

UNIVERSITÀ DEGLI STUDI
DI NAPOLI FEDERICO II

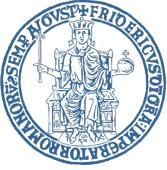
A Novel Computer-Based Set-Up for the Analysis of Group Synchronisation

Authors

Francesco Alderisio*, Maria Lombardi**, Gianfranco Fiore*, Mario di Bernardo* **

* *Engineering Mathematics, University of Bristol, UK*

** *Electrical Engineering and Information Technology, University of Naples “Federico II”, Italy*



Natural human synchronization

Each individual moves differently from the others:

↓ but

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





Natural human synchronization

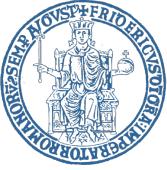
Each individual moves differently from the others:

↓ but

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



Two individuals



Natural human synchronization

Each individual moves differently from the others:

↓ but

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



Two individuals

...in a group?





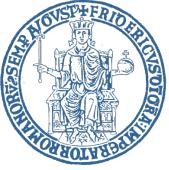
Why and What do we want to study?

What

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

- And what about the spatial disposition of people?





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?

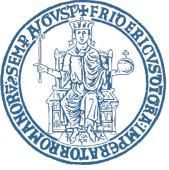


Why

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



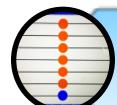
Study of synchronization: HP - HP trials



Design and Validation of Virtual Player



Study of synchronization: VP - HP trials



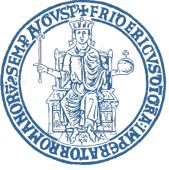
Extension of Software System to a multiplayers game



Study of synchronization: HP group



Study of synchronization: HP - VP group



Road map



Analysis of human movements model



Development of Software to play Mirror Game between two players



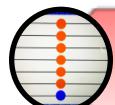
Study of synchronization: HP - HP trials



Design and Validation of Virtual Player



Study of synchronization: VP - HP trials



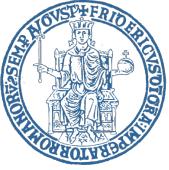
Extension of Software System to a multiplayers game



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.

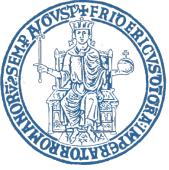
Himberg T, Thompson M. *Group synchronization of coordinated movements in a cross-cultural choir workshop*. 2009.

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

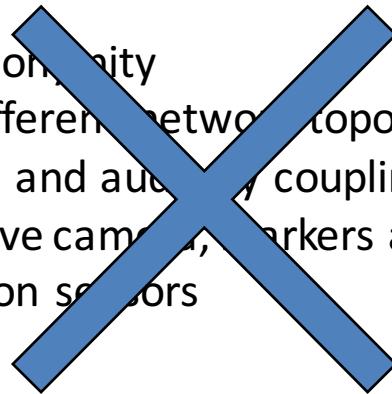
1. No anonymity
2. No different network topologies
3. Visual and auditory coupling
4. Invasive camera, markers and position sensors



The innovation of this work

State of art limits

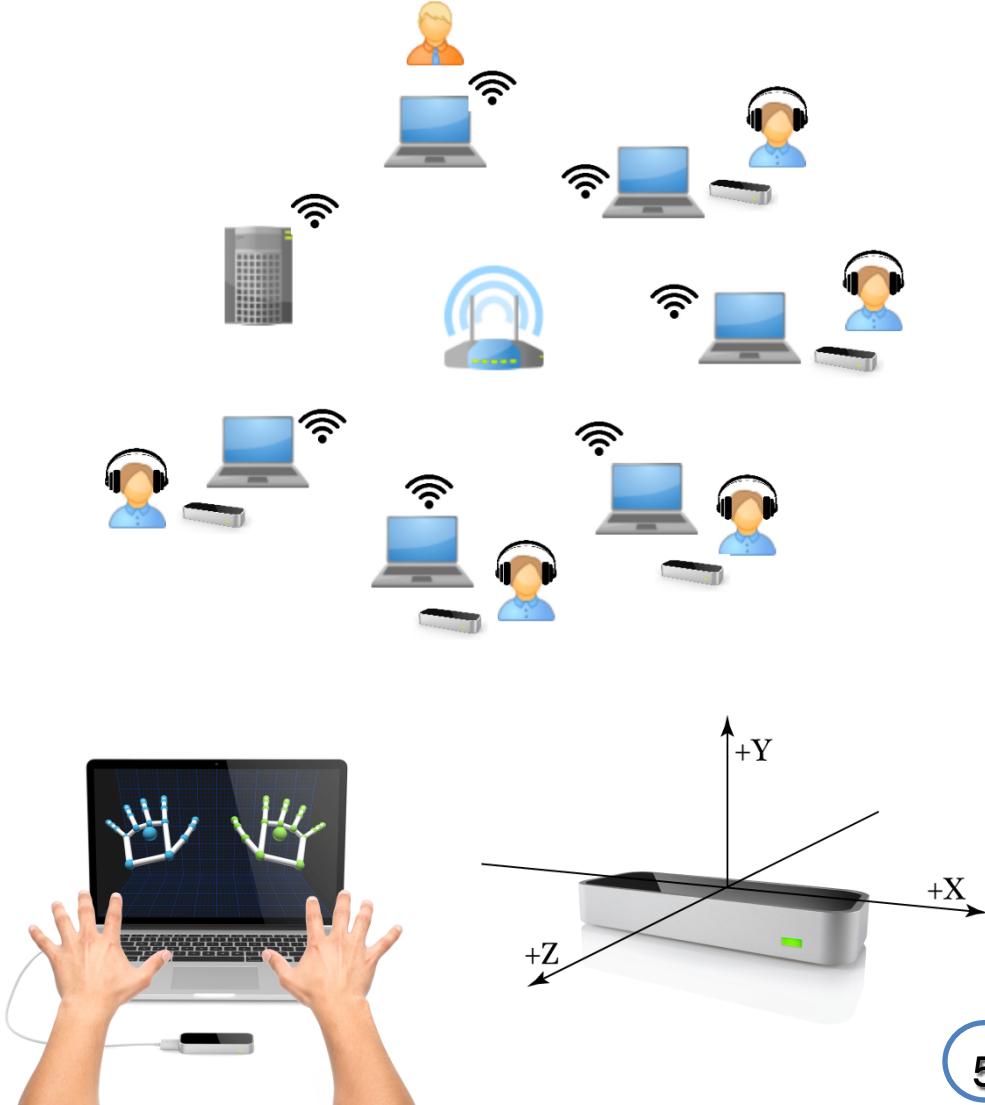
1. No anonymity
2. No different network topologies
3. Visual and auditory coupling
4. Invasive cameras, markers and position sensors

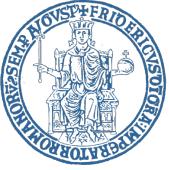


Our approach

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

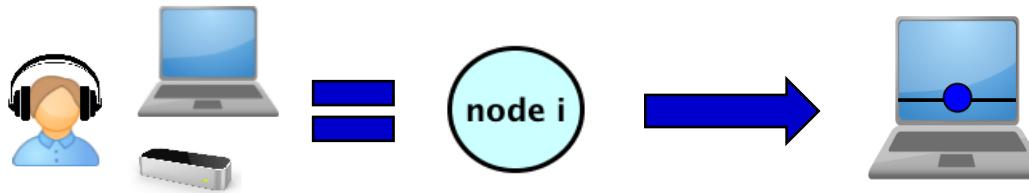




Network topologies to represents different interaction

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

Node

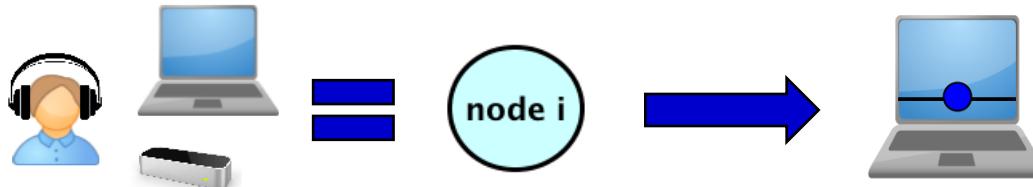




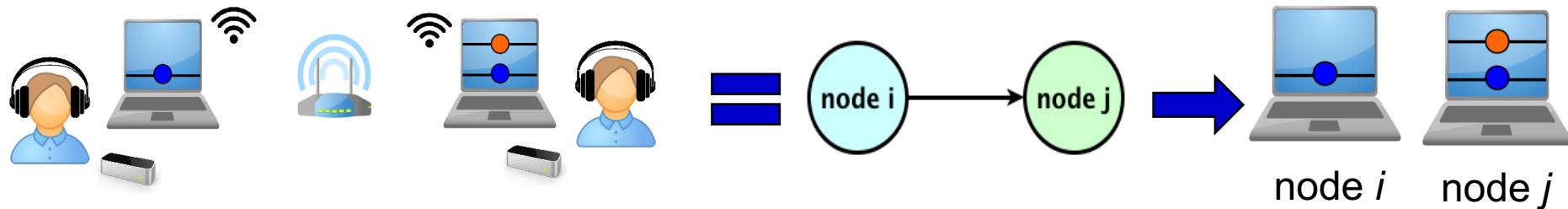
Network topologies to represents different interaction

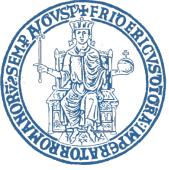
A graph is a tuple $G=(V,E)$ defined by a set of nodes $V=\{1,\dots,N\}$ and a set of edges

Node



Link

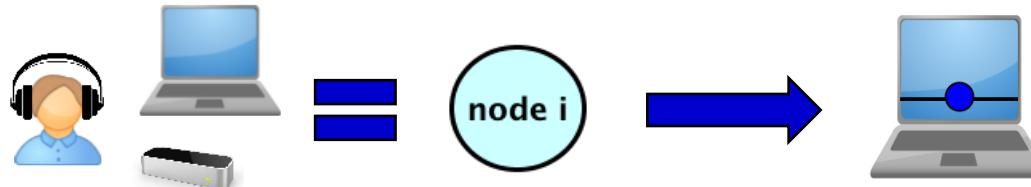




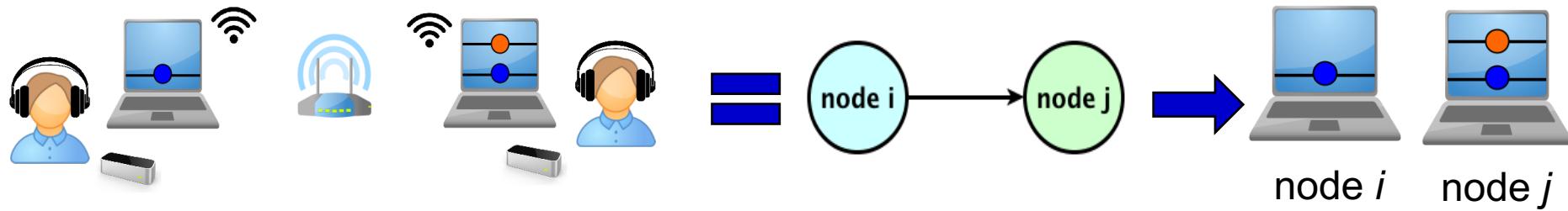
Network topologies to represents different interaction

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

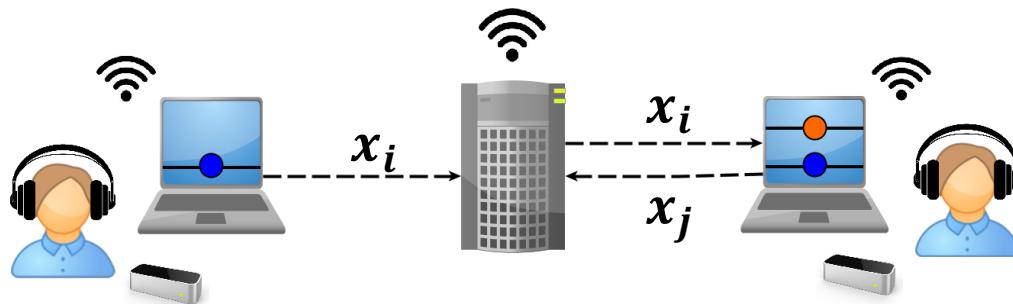
Node



Link

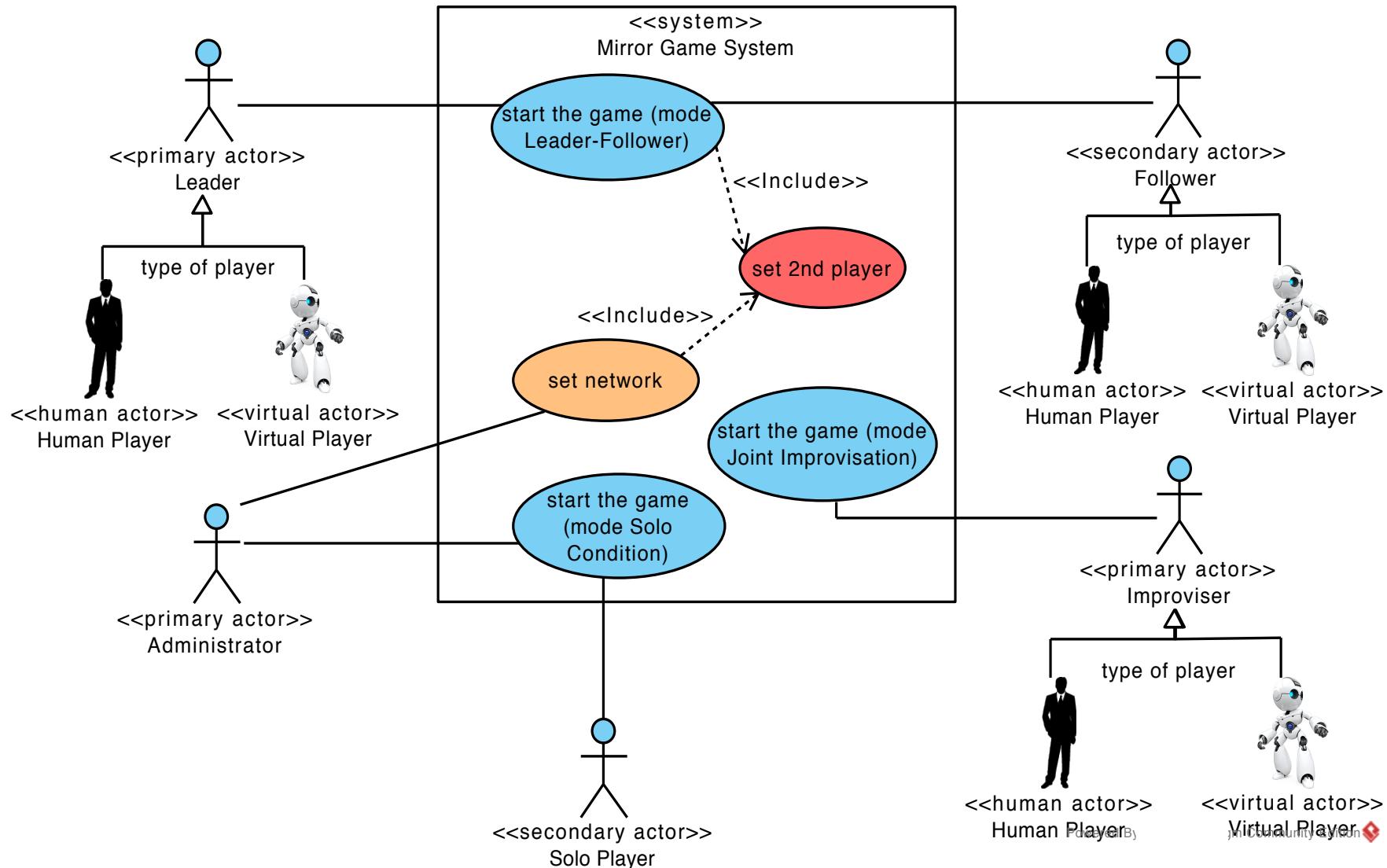


Structure of
interconnections



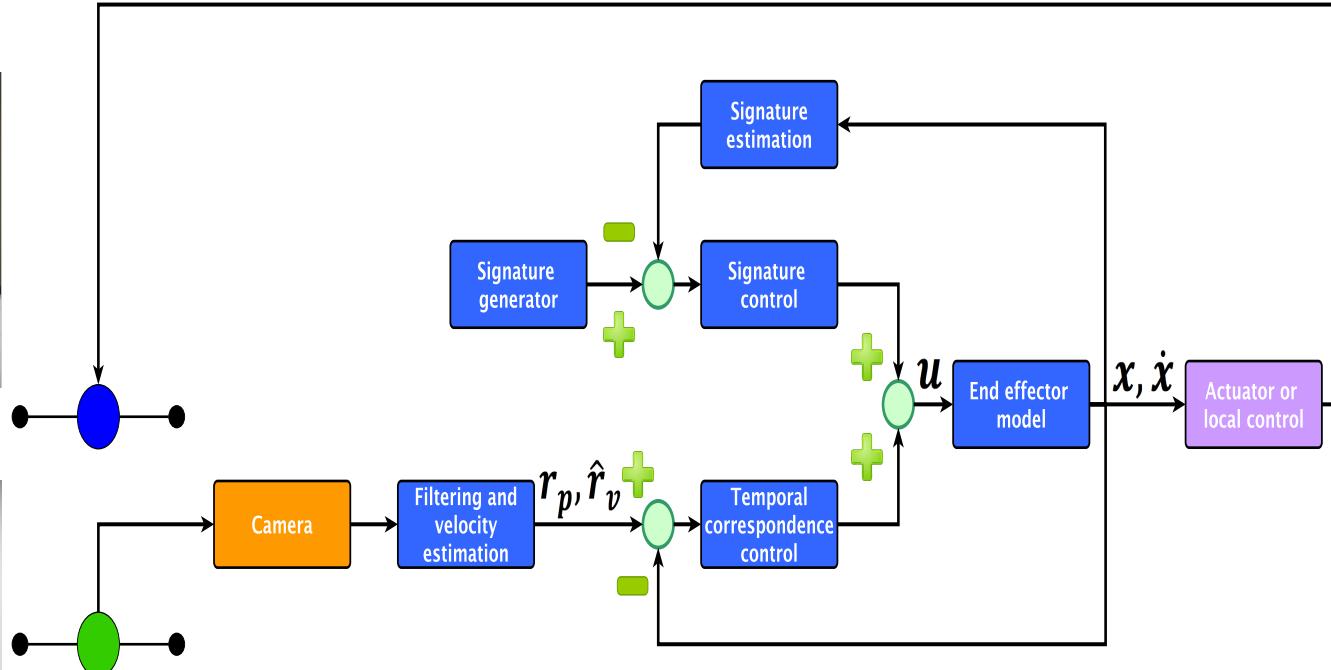
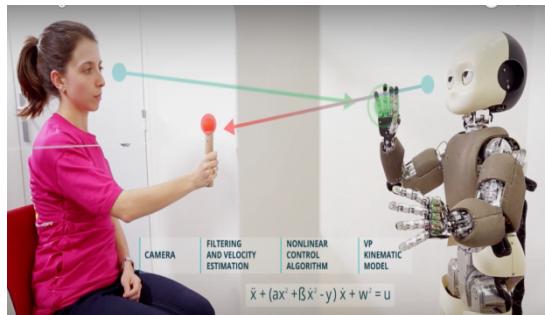


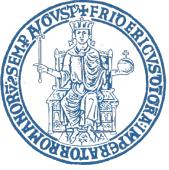
Software System: Use case diagram



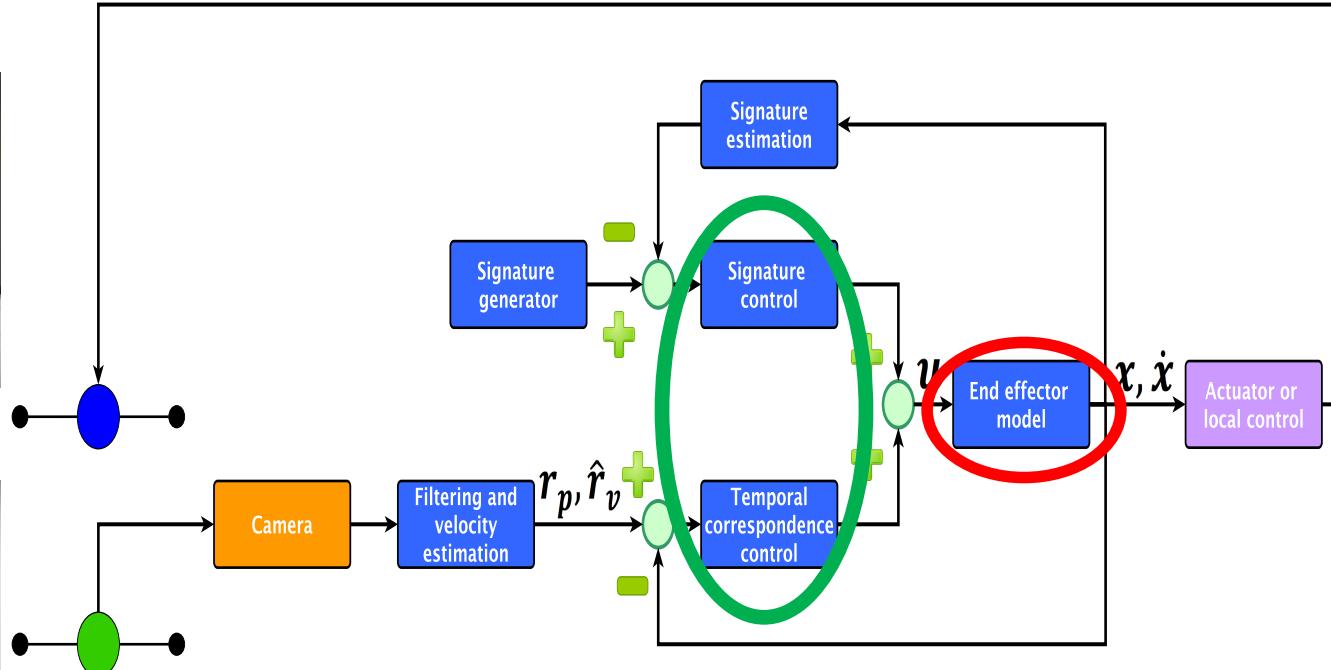
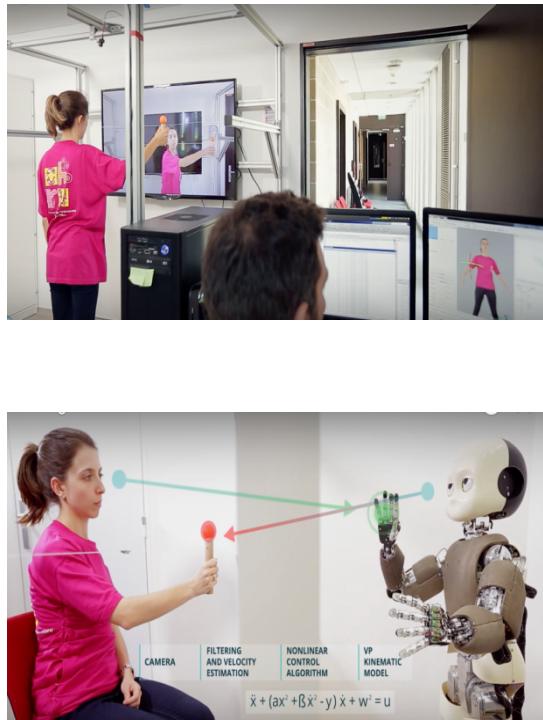


What's the virtual player?





What's the virtual player?

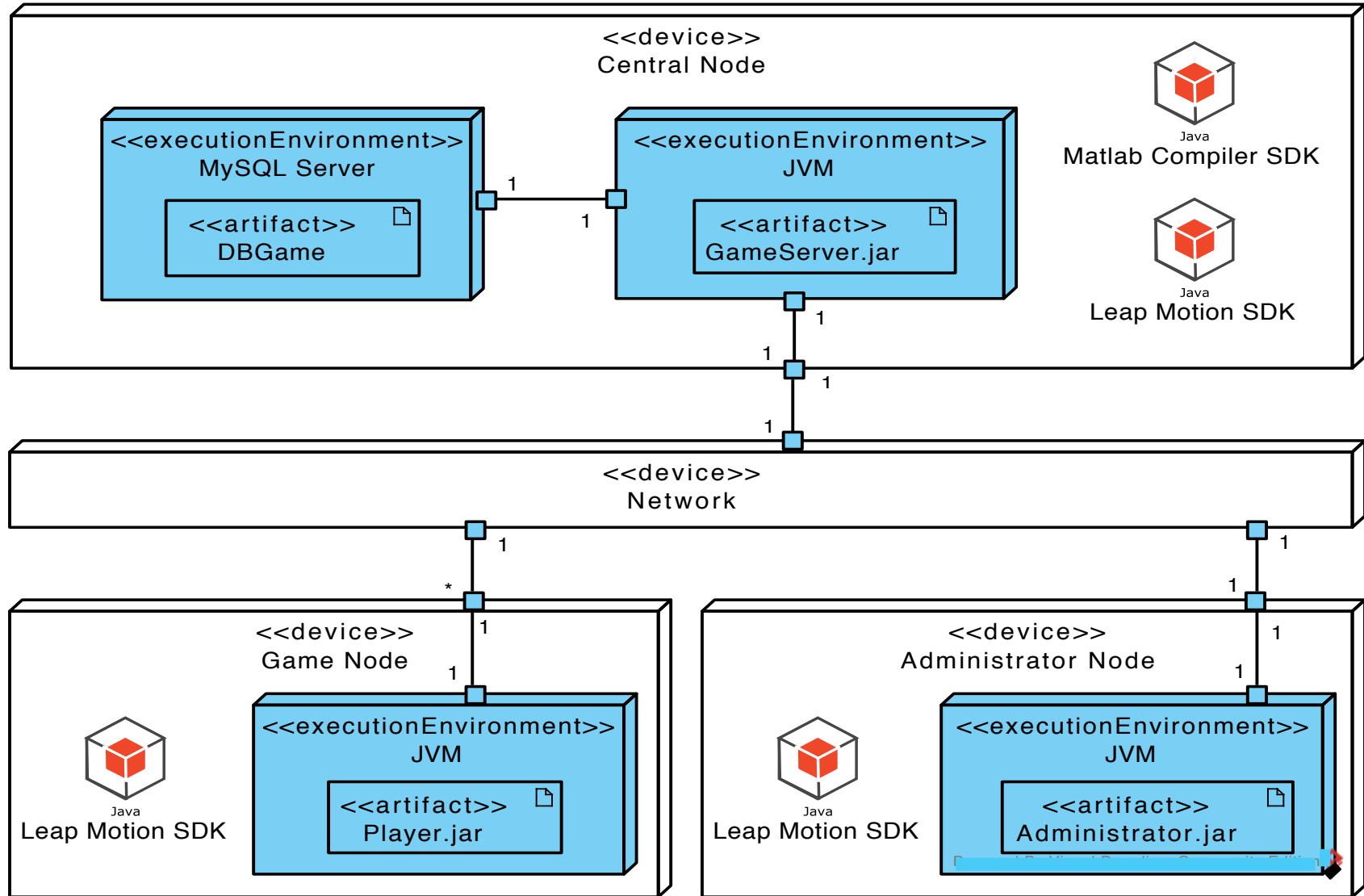


- Adaptive Control
- PD Control

- HKB Oscillator
- Harmonic Oscillator
- Double Integrator

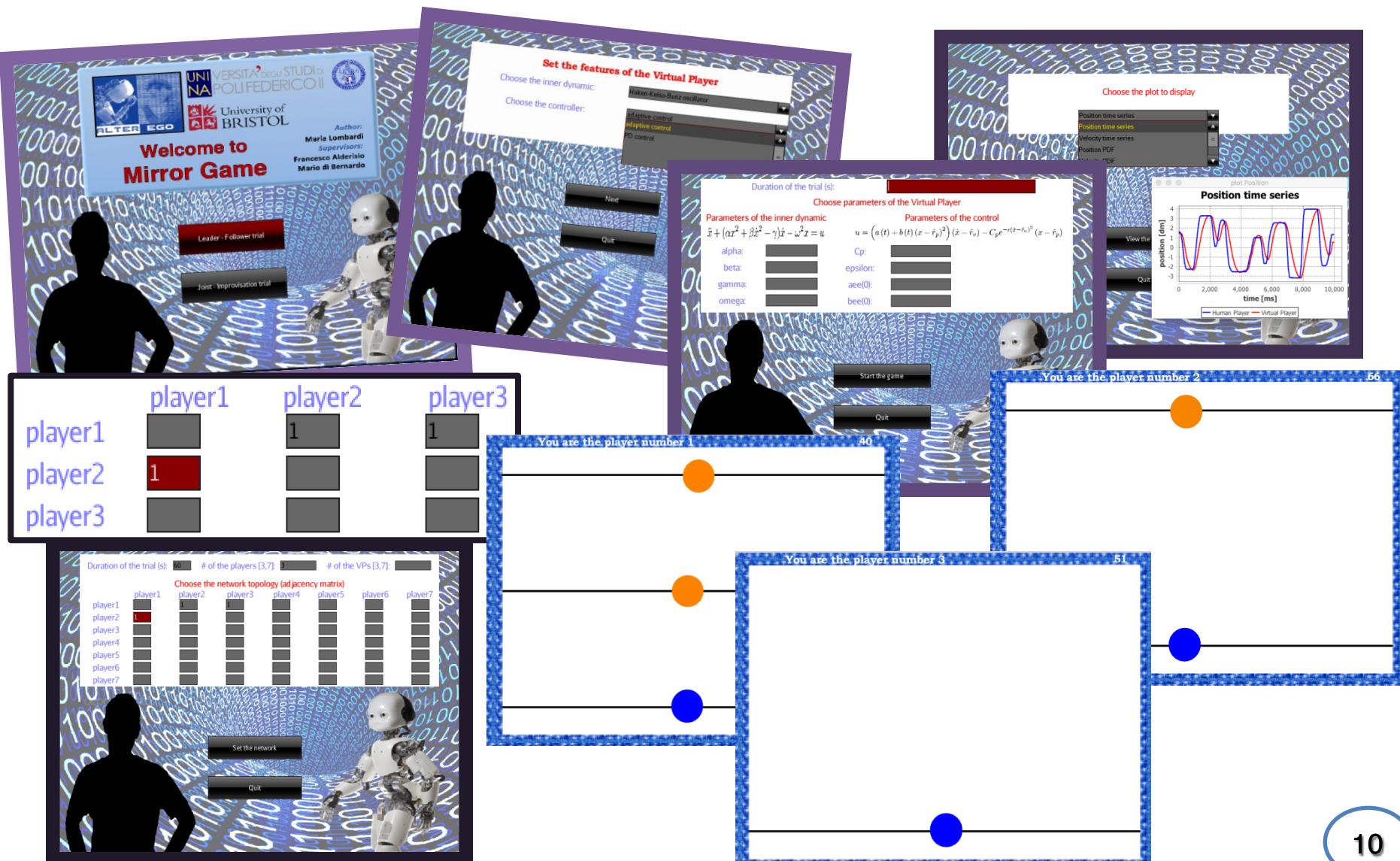


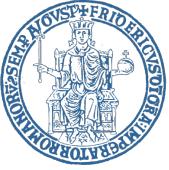
Software System: Deployment diagram



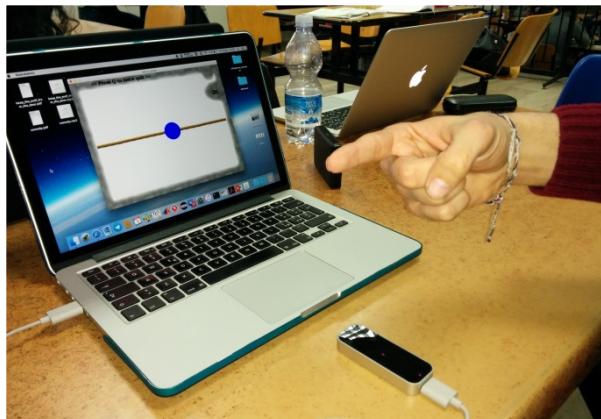


Software System: User interface

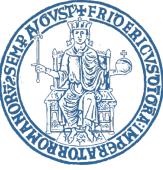




Experimental Protocol



- 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

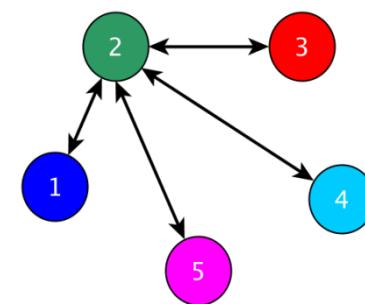
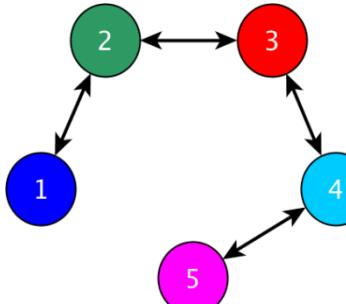
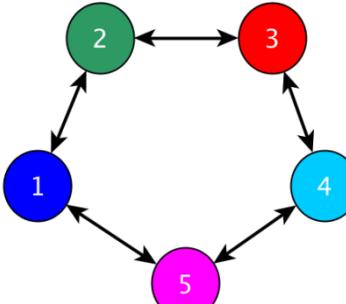
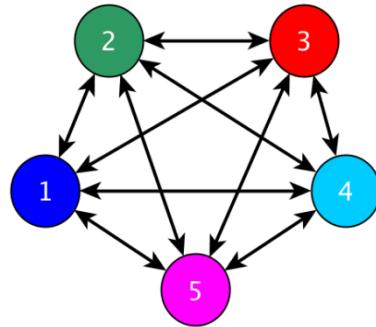


Synchronization metric

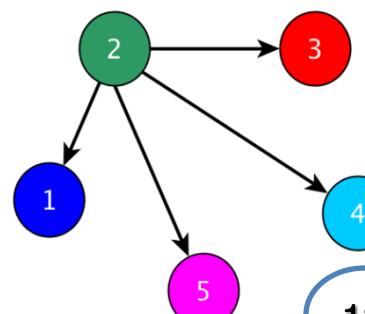
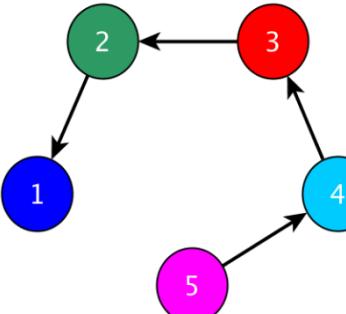
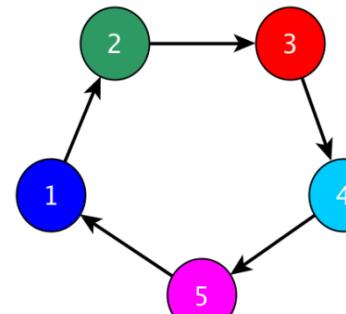
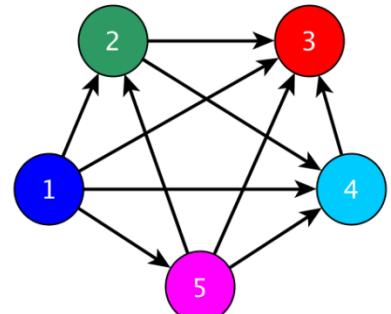
$$\rho_g(t) := \frac{1}{N} \left| \sum_{k=1}^N e^{j[\phi_k(t) - \bar{\phi}_k]} \right| \in [0, 1]$$

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

Undirected Networks

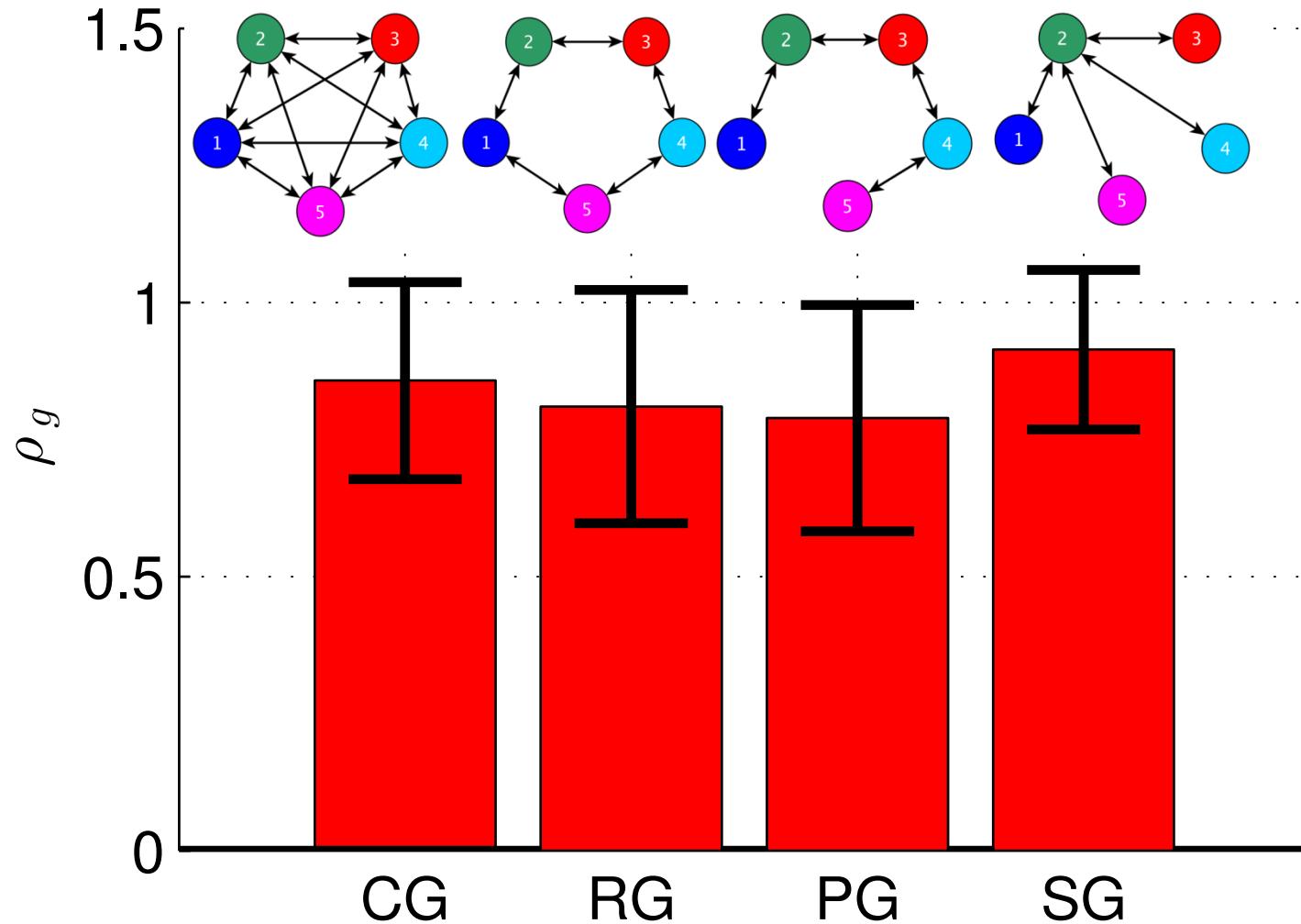


Directed Networks





Experimental results: group synchronization





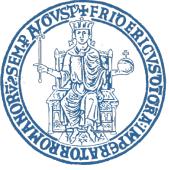
Conclusions and future works

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



UNIVERSITÀ DEGLI STUDI
DI NAPOLI FEDERICO II

THANK you!

