

UNIVERSITÀ DEGLI STUDI
DI NAPOLI FEDERICO II

A Novel Computer-Based Set-Up for the Analysis of Group Synchronisation

Authors

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Natural human synchronization

Each individual moves differently from the others:



An individual, who interacts with another one, tends to reach the synchronization





Natural human synchronization

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➤ **Two individuals**





Natural human synchronization

Each individual moves differently from the others:



An individual, who interacts with another one, tends to reach the synchronization

➤ **Two individuals**

➤ **...in a group?**





Why and What do we want to study?

What

The activities performed by each group member continually influence the activities of others

- And what about the spatial disposition of people?





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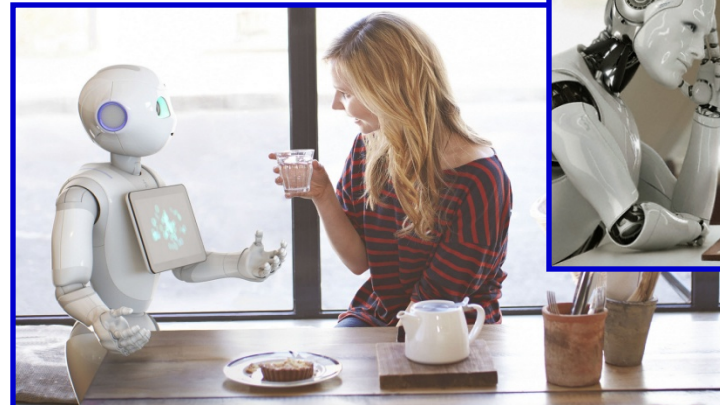
- And what about the spatial disposition of people?



Why

In the future there will be a world in which man and robot will live together

- Integration
- Human-like behavior





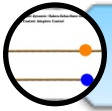
Road map



Analysis of human movements model



Development of Software to play Mirror Game between two players



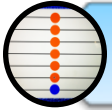
Study of synchronization: HP - HP trials



Design and Validation of Virtual Player



Study of synchronization: VP - HP trials



Extension of Software System to a multiplayer game



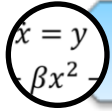
Study of synchronization: HP group



Study of synchronization: HP - VP group



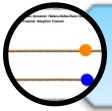
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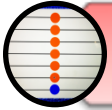
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Study of synchronization: VP - HP trials



Extension of Software System to a multiplayers game



Study of synchronization: HP group



Study of synchronization: HP - VP group



State of the art

With social interaction



Wing AM, Woodburn C. *The coordination and consistency of rowers in a racing eight. Journal of sports sciences.* 1995;13(3):187–197.

Himberg T, Thompson M. *Group synchronization of coordinated movements in a cross-cultural choir workshop.* 2009.

Frank T, Richardson M. *On a test statistic for the Kuramoto order parameter of synchronization: An illustration for group synchronization during rocking chairs. Physical D: Nonlinear Phenomena.* 2010;239(23):2084–2092.

Richardson MJ, Garcia RL, Frank TD, Gergor M, Marsh KL. *Measuring group synchrony: a cluster-phase method for analyzing multivariate movement time-series. Frontiers in physiology.* 2012;3:405.

Codrons E, Bernardi NF, Vandoni M, Bernardi L. *Spontaneous group synchronization of movements and respiratory rhythms. PloS one.* 2014;9(9):e107538.

Iqbal T, Riek L. *A method for automatic detection of psychomotor entrainment,* 2015.



The innovation of this work

State of art limits

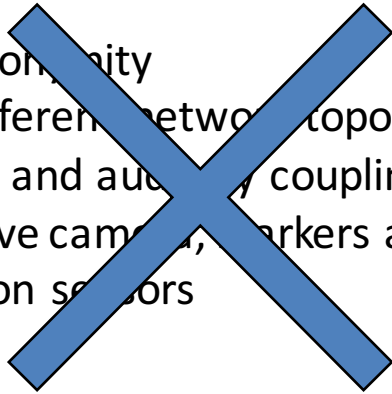
1. No anonymity
2. No different network topologies
3. Visual and auditory coupling
4. Invasive camera, markers and position sensors



The innovation of this work

State of art limits

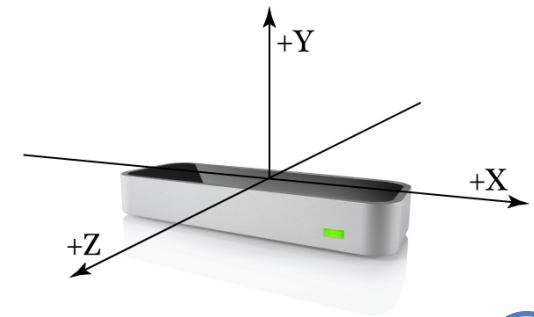
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Our approach

Beyond the limits

1. Interaction through a screen
2. Implementation of different topologies
3. No visual and auditory coupling
4. Leap motion as position sensor

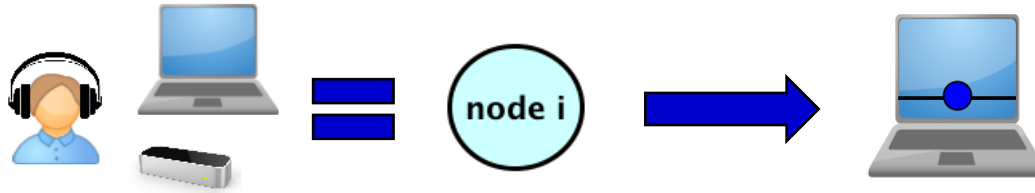




Network topologies to represents different interaction

A graph is a tuple $G=(V,E)$ defined by a set of nodes $V=\{1,\dots,N\}$ and a set of edges

Node

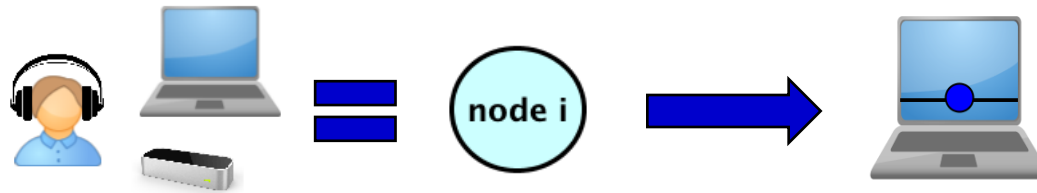




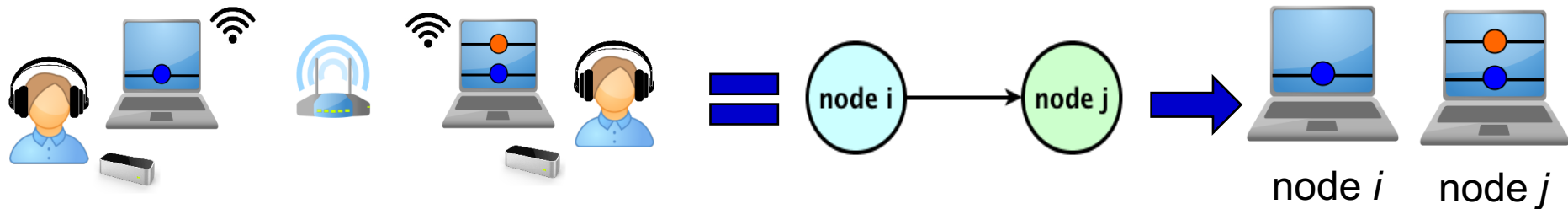
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Link

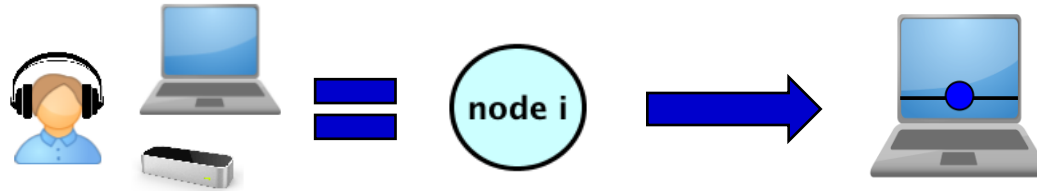




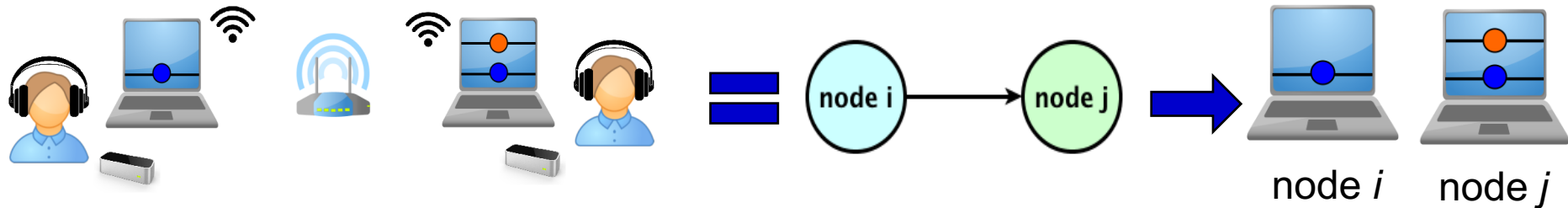
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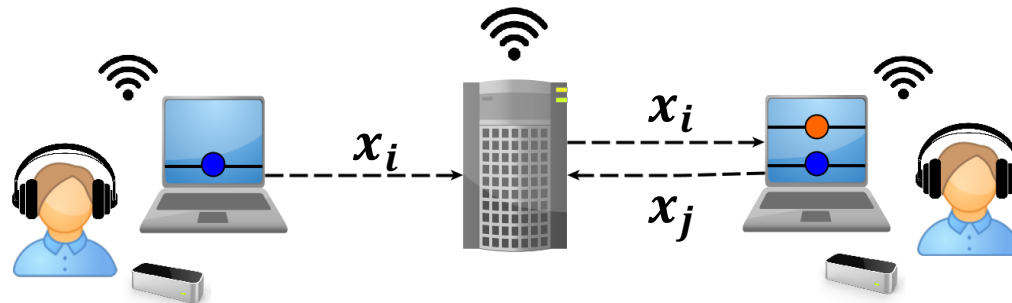
Node



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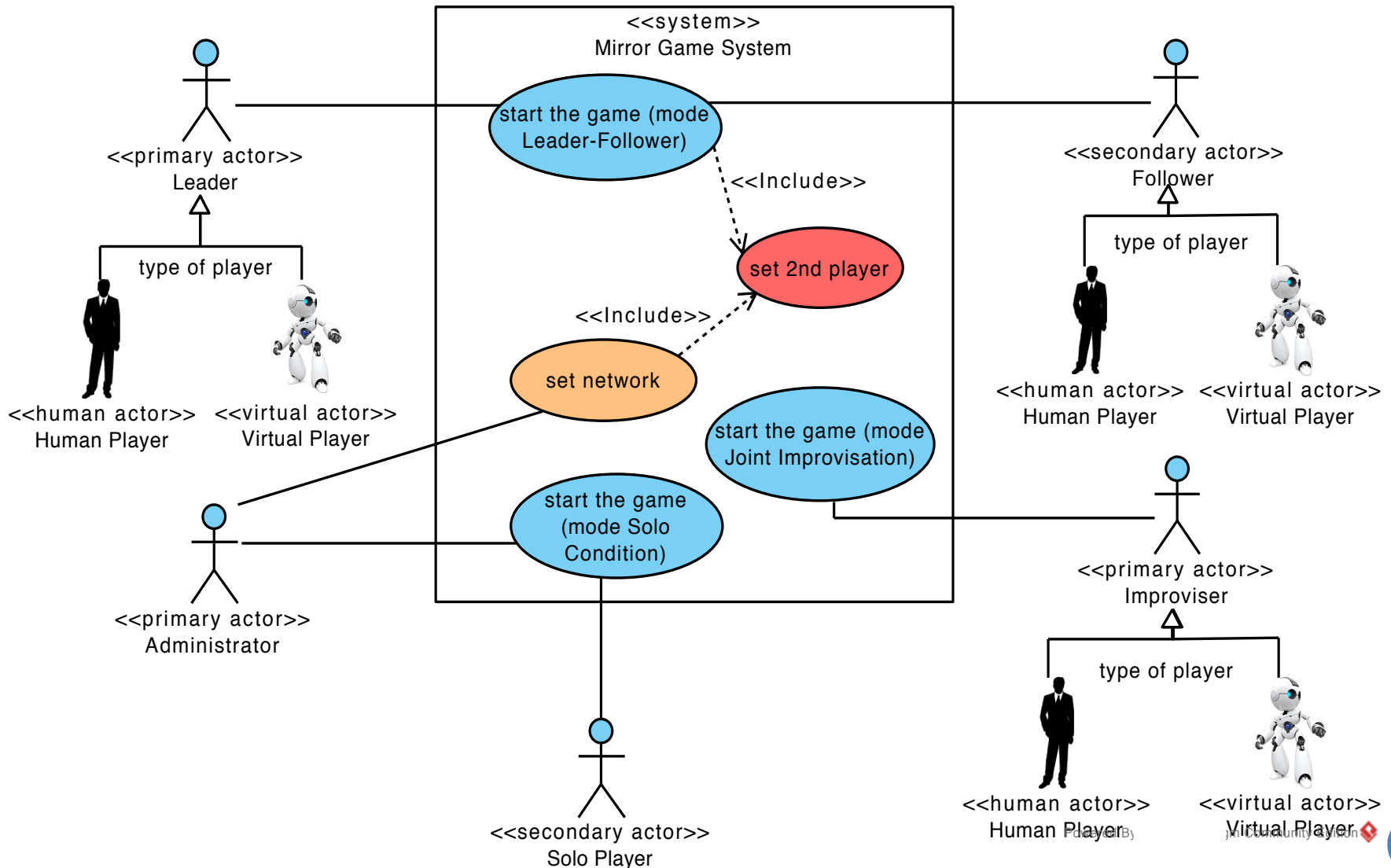


Structure of
interconnections



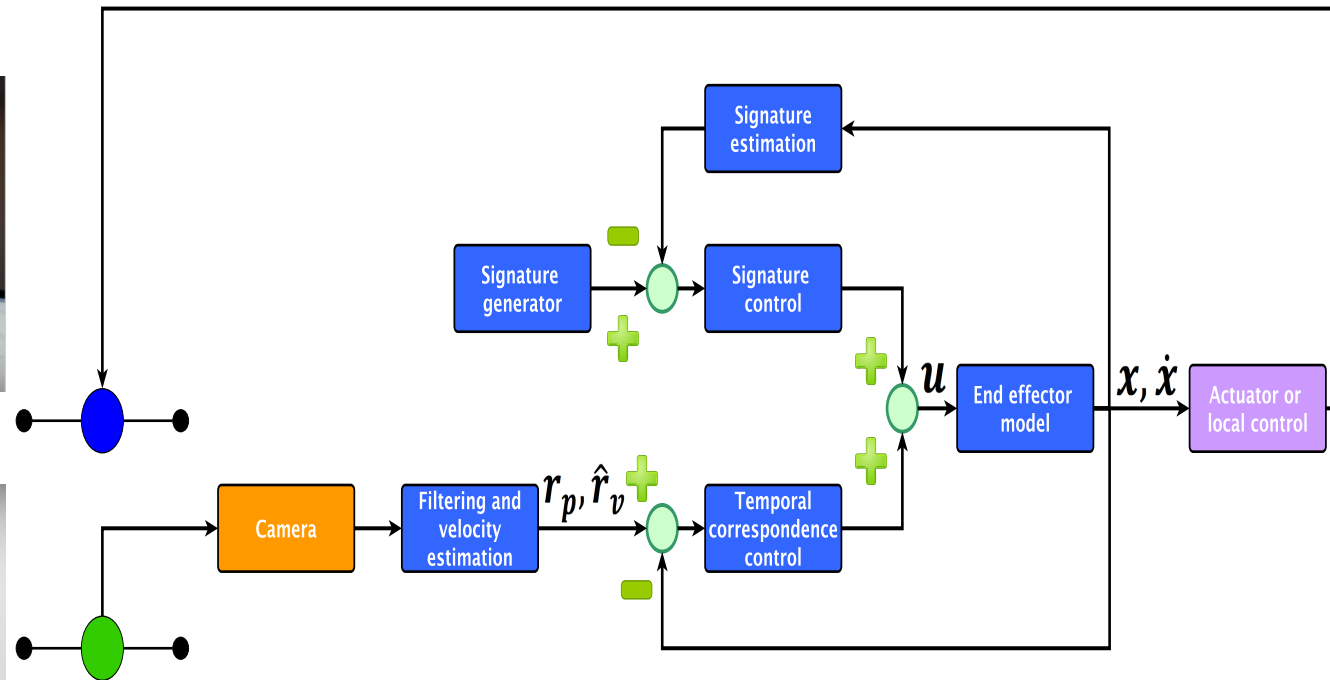
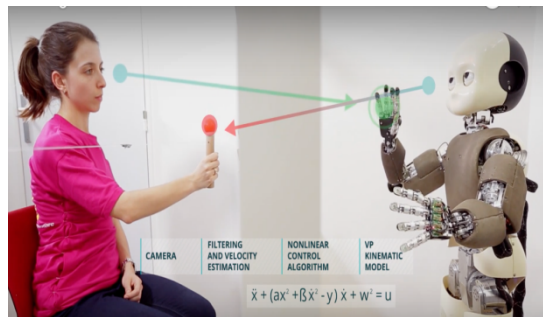


Software System: Use case diagram



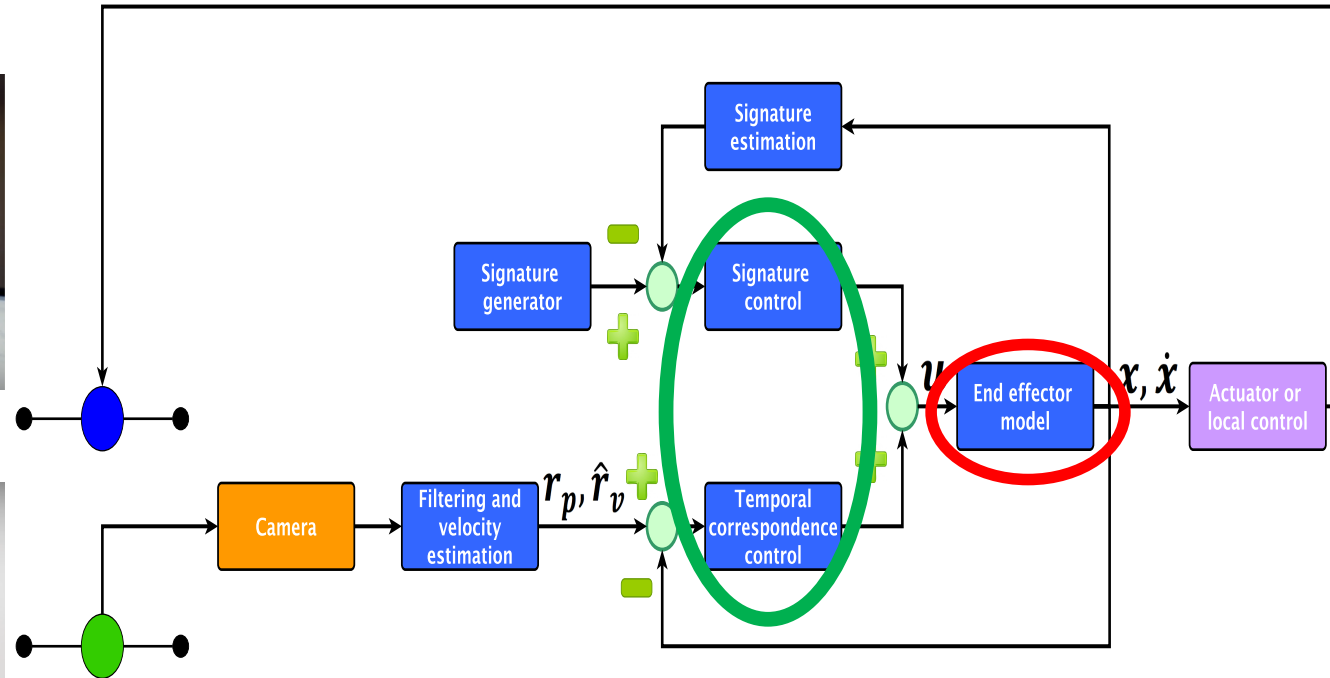
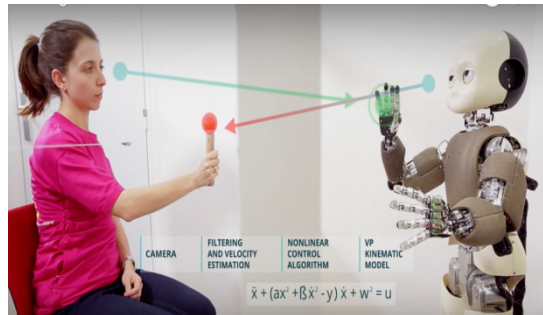


What's the virtual player?





What's the virtual player?

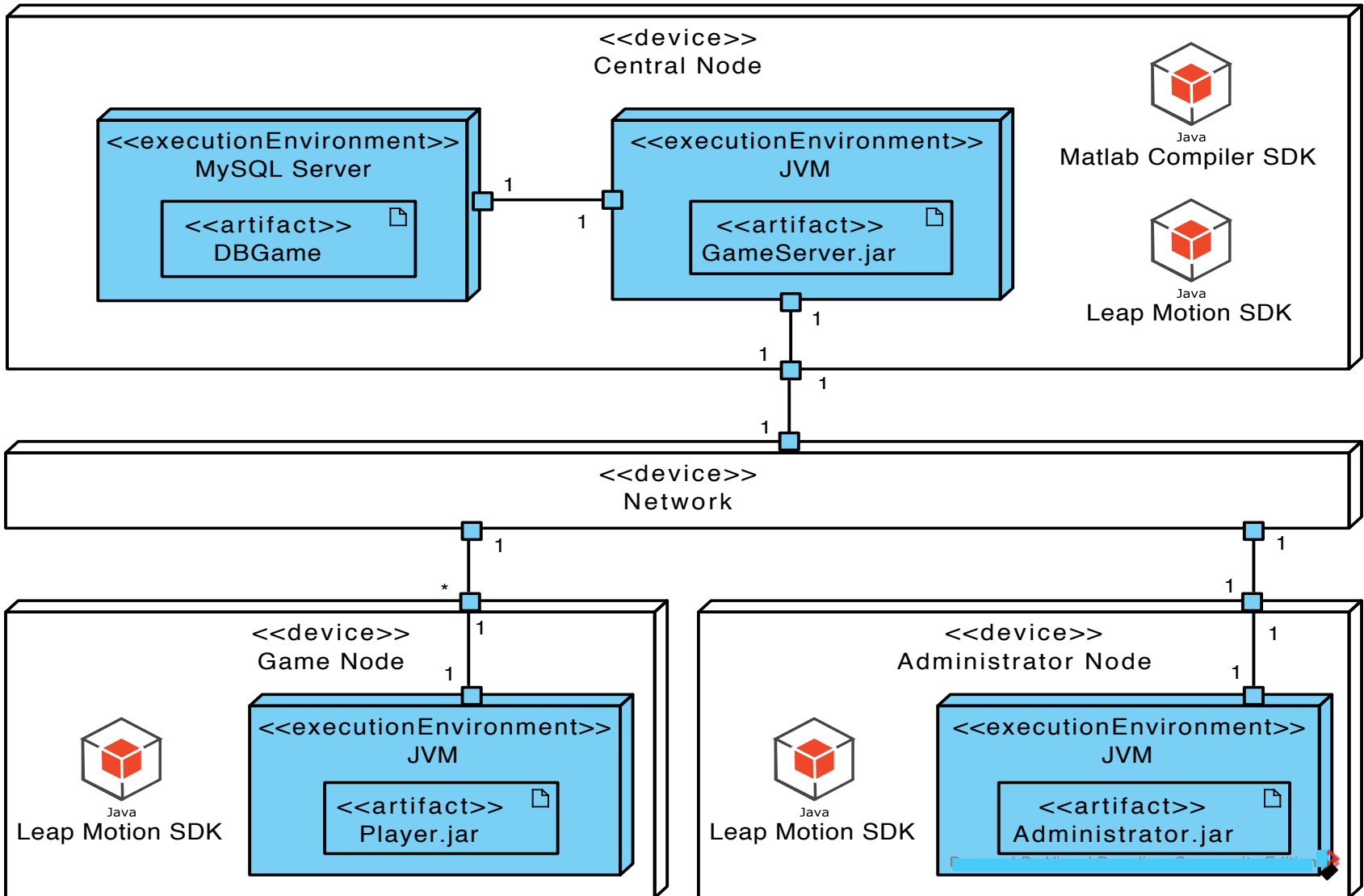


- Adaptive Control
- PD Control

- HKB Oscillator
- Harmonic Oscillator
- Double Integrator



Software System: Deployment diagram





Software System: User interface

Welcome to Mirror Game

Author: Maria Lombardi
Supervisors: Francesco Alderisio, Mario di Bernardo

Leader-Follower trial
Joint-Improvisation trial

Set the features of the Virtual Player

Choose the inner dynamic: Kalman-Buc oscillator
Choose the controller: Adaptive control

Duration of the trial (s): [input field]
Choose parameters of the Virtual Player

Parameters of the inner dynamic: $\ddot{x} + (\alpha\dot{x}^2 + \beta\dot{x}^2 - \gamma)\dot{x} - \omega^2 x = u$
Parameters of the control: $u = (a(t) + b(t)(x - \hat{x}_p)^2)(\dot{x} - \dot{x}_p) - C_1 e^{-(t-t_0)}(x - \hat{x}_p)$

alpha: [input field] Cp: [input field]
beta: [input field] aee(): [input field]
gamma: [input field] bee(): [input field]
omega: [input field]

Choose the plot to display: Position time series

Position time series plot: position [dm] vs time [ms]. Legend: Human Player (blue), Virtual Player (red).

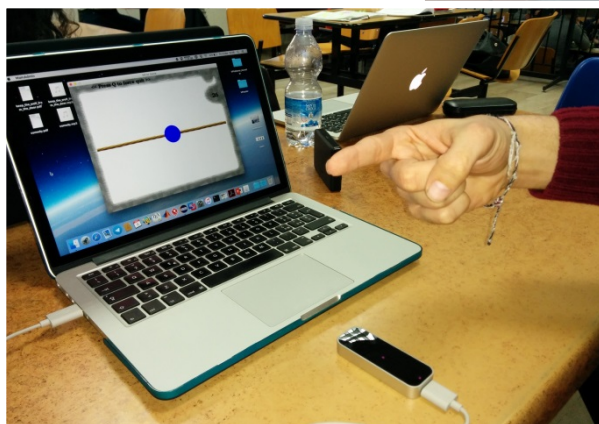
Choose the network topology (adjacency matrix)

| | player1 | player2 | player3 | player4 | player5 | player6 | player7 |
|---------|--------------------------|-------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| player1 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| player2 | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| player3 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| player4 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| player5 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| player6 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| player7 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

You are the player number 1, 2, 3



Experimental Protocol



- Group of five people
- Trials of 30 seconds
- 8 different network topologies
- 6 trials for each network topology
- Without any social interaction among them
- Anonymity among the players
 - No knowledge of the current network topology
 - No knowledge of set links
- Players are asked to coordinate their hand motion

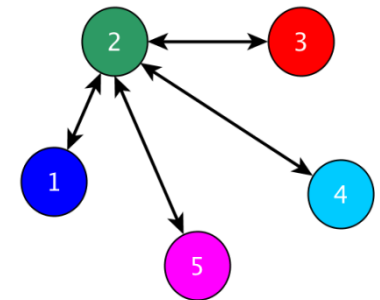
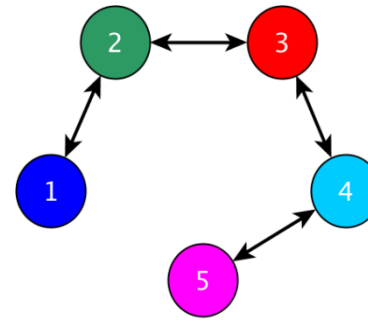
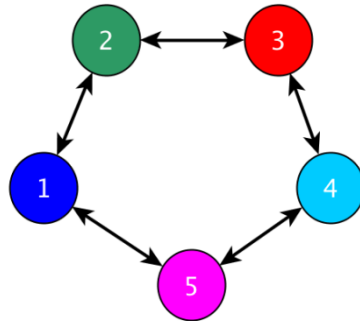
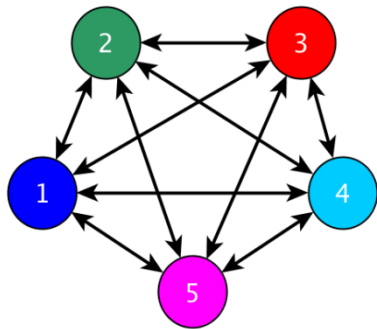


Synchronization metric

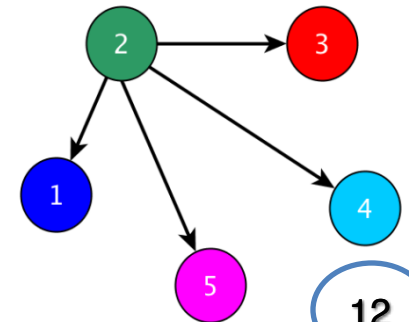
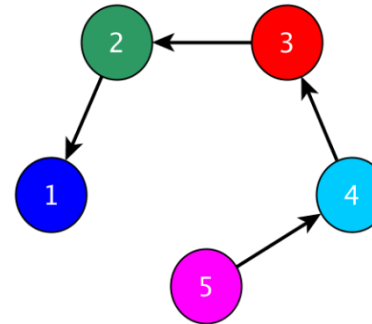
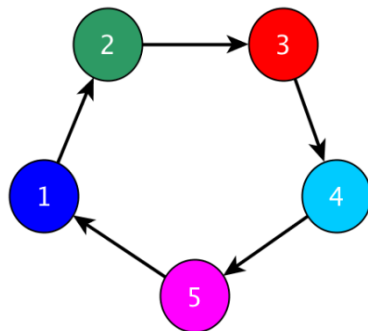
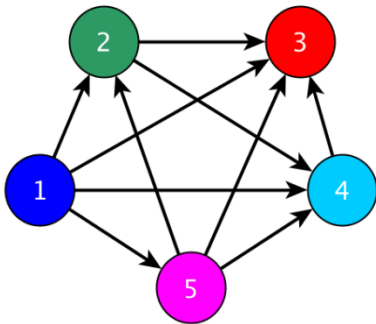
$$\rho_g(t) := \frac{1}{N} \left| \sum_{k=1}^N e^{j[\phi_k(t) - \bar{\phi}_k]} \right| \in [0, 1]$$

- N : number of individuals
- $\phi_k(t)$: Relative phase between k -th participant and the group

Undirected Networks

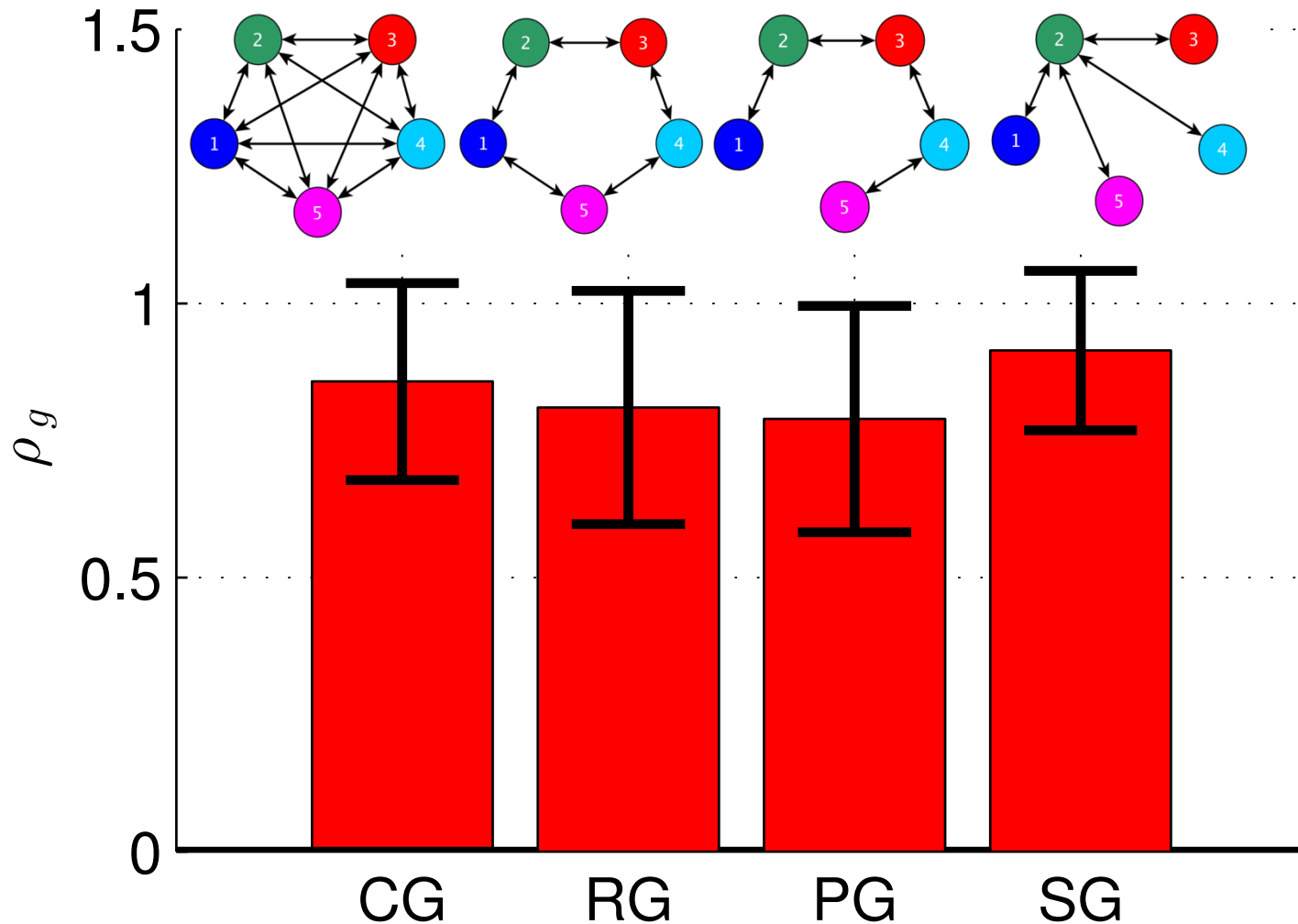


Directed Networks





Experimental results: group synchronization





Conclusions and future works

Now...

- Implementation of an experimental set-up to study of multiplayer coordination without social interaction
- Implementation of different topological connections
- Possibility of performing trials between a human and a virtual player (couple and on the network)

...in the future

- Perform group trials allowing social interaction, and compare them with the case of absence of social interaction



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THANK YOU!

