Grenobl
e

Luis Santos

Jorge Dias

Juan-Manuel Ahuactzin

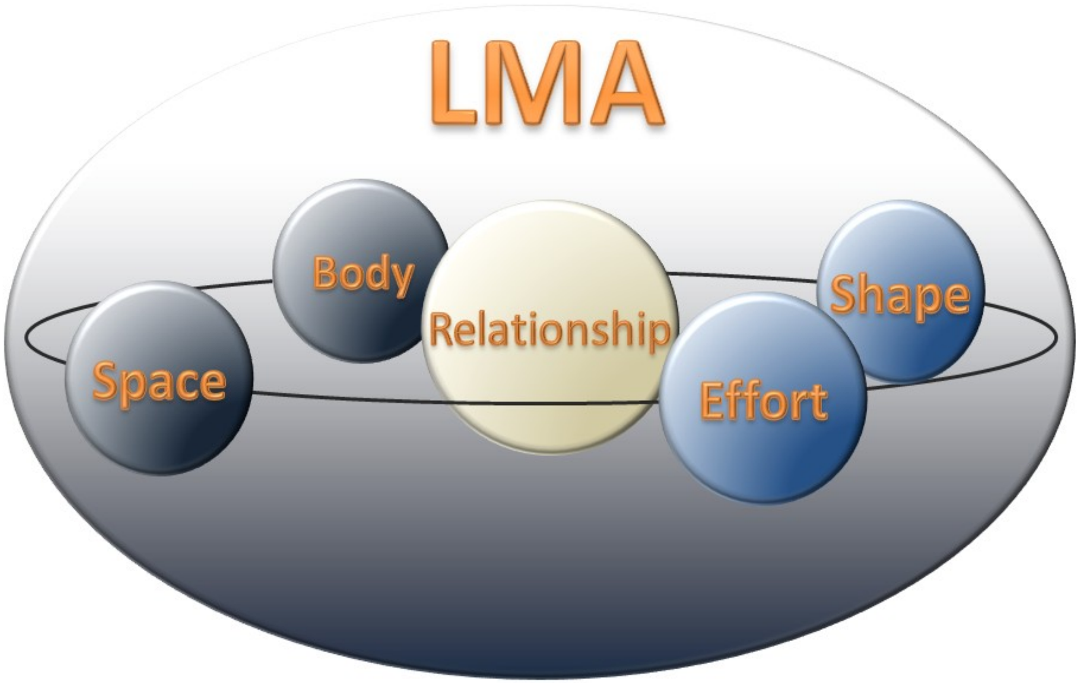
Summary

- Brief introduction to Laban Movement Analysis(LMA)
- Introduction to Database (Contextualize with Bayesian Approach)
- Review of LMA principles within Bayesian framework (Jorg Rett Ph.D Thesis)
  - Components and Bayesian models.
- Results for implemented Laban Components
- Multi-Ocular approach for movement analysis
- Antecipation and certainty, a consequence of bayesian approach.
- Conclusions

Defining Laban Movement Analysis

- ·LMA
- Introduction
- ·Database
- ·LMA: Description and Models
- ·Learning
- ·Classification
- ·Results
- ·Multi-Ocular
- ·Antecipation
- ·Conclusions
- ·Future

- Language to describe dancing movements (Rudolf Laban 1879-1958)
- Helps to identify useful low-level features.
- Defines a framework of mid-level descriptors for properties of a movement.
- Five components.
- Provides intuitive way of building a Bayesian framework for classification of expressive movements.



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Database of Expressive Movements (1)

Bayesian Framework

- Input: Set of observable Low Level Features (LLF)
- Bayes Net: Probabilistic approach built from Bayesia framework
- Output: Result in form of probabilistic distribution

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Database of Expressive Movements (2)

Existing Databases

- Set I : Designed to study Space Component, 8 different movements.
- Set II : Designed to study Effort Component, 4 different movements.
- Aprox. 120 Trials Overall

Feature extraction

- Features are physical characteristics taken from the mapped 3-D discretized trajectories. (displacement vectors, velocity, etc)

New database

- Set I: 6 Singular Movements, perfomed by 10 different people, 10 trials/movements (ongoing work)
- Set II: 6 Duals Movements (2 person interaction, in predefined standard actions), 6 different pairs of persons, 10 trials/pair. (follow-up set I)
- Aprox 1200 Trials Overall

Database of Expressive Movements (3)

- LMA Introduction
- **Database**
- LMA: Description and Models
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- Classification
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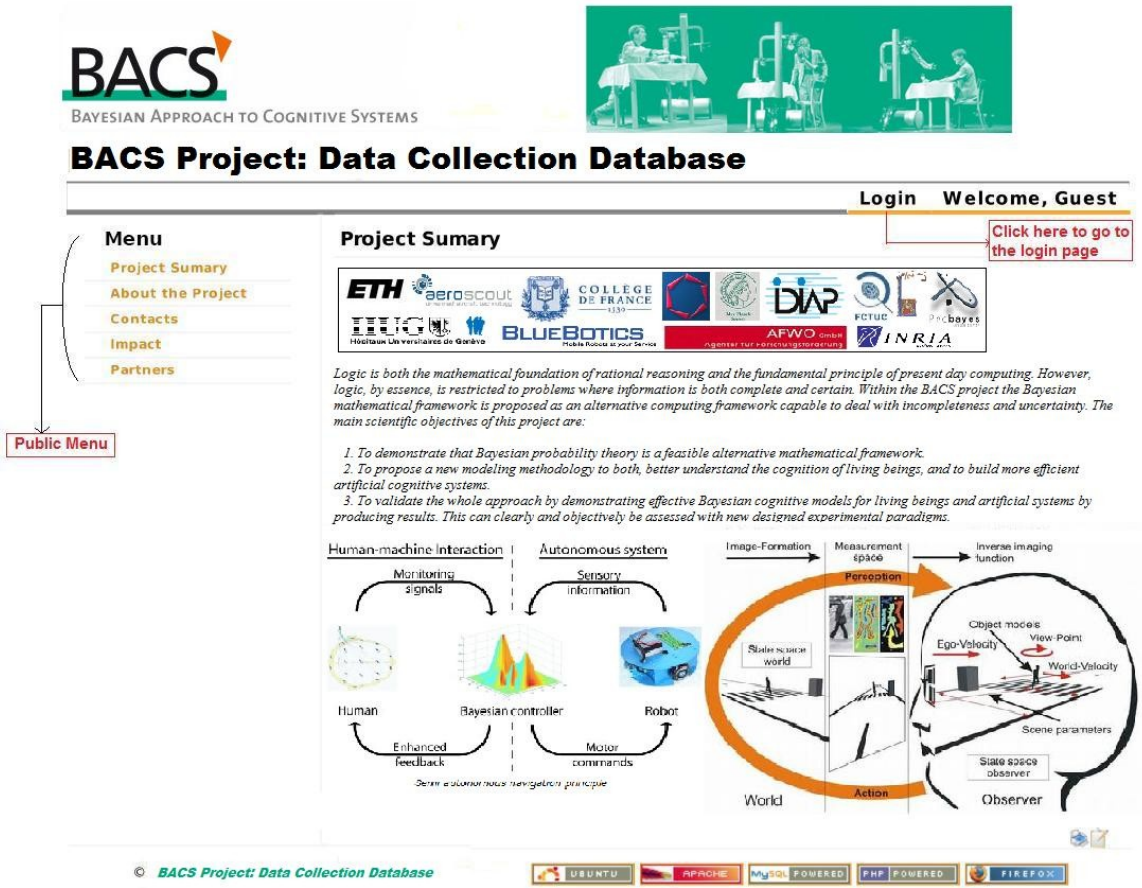
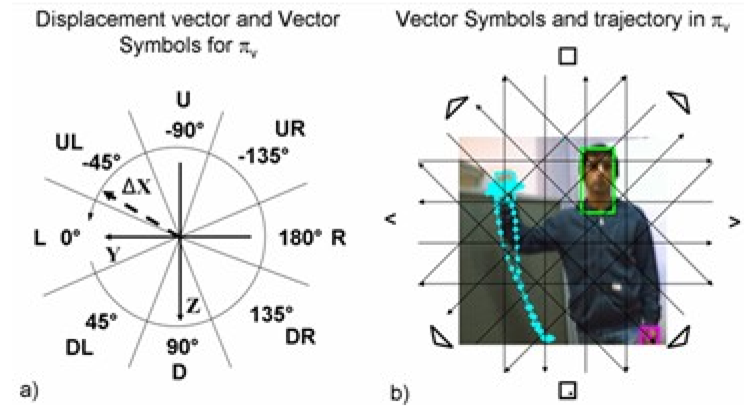
in progress

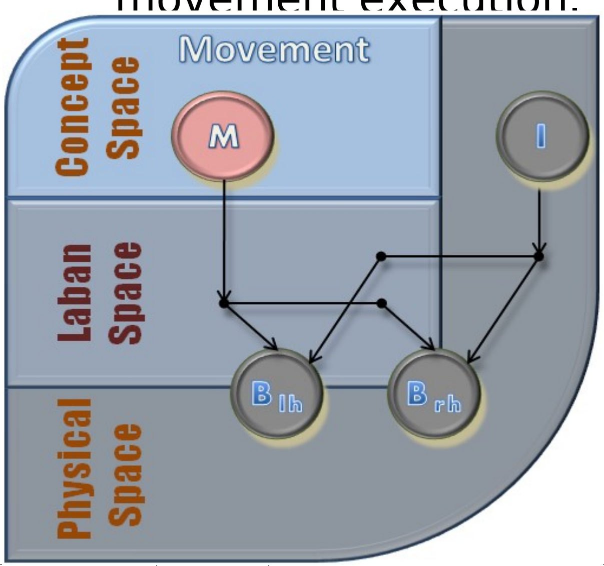


Kinematic Components

Space

- Deals with spacial displacements in form of vectors (atoms).
- Extracted directly from the spacial characteristics of the trajectories resulting from movement execution.





·*Space* **Bayesian Model**

Probability distribution of a movement M given frame I and Atoms B for left and right hands

$$P(M\ I\ Blh\ Brh) = P(M)\ P(I)\ P(Blh \mid M\ I)\ P(B\ \mathrm{rh} \mid M\ I)$$

Kinematic Components

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Body

- Closely related to space component;
- Concerns relative movement of body parts related to body center;
- Which body parts are moving.

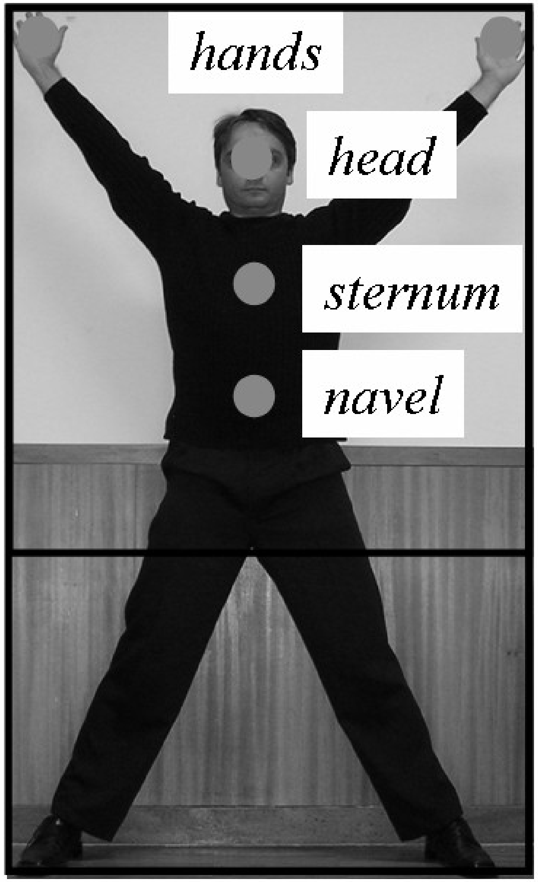
***Body* Bayesian Model**

In development

Notes:

- we consider the center of mass of the body to be in the sternum.
- Features: euclidean distance, body part (and maybe velocity and aceleration).

LMA *Body* component



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Non-kinematic Components

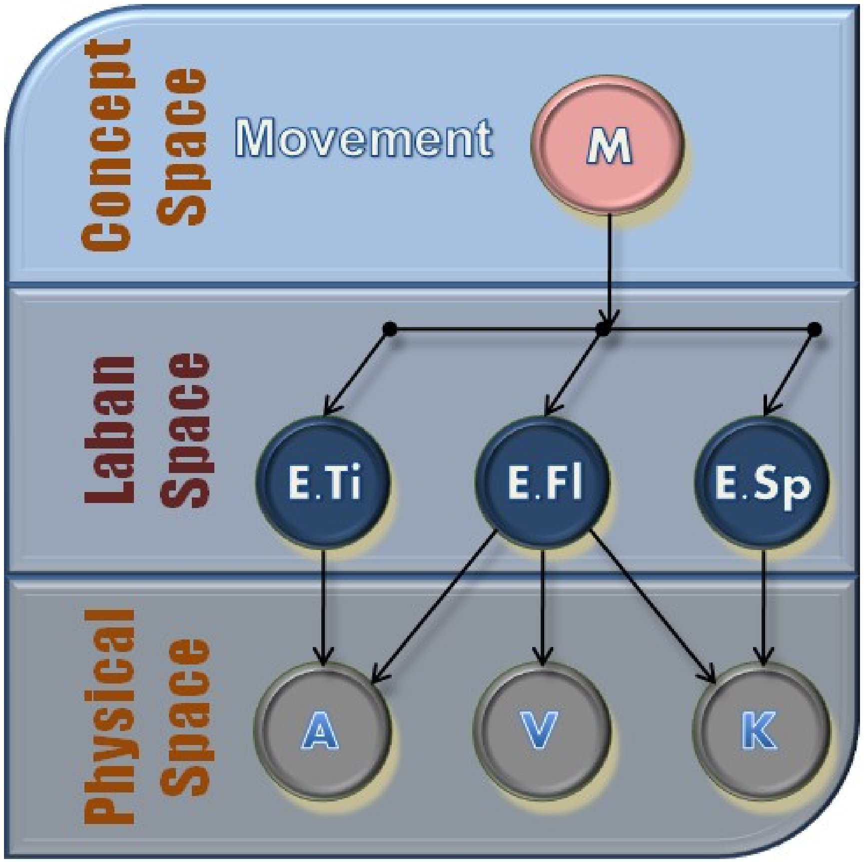
Effort

- Dynamic qualities of the movement.
- Inner attitude towards using energy
- Probably the decisive component when dealing with ‘expressiveness’
- Has four qualities

LMA Effort Qualities	Physical entities
Time.sudden	**High acceleration**, High velocity
Time.sustained	**Low acceleration**, Low velocity
Space.direct	**Small curvature**, Small angular velocity
Space.indirect	**High curvature**, High angular velocity
Flow.free	**High curvature, High angular velocity**
Flow.bound	**Low acceleration, Low velocity**
Weight.strong	Muscle tension, Medium acceleration
Weight.light	Muscle relaxed

- Non-kinematic Components

- **Effort Model**



Effort Time

$P(M\ E.ti\ A)$
$=P(M)\,P(E.ti|M)\,P(A|E.ti)$

Effort Space

$P(M\ E.sp\ K)$
$= P(M)\,P(E.sp|M)\,P(K\mid E.sp)$

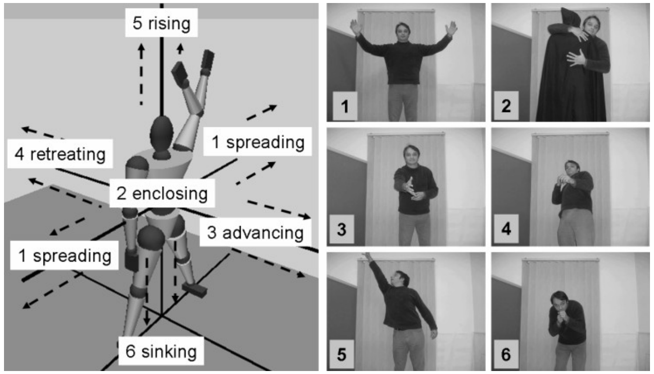
Effort Flow

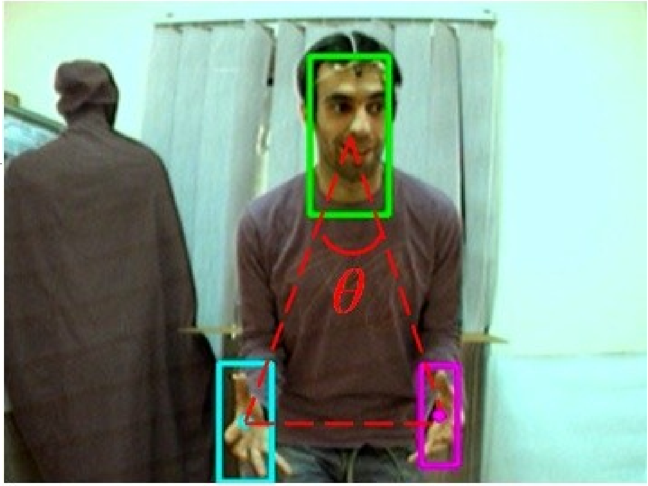
$P(M\ E.fl\ V\ A\ K)$
$=P(M)\,P(E.fl|M)\,P(V|E.fl)\,P(A|E.fl)\,P(K|E.fl)$

Non-kinematic Components

Shape

- Emerges from Space and Body components;
- Focus on: body itself, a goal towards space,
- Uses descriptors like *shrinking* and *growing*, *bulging* and *hollowing*;





***Shape* Bayesian Model**

Ongoing work

Notes:

- Consider the triangle formed from the head and hand positions
- Features: Angle θ , size (perimeter) of the triangle (the angle and the perimeter will give good descriptors on whether the expressive movement is growing/shrinking).

Global Bayesian Framework

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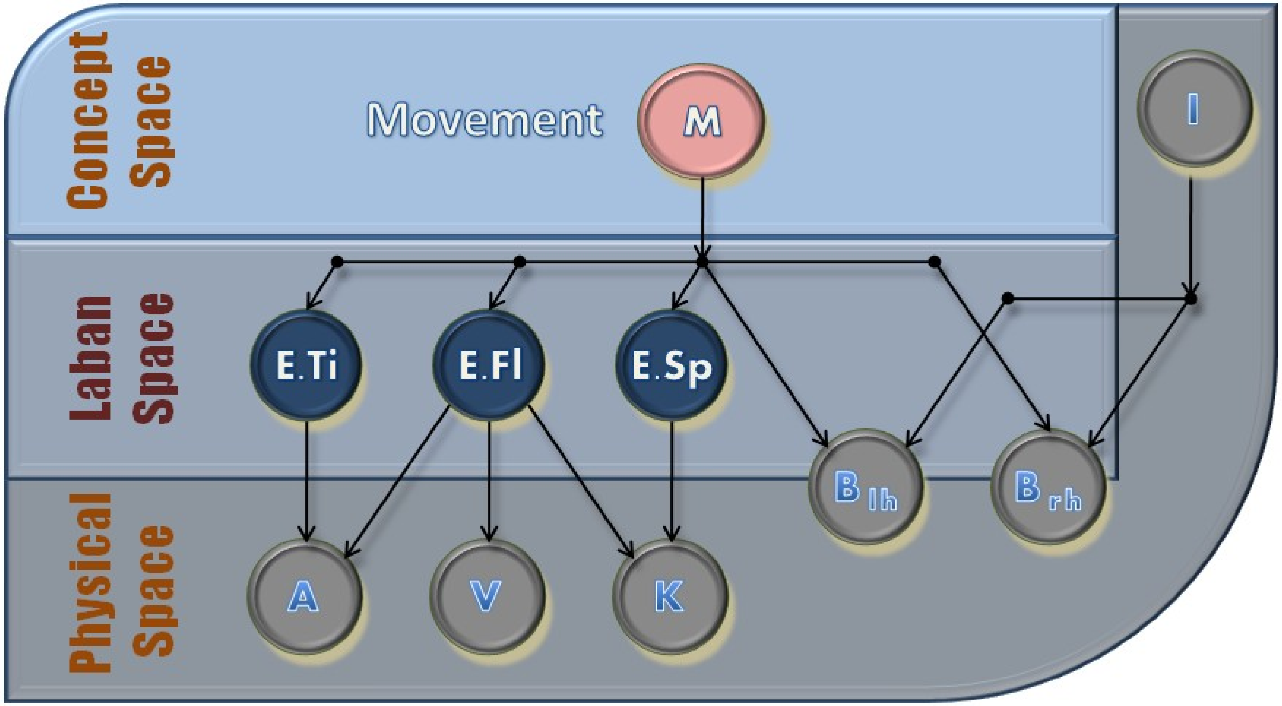
Global Model



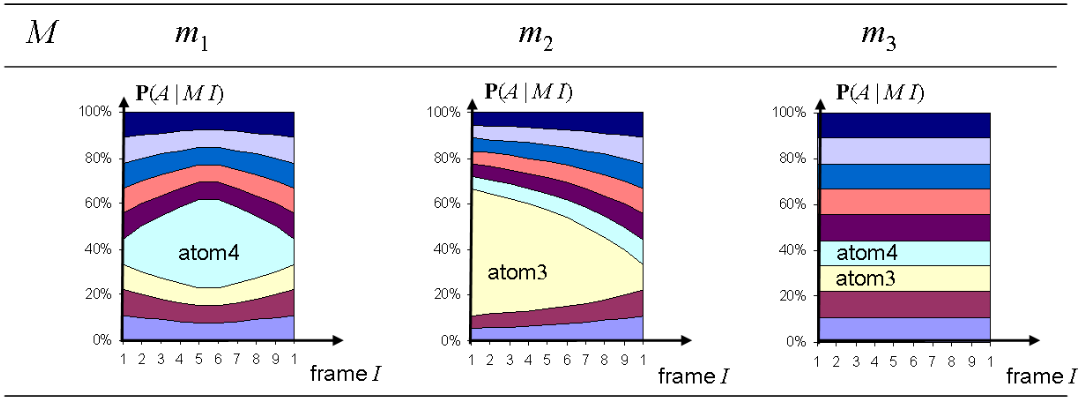
·***Bayesian Global Model***

$$P(M\ E.ti\ E.sp\ I\ Brh\ Blh V\ A\ K) = P(M)\ P(M|\ Brh)\ P(M|\ Blh)\ P(E.ti|M)\ P(E.sp|M)\ P(E.fl|M)\ P(A|E.ti)\ P(K|E.sp)\ P(V|E.fl)\ P(A|E.fl)\ P(K|E.fl)$$

Learning (1)

Scheme based on histogram approach

- Space

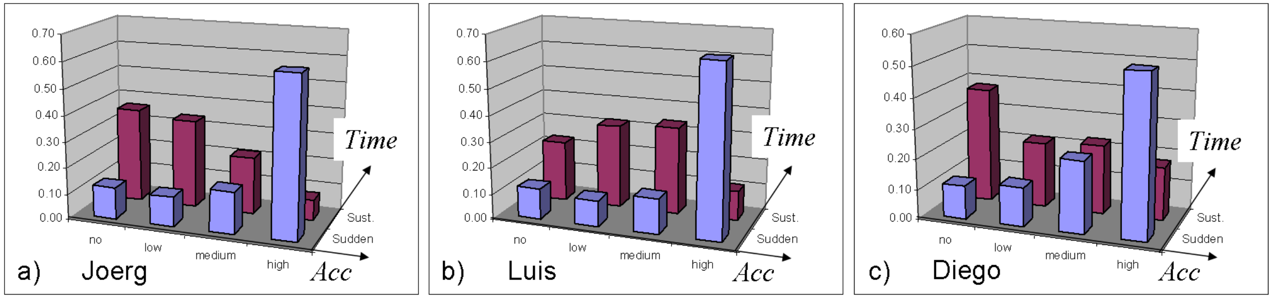


$$P(B|M\ I)$$

Learning (2)

Scheme based on histogram approach

- Effort



$$P(LLF|Effort)$$

$$(e.g.\ P(A|E.ti))$$

- Classification

- **Questions for Classification**

	Question
Space	$P(M\|i\ b) = P(M)\ P(b\|M\ i)$
Effort	$P(M\|E.ti\ E.sp) = P(M)\ P(E.ti\|M)P(E.sp\|M)$
Joint	$P(M\|i\ b\ E.ti\ E.sp) = P(M)\ P(i\_obs\|i)\ P(b\|M\ i)\ P(E.ti\|M)\ P(E.sp\|M)$

- **Continuous Classification:**

Based on a scheme of likelihood computation.

E.g. For Space Component: For a sequence of *n* observations of *a*.

$$P(Mn+1|i1:n+1\ bi:n+1) = P(Mn)\ P(bn+1|M\ in+1)$$

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Results

Effort Qualities Classification Results

	Effort Qualities					
	Space		Time		Flow	
	Direct	Indirect	Sudden	Sustained	Free	Bounded
C.R.	79.3%	90.2%	84.8%	97.1%	61.2%	58.7%

Overall Classification Results

	Laban Component		
	Space	Effort	Effort+Space
C.R.	61.3%	86.4%	79.4%

C.R. : stands for *Classification Rate*, or the number of positive identifications.

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Space Component Result Analysis (1)

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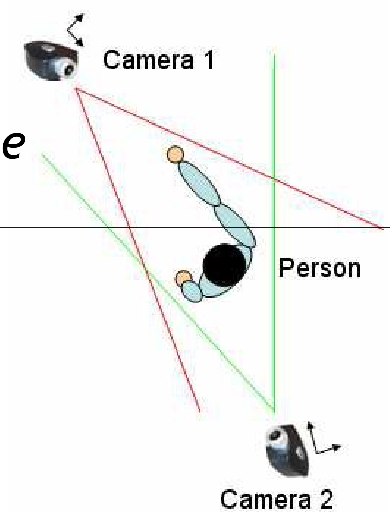
Overall Classification Results

	Laban Component		
	Space	Effort	Effort+Space
C.R.	61.3%	86.4%	79.4%

- ***Space*** results are not as good as they could be.
- *Main reasons?*
    - *Occlusion*
    - *Rotation Invariance*



Camera 1

Camera 2

- **Aditional advantages:** Unconstrained movement and extra information

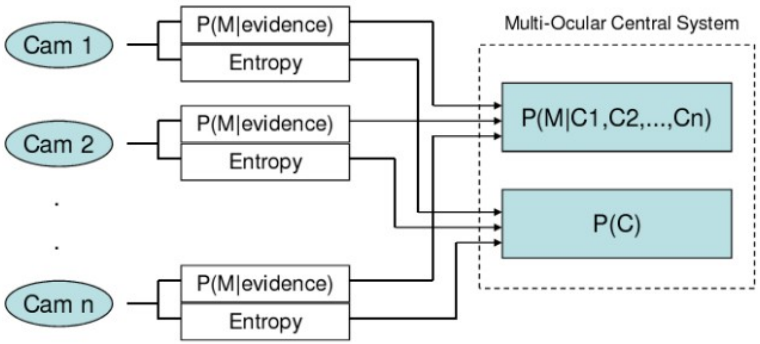
Space Component Result Analysis (2)

·Solution proposed: Multi-Ocular Model

·Each monocular system provides a probability distribution (as P(M|C)) of movement M for each camera C and entropy value;

·P(C) is the confidence distribution for each camera, calculated through entropy values;

$$P(M)\ \alpha\ P(C)P(M|C)$$



·Results: Multi-Ocular Model

	Space Component	
	Monocular	Multi-Ocular
C.R.	61.3%	81.0%

Antecipation and Certainty

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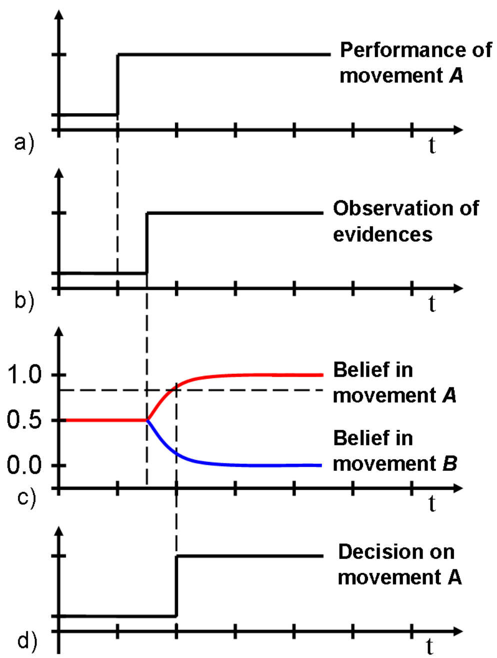
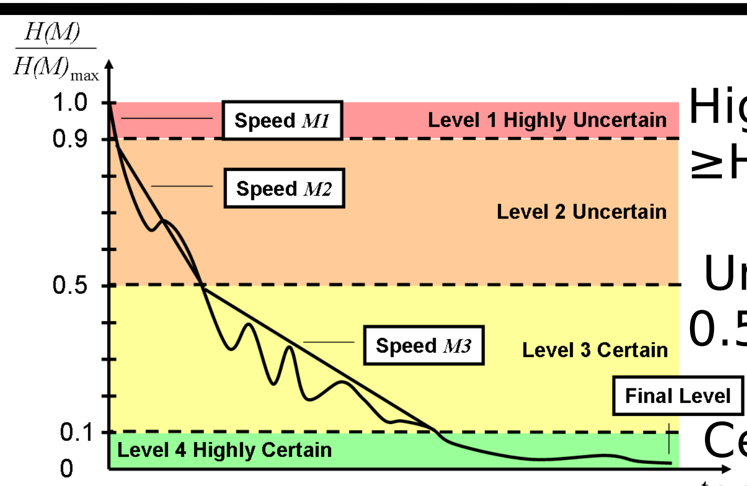


a) Subject starts to perform movement

b) After a short period, evidences start to be computed;

c) A few instants later, a certainty measure (entropy) is computed derived from probability distributions.

d) measure (entropy) triggers what will be the final result.



Highly Uncertain: H(M)max ≥H(M)>0.9H(M) max

Uncertain: 0.9H(M) max ≥ H(M) > 0.5H(M) max

Certain: 0.5H(M) max ≥ H(M) > 0.1H(max

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Conclusions

There are 2 main conclusions from this year's development

1. Multi-Ocular improved spacial results (from 61.3% classification rate to 81%)

2. *Effort* improved results (from 61.3% classification rate to 86.4%.)
   - When joinning Effort and Space components
   - Effort.Weight is still being investigated for visual features
   - Results for effort.flow are not as good as the other 2 components due to uncertainty inherent to its features and state.

Other facts:

- The process of implementing *effort* was accomplished.
- The Bayesian approach was used for multi-ocular model designing.
- Having online-classification opens the possibility for anticipatory behaviour.
- Entropy can be used as a measure of certainty

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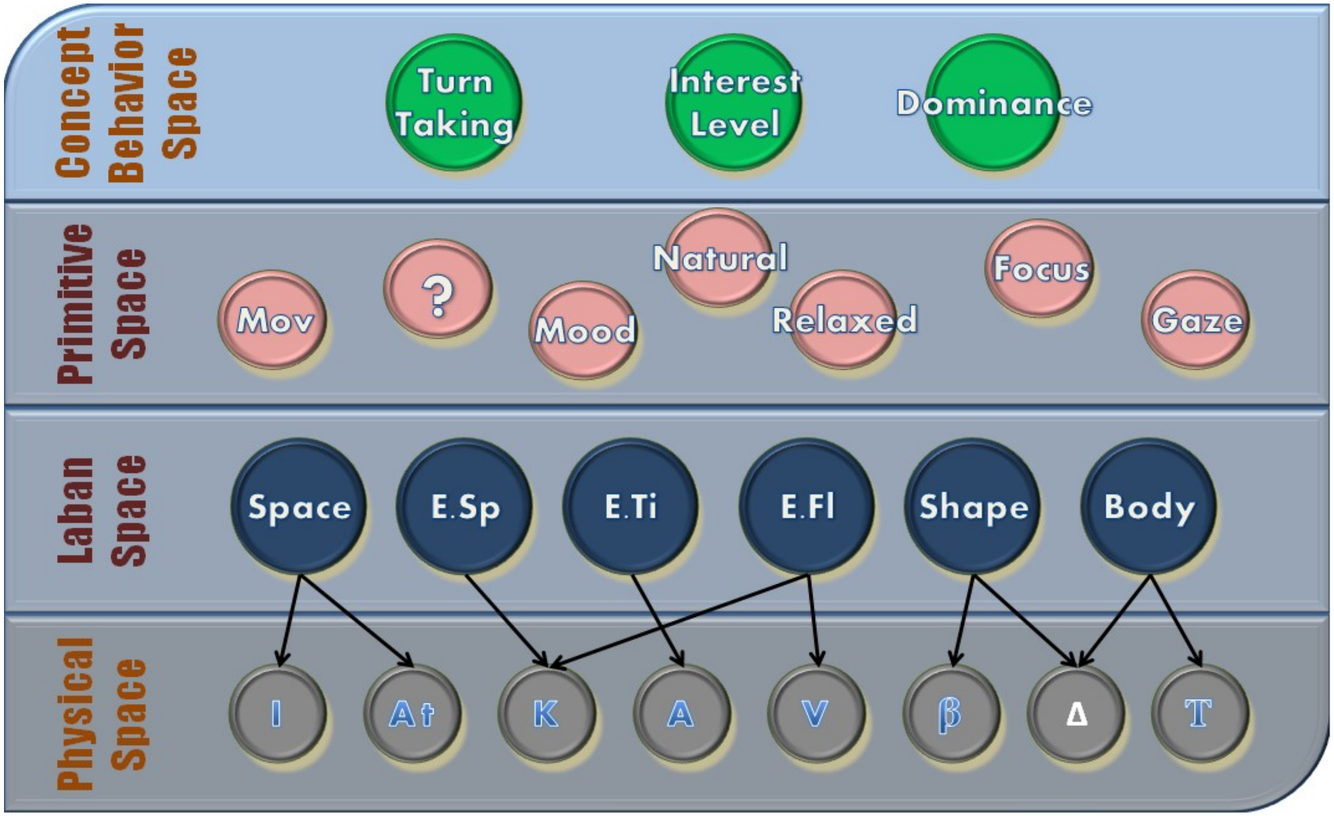
Future Work: Towards Behavior Patterns (1)



Future Work: Towards Behaviour Patterns (2)

We intent:

- Implement remaining LMA Components (Body and Shape).
- To use LMA components to describe basic primitive behaviour.
  - (e.g. Aggressive, natural, gaze, etc.)
- To use those basic primitives to describe and classify more complex behaviour within the context of Small Group Conversations.
  - Turn Taking
  - Interest Level
  - Dominance
- Build a database of multiple people interacting within the already reference context.
- Build Bayesian models for behaviour classification.

Thank you for your attention!

Publications & Deliverables

This research produced, along with the results shown, the following documents:

- D5.17 Laban Movement Analysis using a Bayesian model and perspective projections.
- D5.18 Bayesian Model for Computational Laban Movement Analysis.
- D5.20 Computational Laban Movement Analysis using Multi-Camera Systems.
- Joerg Rett, “Robot-Human interface using Laban Movement Analysis inside a Bayesian framework.”, PhD thesis.
- Extended abstract published in conference proceedings at “14ª Conferência Portuguesa de Reconhecimento de padrões (RecPad) 2008”
- Article “Human Robot Interaction: Studies on Laban Human Movement Analysis and Dynamic Background Segmentation”, submitted to IROS09 (In review).