Atom Based Control of Mobile Robots for environment exploration

Laboratoire Informatique Robotique Microélectronique Montpellier

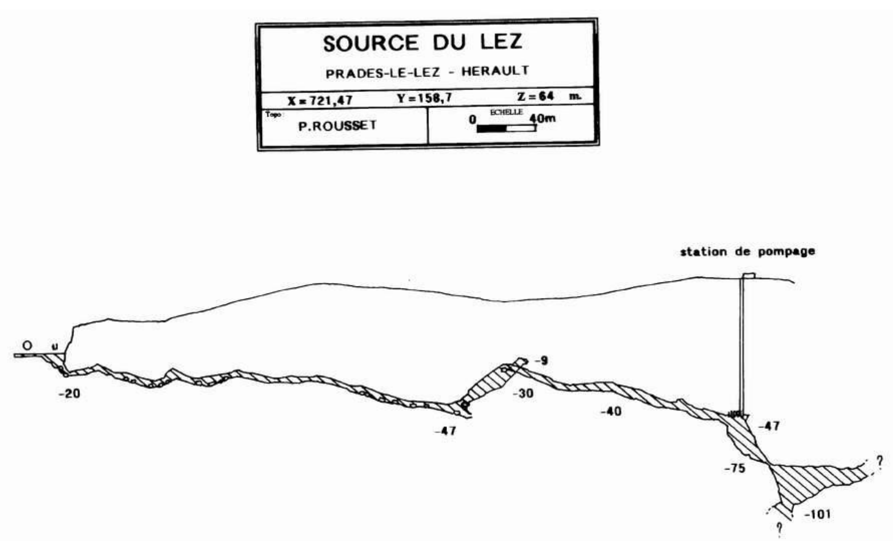
Labex NUMEV

Plan

- Introduction
- Control Laws Decomposition : towards Atoms
- Atoms Assembly and implementation constraints
- Conclusion

Context : Karstic Exploration

- Complex and challenging environments
- Dangerous for human exploration
- Integrating knowledge from specialists



Source : *http://www.plongeesout.com/sites/roussilonpyrenees/herault/lez.htm*

Source : *Spéléo Magazine n°83 Septembre 2013*

Issues related to monolithic control design

- Contributions not clearly expressed
- Cannot reuse efficiently knowledge
- Lack of flexibility at implementation
- Integration of models coming from other scientific fields

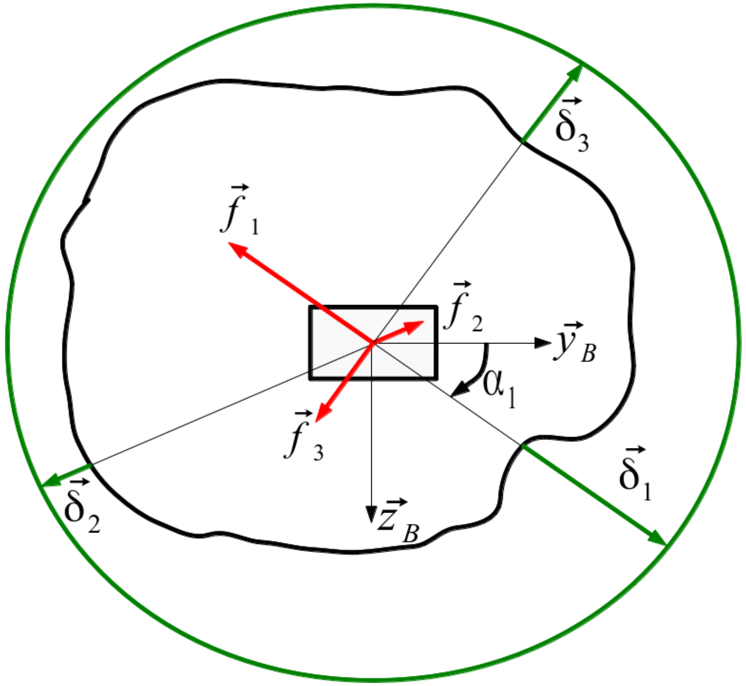
Goals

- Design control as a composition of knowledge :
  - Decomposition in independent models
  - How to make these model interact ?
  - Independent from implementation characteristics

- Take into account control concerns for implementation

Example

Centering in Karst conduits



$$F_{v_{co}} = -K_{DVZ} \sum_{i=1}^{N_R} [\cos(\alpha_i)(R_{DVZ} - d_i)] - (c_v + d_v) v$$

$$F_{w_{co}} = -K_{DVZ} \sum_{i=1}^{N_R} [\sin(\alpha_i)(R_{DVZ} - d_i)] - (c_w + d_w) w$$

$$\Gamma_{p_{co}} = -(m_p K_p + d_p) p - K_r m_p (\phi - \phi^d)$$

Example

Decomposition in independent models

Robot pose

y, z, ϕ

Robot Speeds

v, w, p

Roll Control

$$\dot{p}_{co} = -K_p p - K_r (\phi - \phi^d)$$

Sonar Measurement

$$\{(d_i, \alpha_i)\} \quad i = 1..\mathrm{N}_R$$

Intrusions in the DVZ

$$\{(\delta_i = R_{DVZ} - d_i, \alpha_i)\} \quad i = 1..\mathrm{N}_R$$

Resulting Force

$$F_{R_y} = -K_{DVZ} \sum_{i=1}^{N_R} \cos(\alpha_i)\delta_i$$

$$F_{R_z} = -K_{DVZ} \sum_{i=1}^{N_R} \sin(\alpha_i)\delta_i$$

Set Force to 0

$$\dot{v}_{co} = \frac{F_{R_y}}{m_v} - \frac{c_v v}{m_v}$$

$$\dot{w}_{co} = \frac{F_{R_z}}{m_w} - \frac{c_w w}{m_w}$$

Dynamic Model (simplified)

$$F_{v_{co}} = m_v \dot{v}_{co} - d_v v$$

$$F_{w_{co}} = m_w \dot{w}_{co} - d_w w$$

$$\Gamma_{p_{co}} = m_p \dot{p}_{co} - d_p p$$

To be published

Example

Classification of models

Legend :
- Robot/Technology
- Environment
- Task

Robot pose
y, z, ϕ

Roll Control
$\dot{p}_{co} = -K_p\, p - K_r(\phi - \phi^d)$

Robot Speeds
v, w, p

Sonar Measurement
$\{(d_i, \alpha_i)\}$
$i = 1..N_R$

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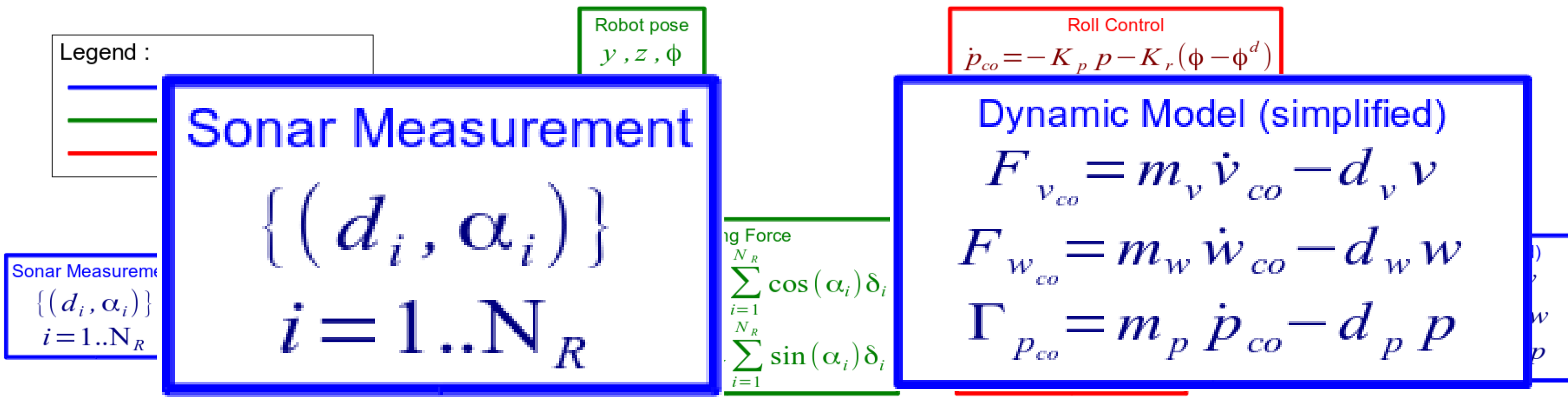
Example

Classification of models



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Example

Classification of models

Intrusions in the DVZ

$$\{(\delta_i = R_{DVZ} - d_i, \alpha_i)\}$$
$$i = 1..N_R$$

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To be published

Example

Classification of models

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$(\phi - \phi^d)$

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To be published

Example

Classification of models

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Robot pose
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Roll Control
$$\dot{p}_{co} = -K_p\, p - K_r(\phi - \phi^d)$$

Robot Speeds
v, w, p

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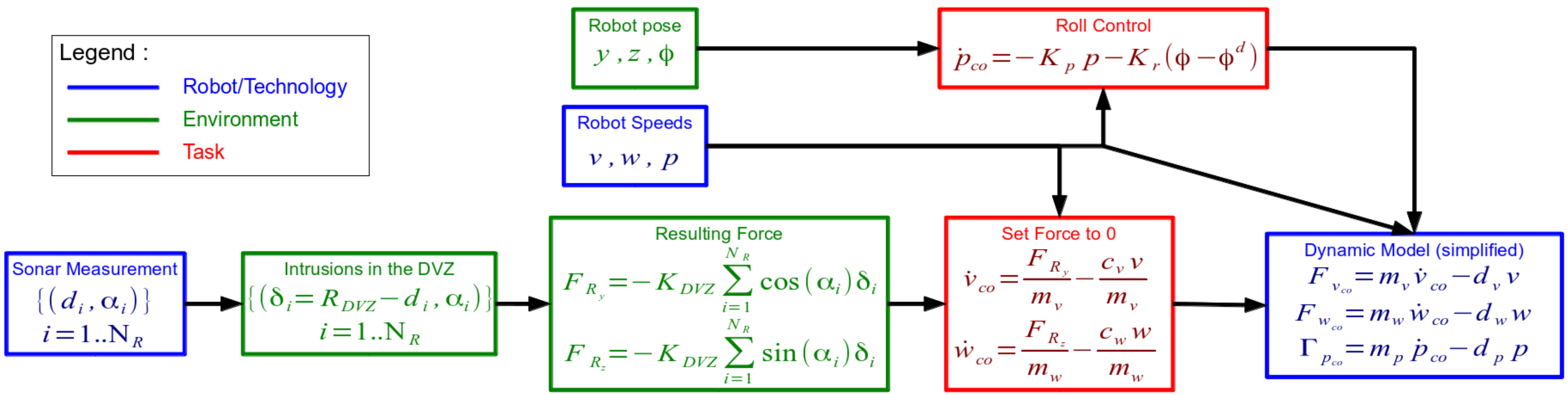
Example

Composition of models



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Atoms

- An indivisible unit encapsulating knowledge
- A DESCRIPTIVE entity

An atom has :

- A physics : a set of equations
- An interface to connect it with other atoms
- A set of implementation constraints :
  - T_{cyc} = set of periods of execution of the atom
  - T_{input} = set of periods of update for each input

The term Atom was already defined in the context of works over MDL and MDLe but with a different meaning.

Manikonda et al. **Languages, behaviors, hybrid architectures and motion control**. *Mathematical Control Theory*

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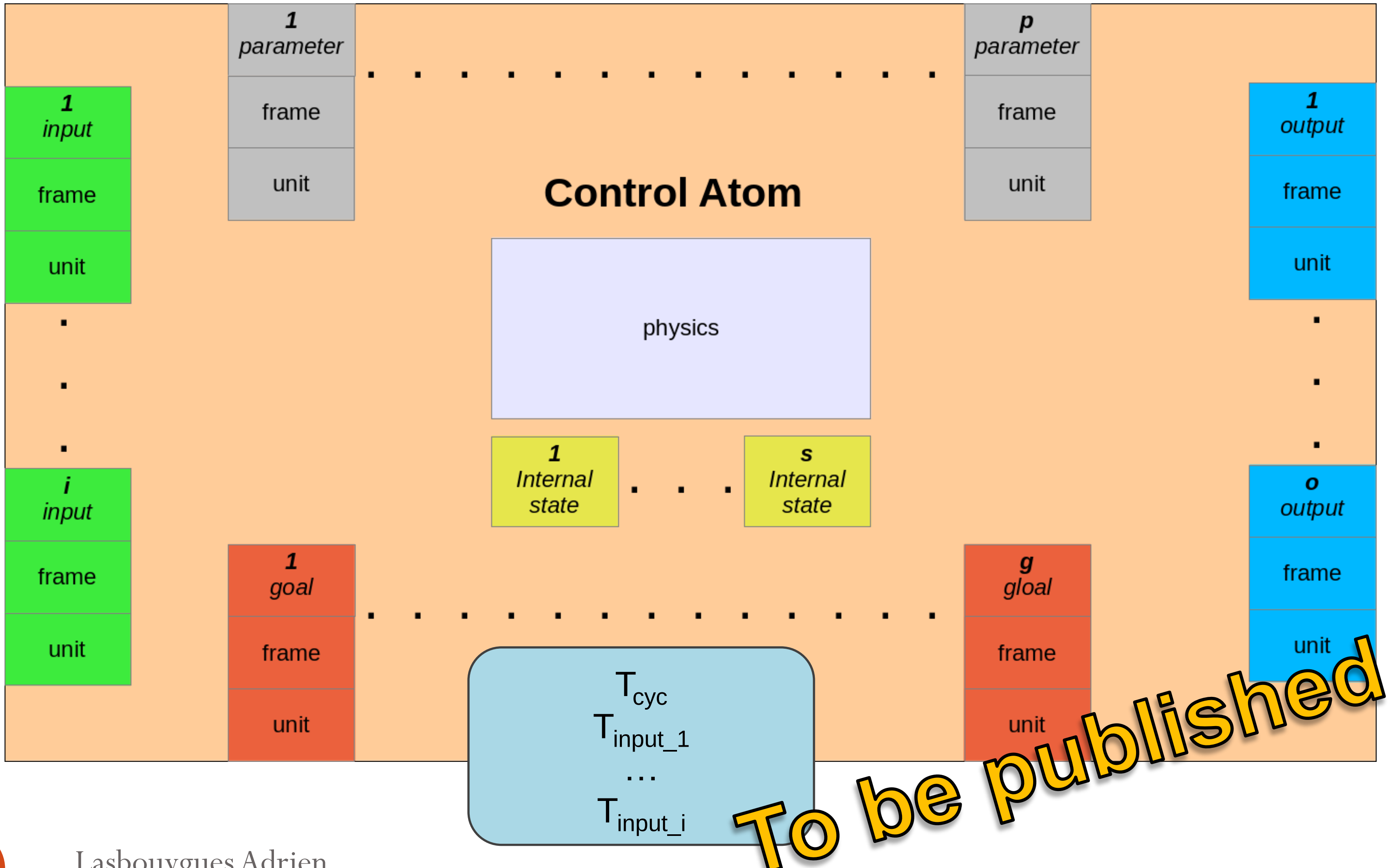
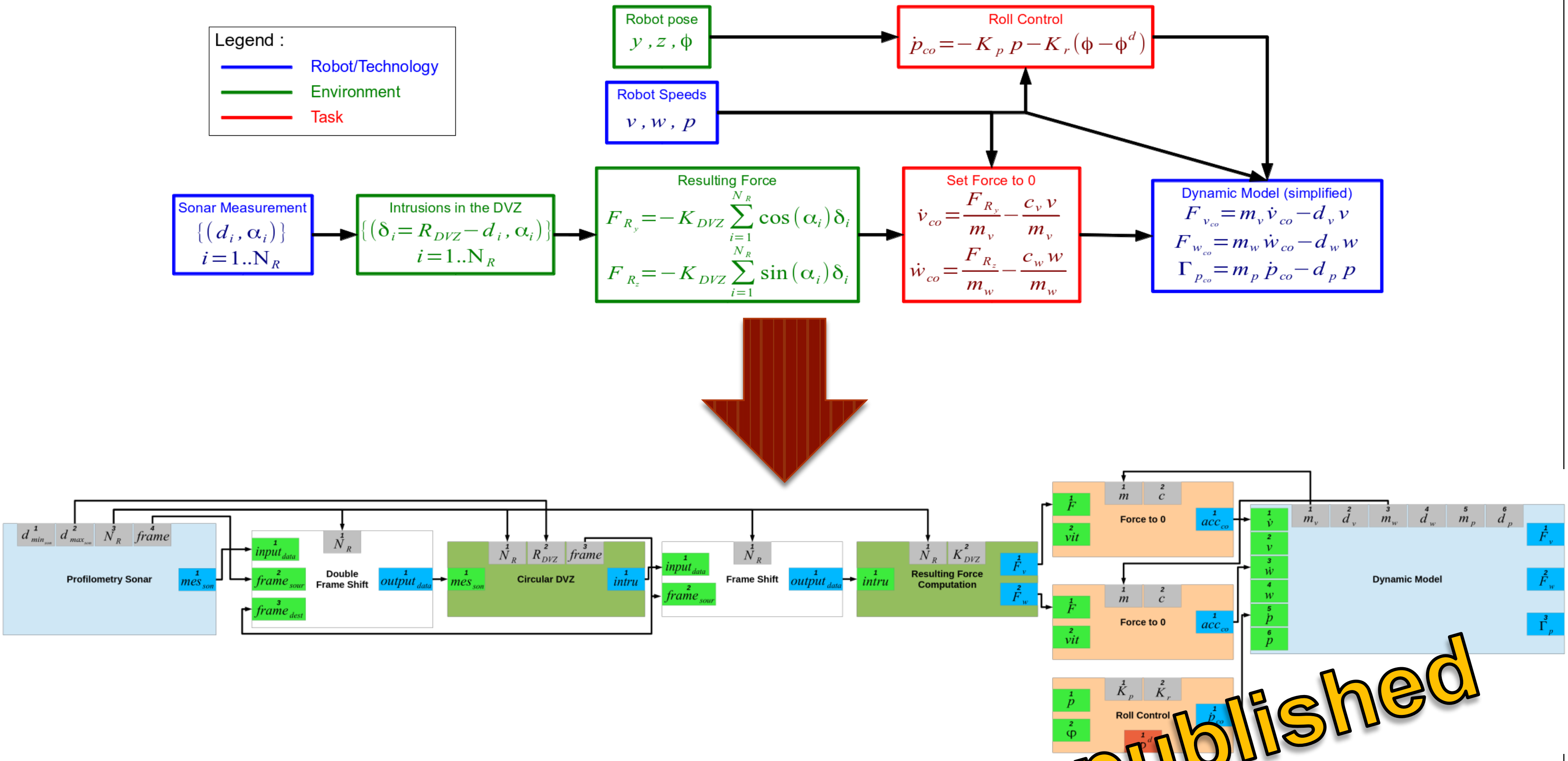
Atoms



Lasbouygues Adrien

Atoms Composition



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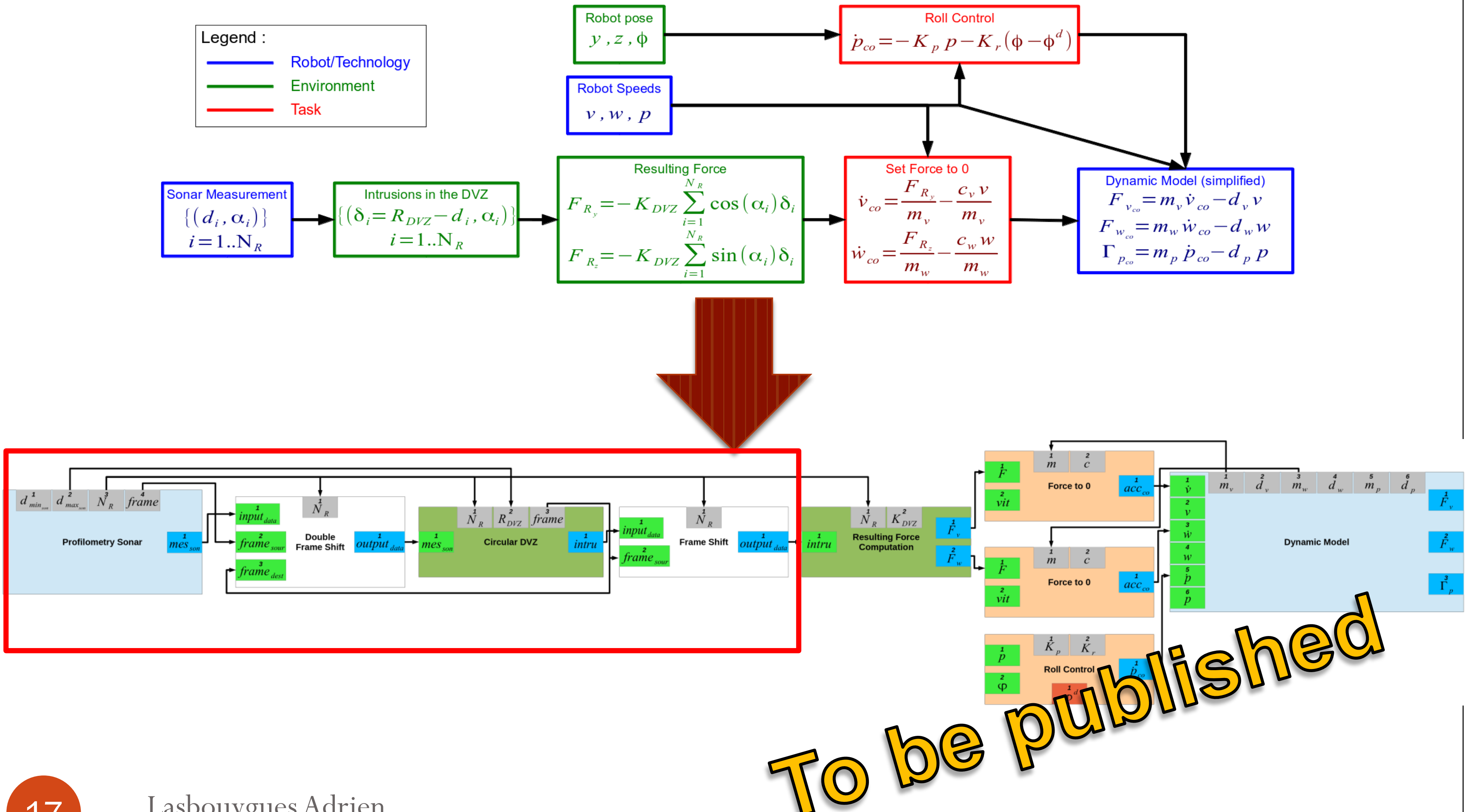
Atoms Composition



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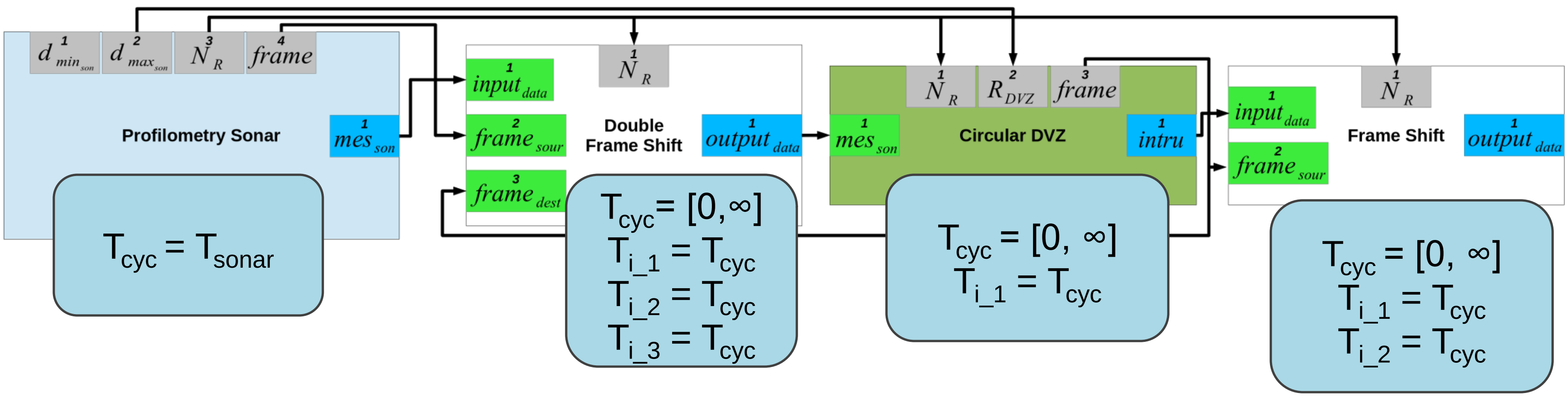

To be published

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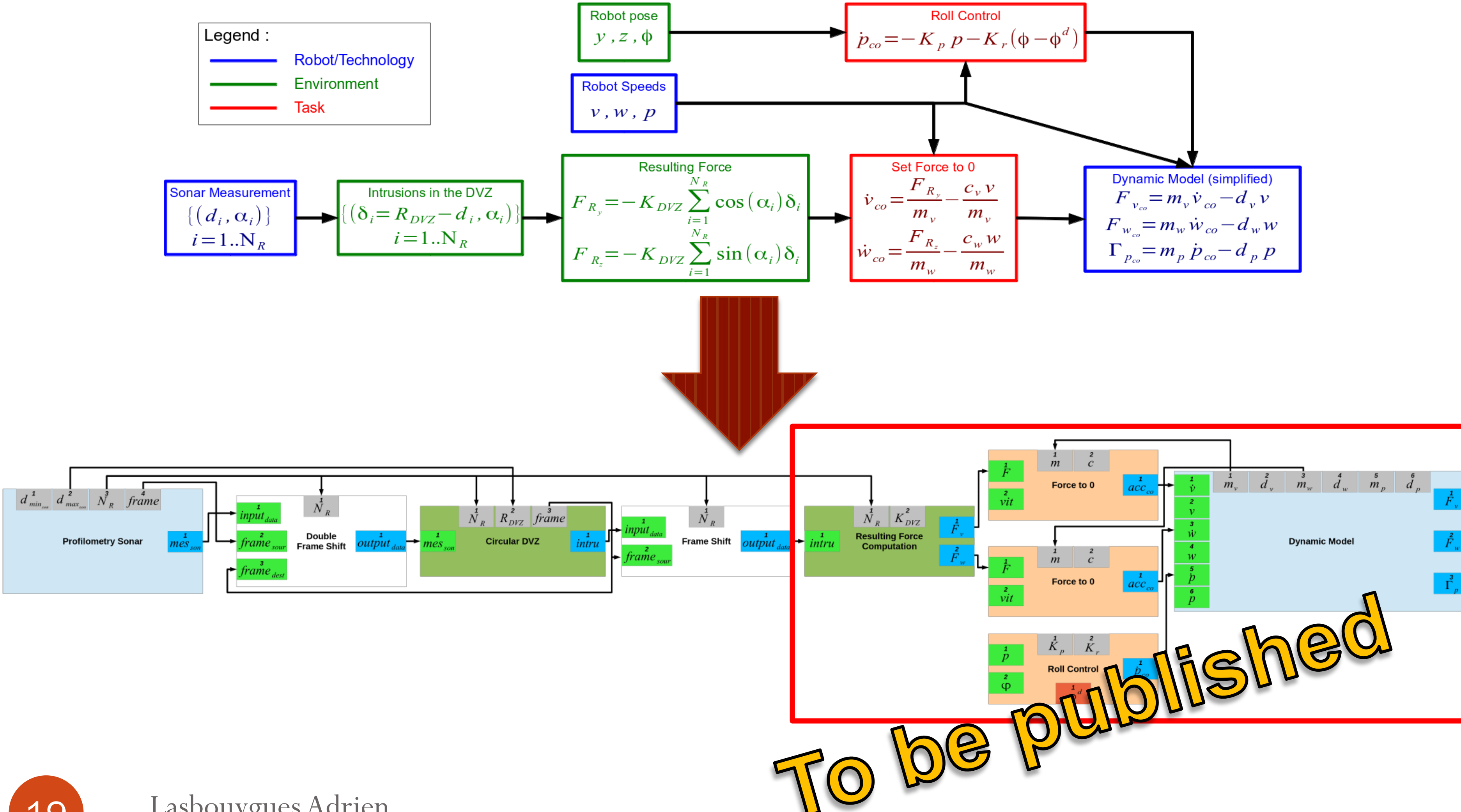
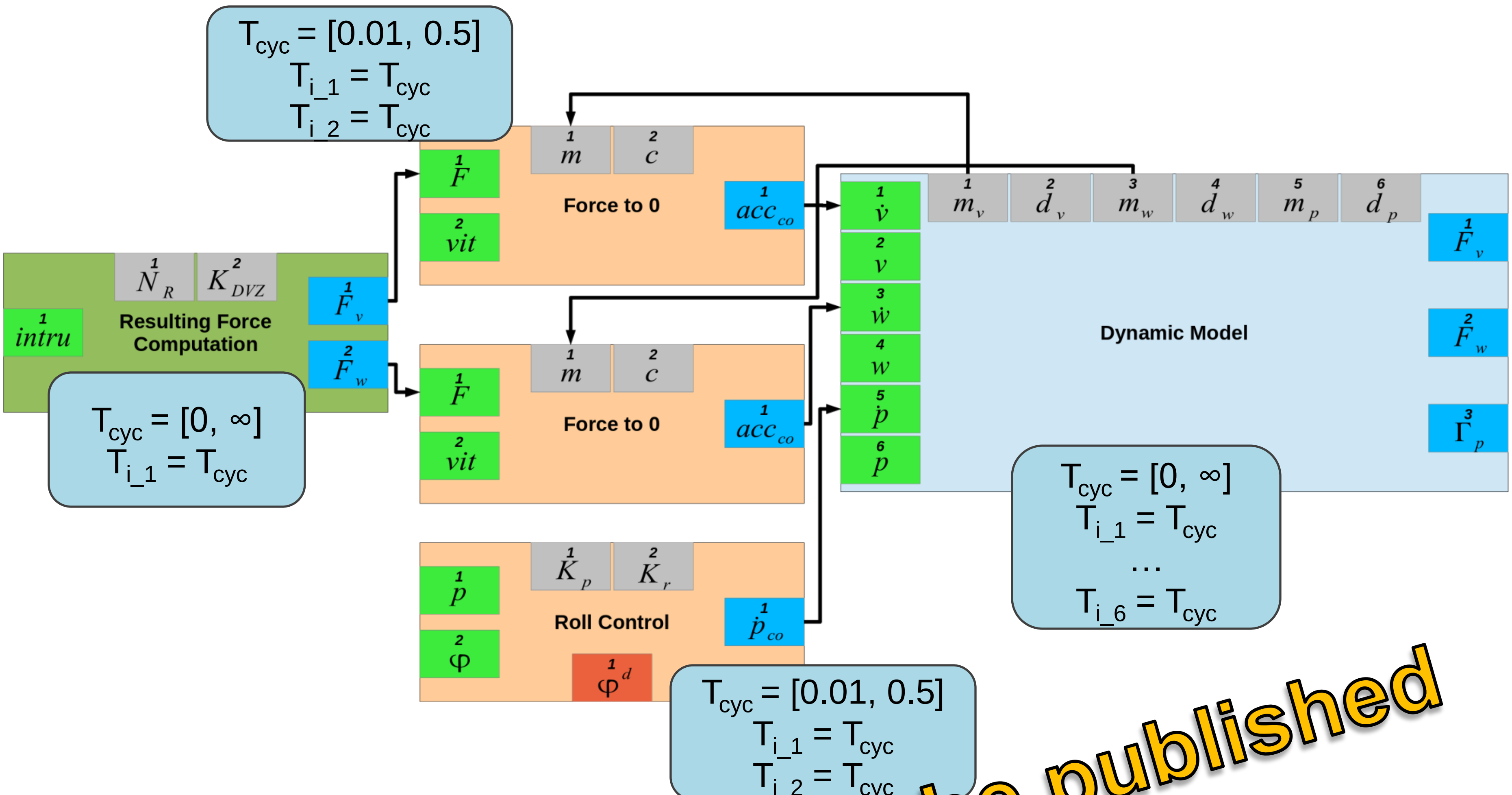


Atoms Composition



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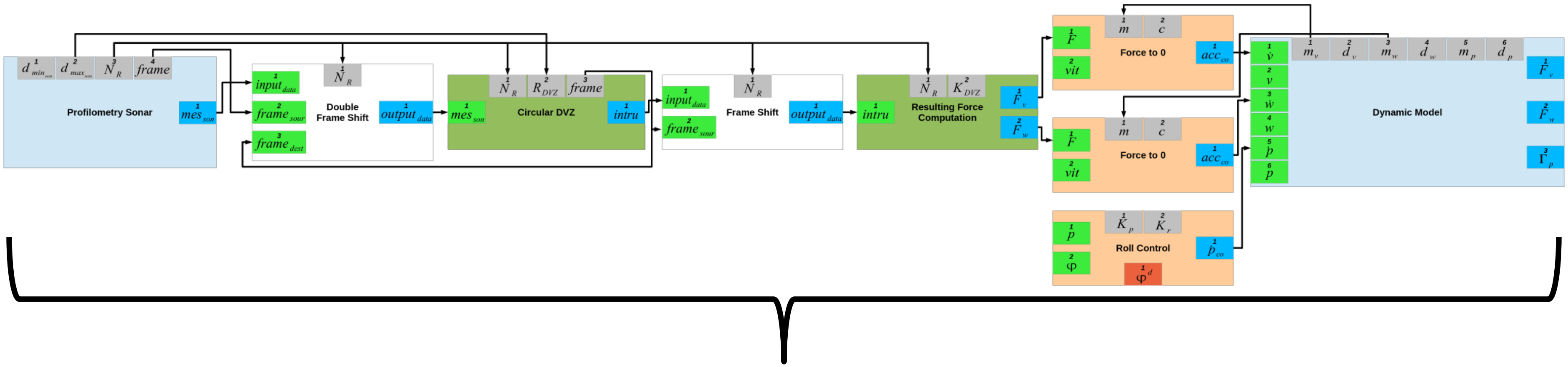
Composition constraints



$T_{cyc} = [0.01, 0.5] \cap T_{sonar}$

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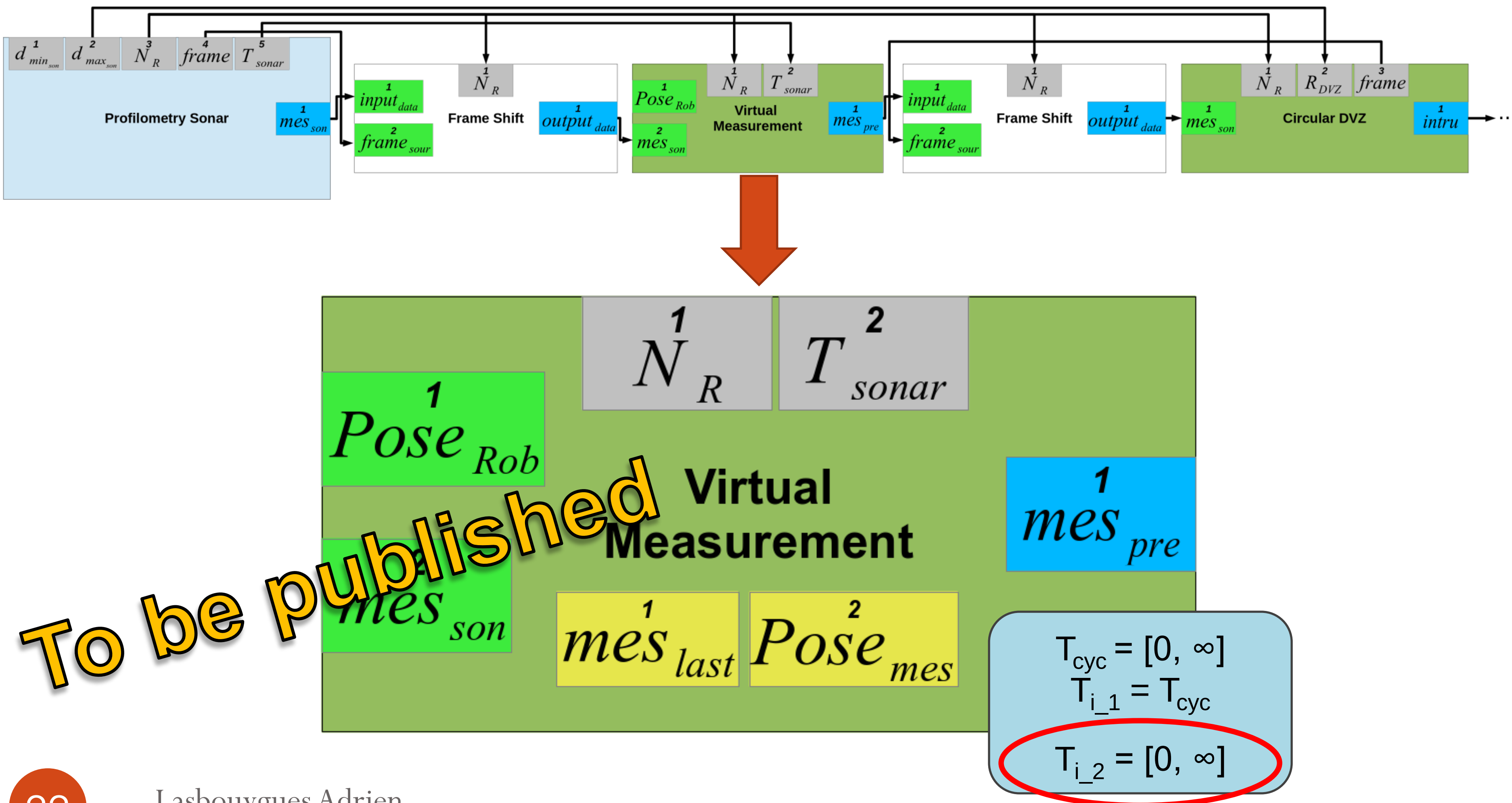
Implementation : $T_{sonar} = 4{,}5s$

NO INTERSECTION :

Implementation cannot respect stability constraints

Modification of the control



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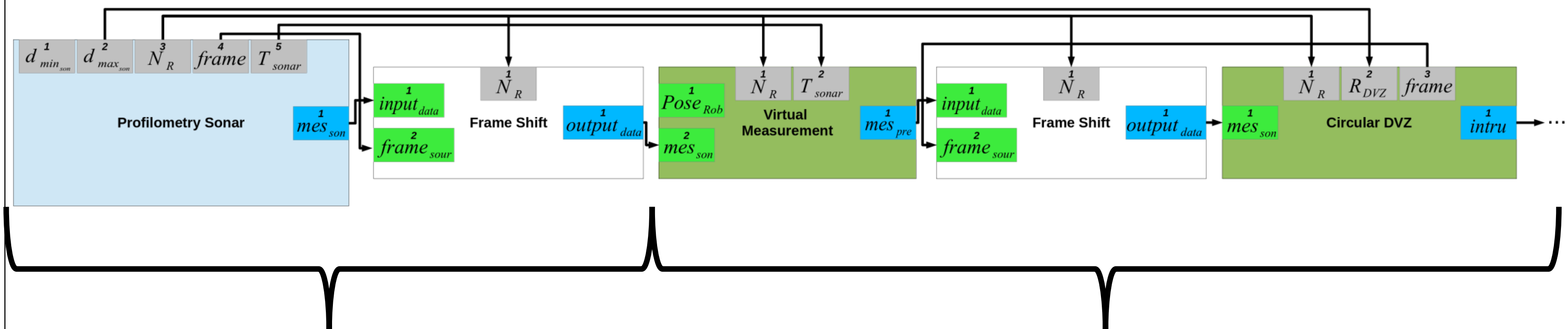
Modification of the control



$T_{cyc} = T_{sonar}$

$T_{cyc} = [0.01, 0.5]$

Implementation respect stability constraints

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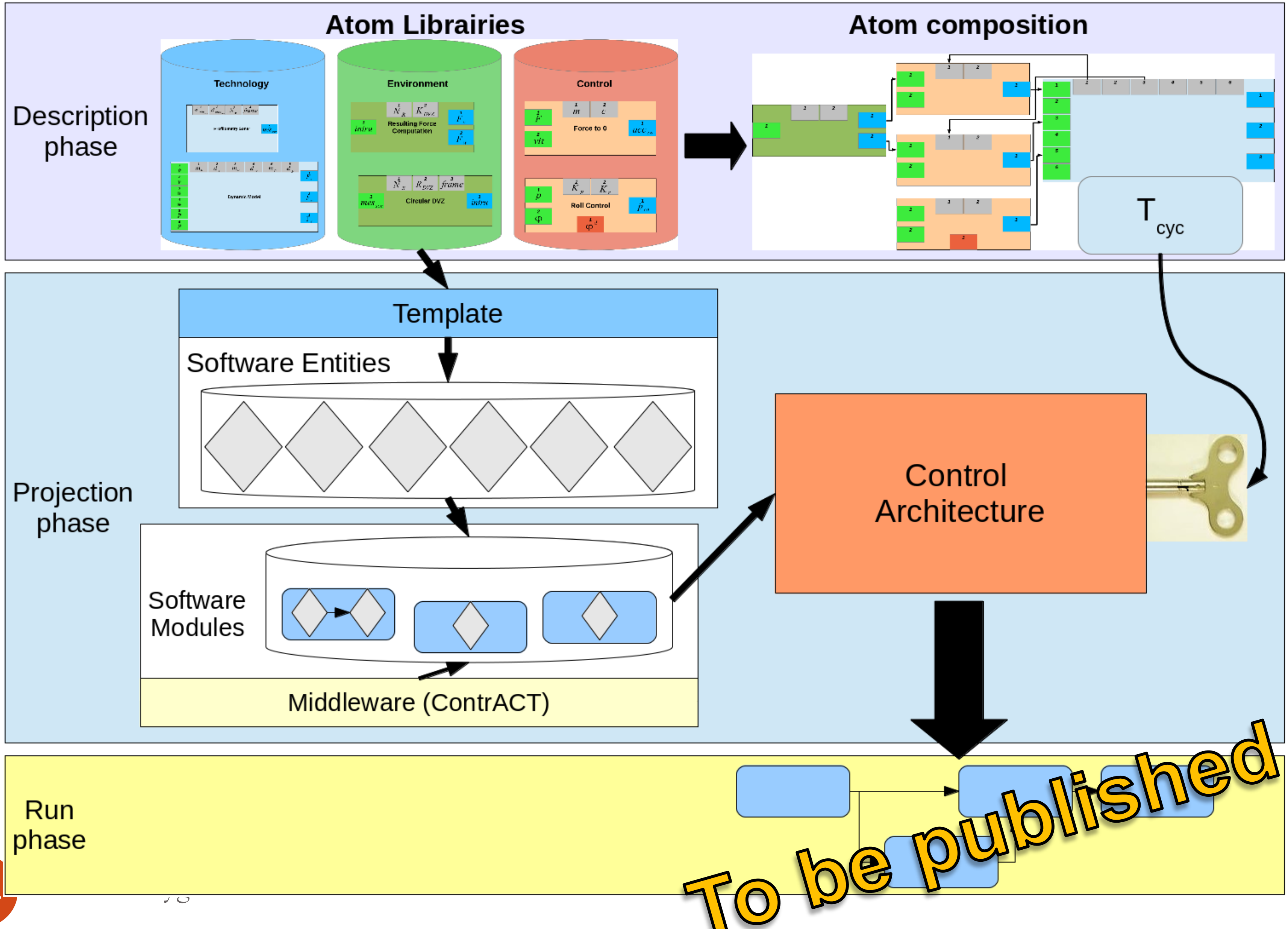
From description to implementation



Opening towards hybrid control

- How to describe control limit conditions ?
  - Representation
  - Alternatives / composition

- How to describe junction functions ?
  - Models

- How to manage constraints on commutation ?
  - Boundaries on commutation time
  - Boundaries on commutation frequency

Thank you for your attention