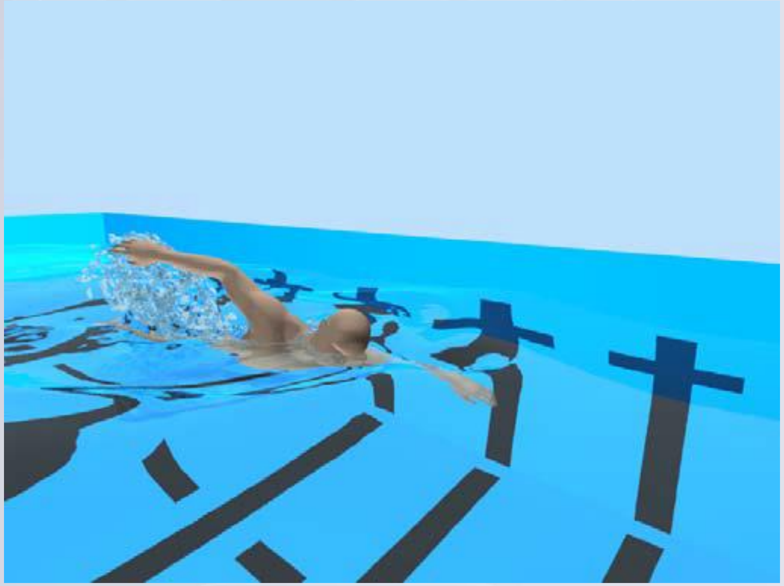
UMR 5205 CNRS

Walking Motion Control in Partial Immersion

Laboratoire d'InfoRmatique en Image et Systèmes d'information

Context

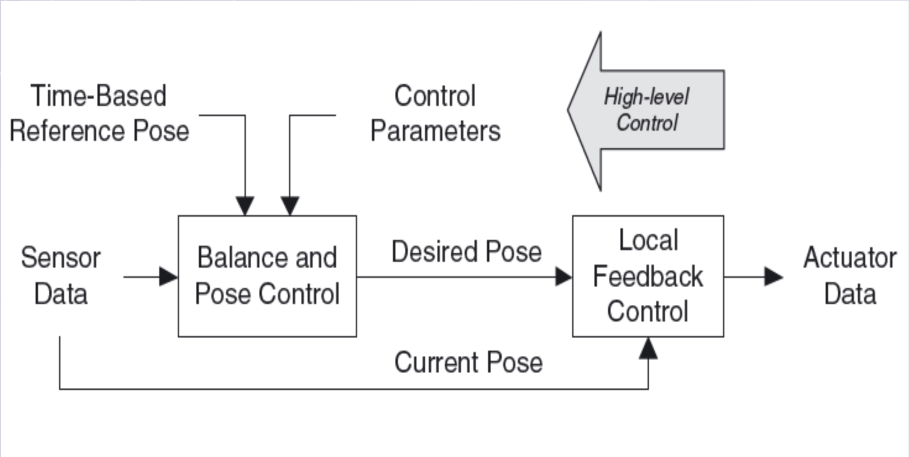


Biomechanical simulation of human swimming [Si2014]

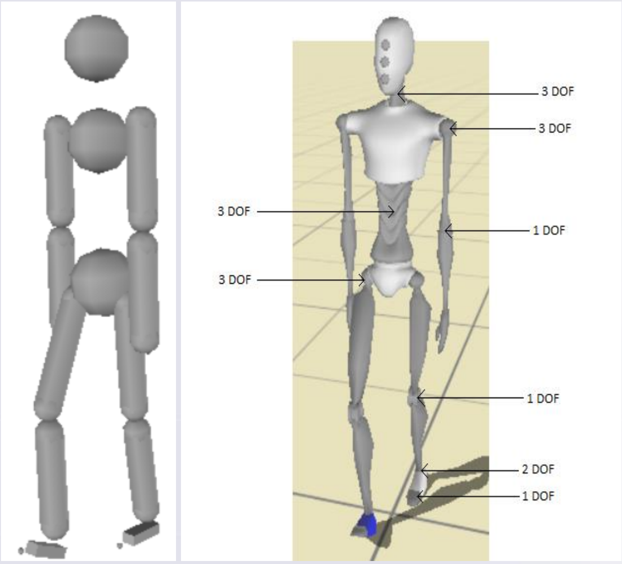
A dancing crowd [coros2010]

Previous works

Physic-based controller



Example of physic-based controller [Geijtenbeek2012]



Example of human model

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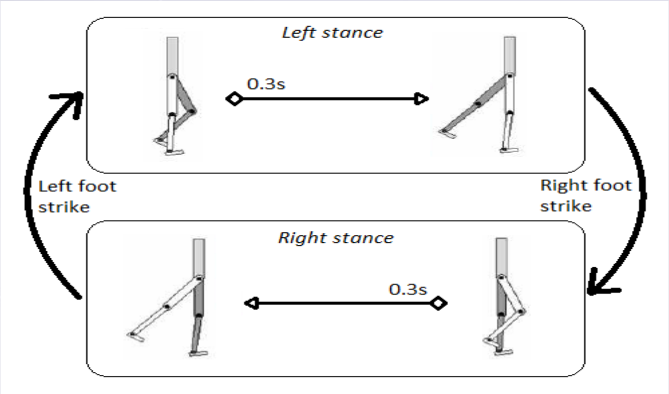
SIMBICON

- **SIMple Biped CONtroller [Yin2007]**



Finite state machine for forward walk [Yin2007]

- **Proportional Derivative (PD)- controller:**

$$\tau = k_p(\theta_d - \theta) + k_v(\dot{\theta}_d - \dot{\theta})$$

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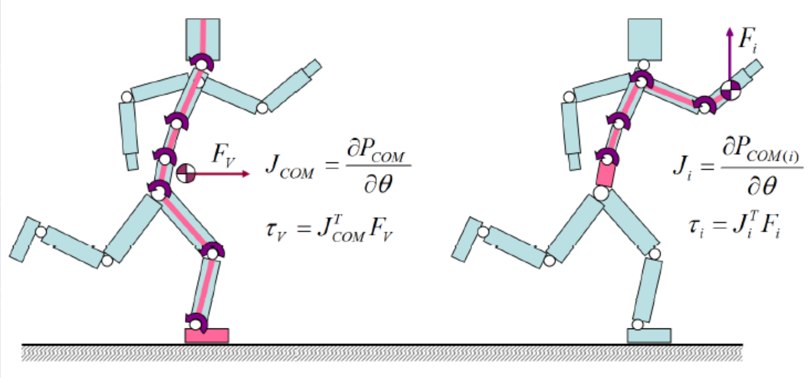
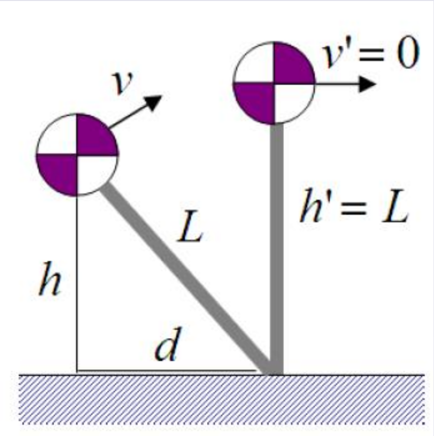
- Stable state combiner [Coros2009]



Fine scale velocity tuning (left) and gravity compensation (right). [Coros2010]



IPM [Coros2010]

- Gravity compensation [Coros2010]
- Inversed pendulum Model (IPM) [Coros2010]
- Fine scale velocity and balance control [Coros2010]

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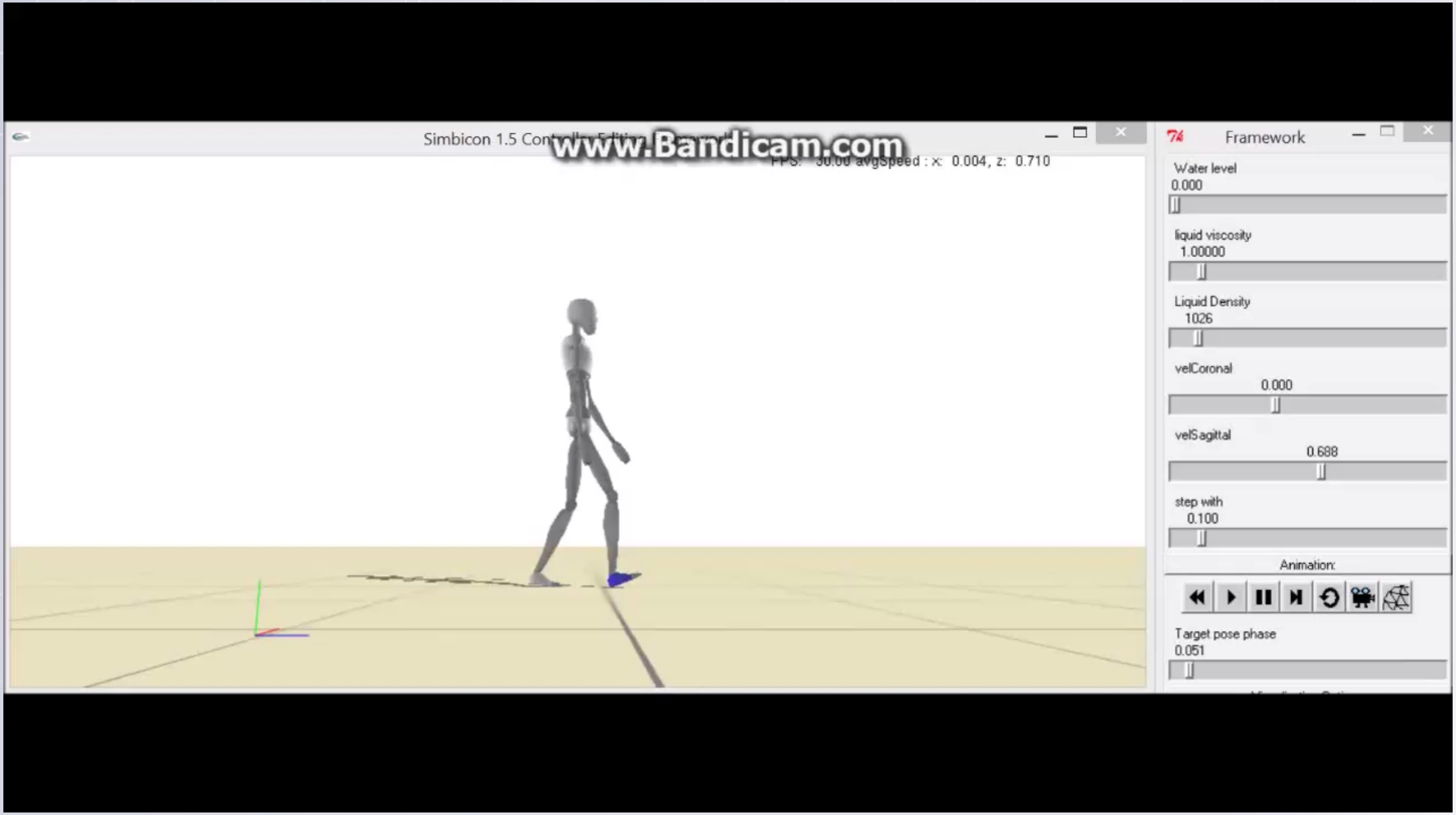
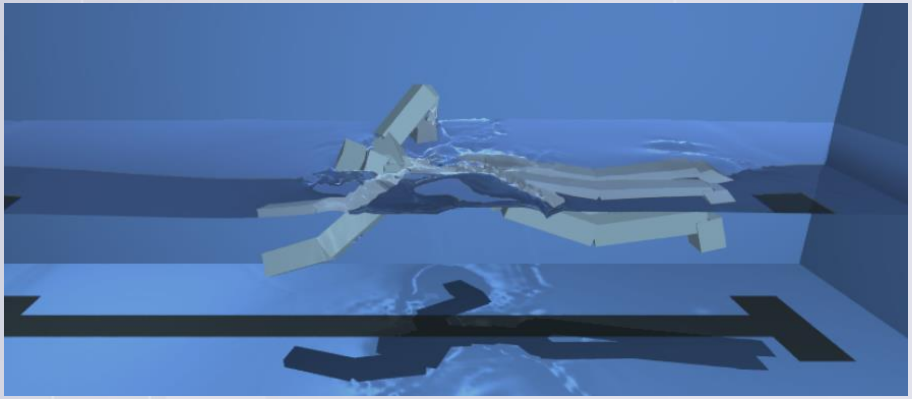


www.Bandicam.com
avgSpeed : x: 0.004, z: 0.710
Framework
Water level
0.000
liquid viscosity
1.00000
Liquid Density
1026
velCoronal
0.000
velSagittal
0.688
step with
0.100
Animation:
Target pose phase
0.051

Physic based controllers in fluids



Human swimming driven by motion capture [Kwatra2010]

Human walking under constant wind force [Lentine2011]

- **Navier-Stokes equations in Eulerian space**

Limits and contributions

Limits	Contributions
liquid interactions not in real time	Simplified liquid model
Gait specifications limited	Smart IPM usage State combiner
Unable to follow desired speed	IPM alteration Intra-step speed variation consideration
Unable to handle immersion	Immersion aware gravity compensation.

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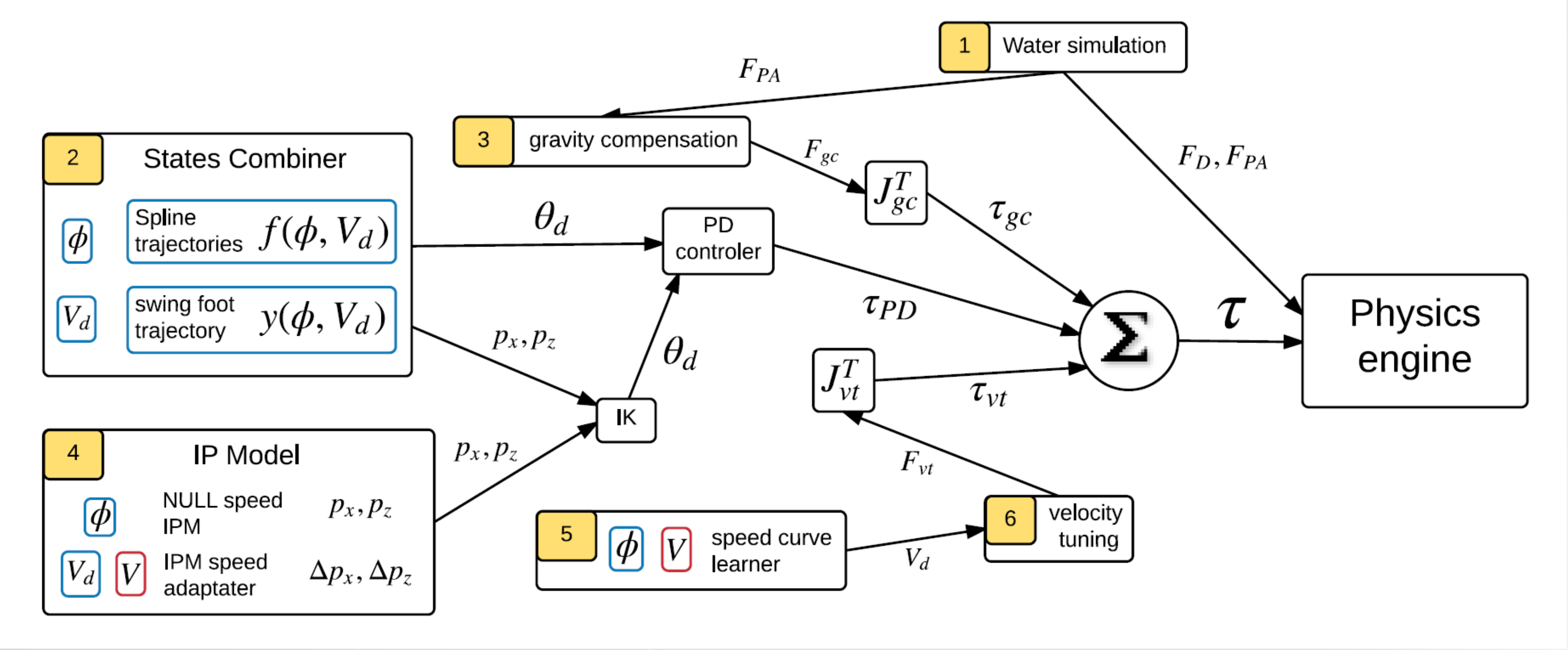
Contributions

Controller overview



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Liquid model

- **Liquid drag:**

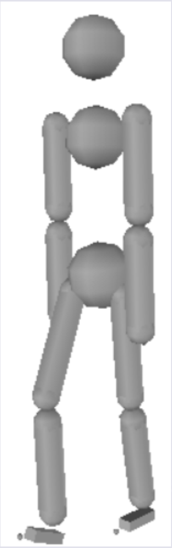
$$F_D = \frac{1}{2}\rho v^2 A_n$$

- **Friction:**

$$F = F_D * \mu$$

- **Buoyancy:**

$$F_{PA} = -V_i \rho g$$



Physic model of our character

Gait Specification: States combiner

- **Goals:**
  - Define main characteristic of the gait
  - Define conditions specific gaits
- **Can be enable on selected joints**
- **Interpolation following a square law**

Gait Specification: IPM

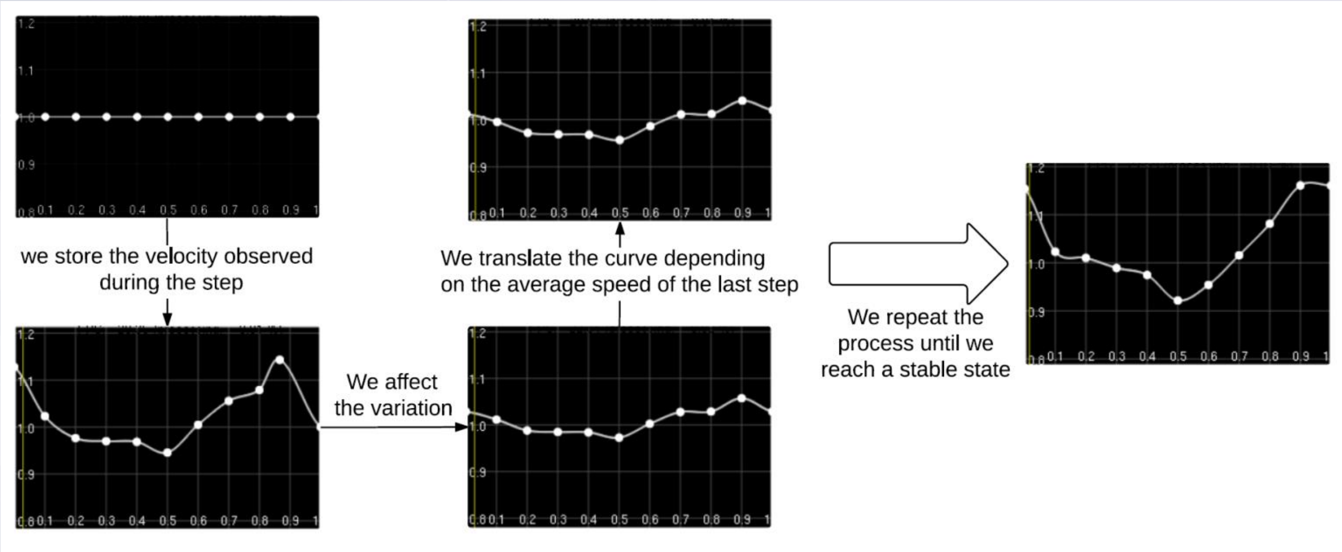
- Used in the descending phase of each step
- User defined swing foot trajectory for ascending phase
- IPM override user defined trajectory if the balance is lost

Speed Control

- **IPM result alteration**
  - Next step nearer → accelerate character
  - Next step further → slow character
  - Principle:
    - Add a Δ to the IPM result.
    - Adapt the Δ depending on speed at the end of each step

Speed Control

- **Based on fine scale control from (coros2010)**
- **Goal:**
  - adapt virtual force to intra-step speed variations.



Speed curve learning process

Gravity compensation

- **Virtual force applied to each rigid body composed of:**
  - Weight compensation $F_W = -mg$
  - Buoyancy compensation $F_B = \rho V_{im}$

- **Final force may be positive in liquid with high density**

Optimization

- **Evaluation formula:**

$$f_{eval} = \sum_t (\alpha f_{energ} + \beta f_{drag} + \gamma f_{acc}) * (1 + 0.1 * R_{ipm\_alt}) + f_{speed} + f_{balance}$$

- f_{energ} : consumed energy
- f_{drag} : opposition of liquid
- f_{acc} : sum of desired and observed angular acceleration

- R_{imp_alt} : ipm alteration utilization $\quad R_{imp\_alt} = \frac{\Delta(x,y)}{max(\Delta(x,y))}$
- f_{speed} : respect of desired speed
- $f_{balance}$: maintains stable motion

- Covariant Matrix Adaptation (CMA)

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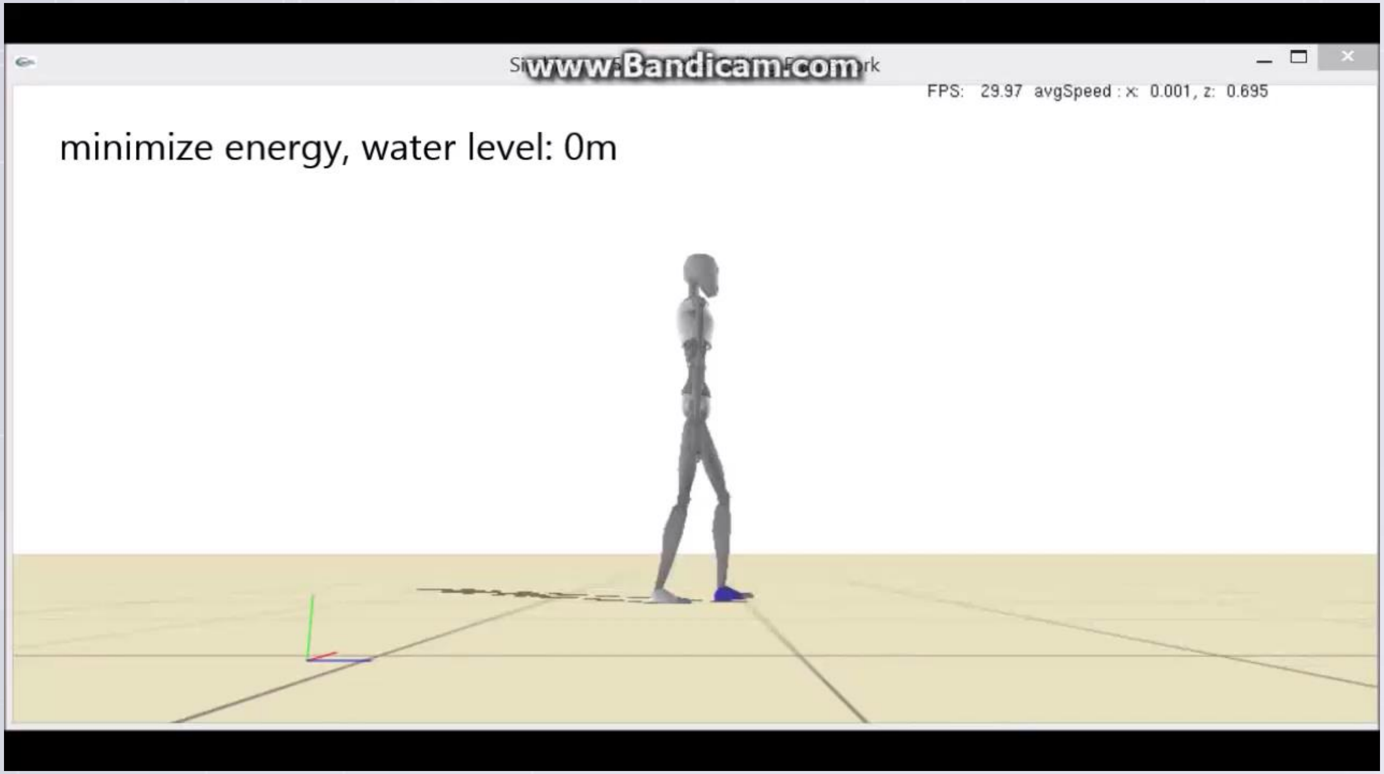
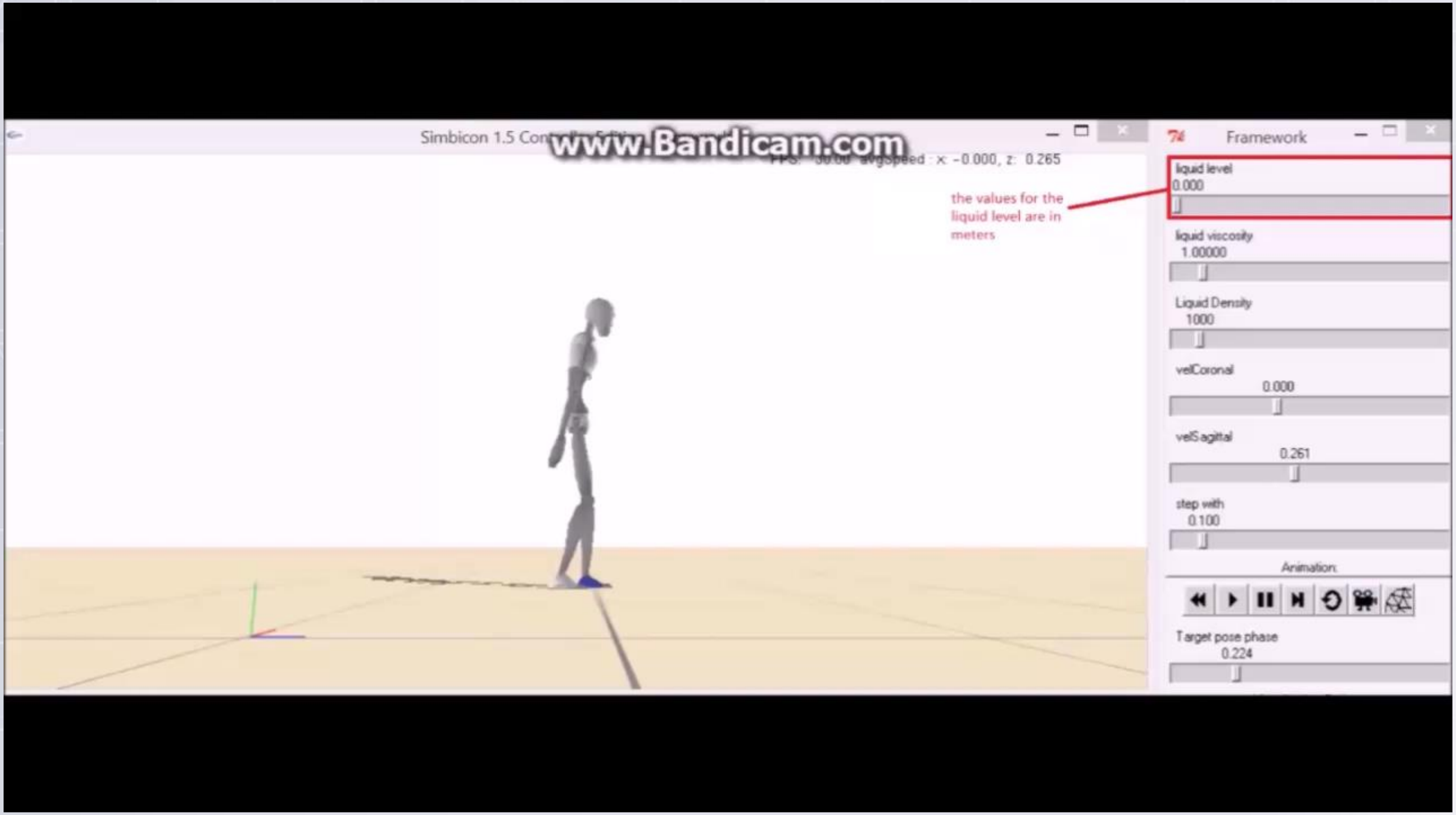
Results

Analyze optimization results



- 10 reference states (5 liquid levels, 2 speed)

Final controller



Conclusion

- **Contributions:**
  - Simple liquid through basic hydrodynamics
  - States combiner and Balance strategy activated on need only
  - Learning strategies to obtains the desired velocity
- **Limits:**
  - Static Thresholds based systems
  - Unstable contact between foot and ground.
  - Simplified liquid model may create unrealistic results
- **Future works:**
  - More realistic liquid model
  - Extension to more motions and more environments

Questions ?

References

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