How does computational thinking help in interdisciplinary research: a journey from Mathematics to Bioengineering

Liu-Di LU

Matematikcentrums
Lunds Universitet

Interdisciplinary PhD Conference on Computational Thinking

March 19th, 2026

Personal background

Training:

- Bachelor: Mathematics
- Master: Mathematics and applications
- PhD thesis:

Lagrangian approaches for modelling and optimization of hydrodynamics–photosynthesis coupling

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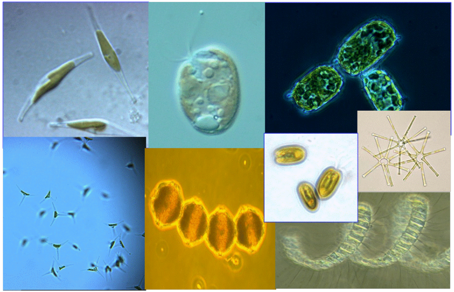
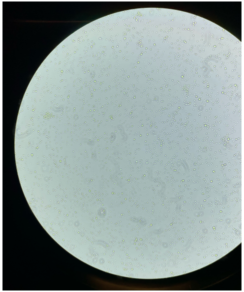
- PhD topic:

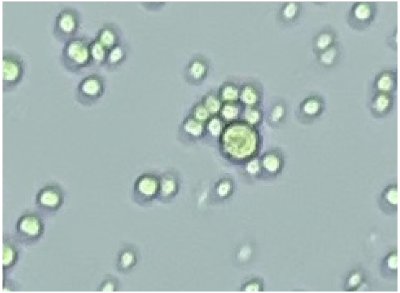
Modelling and optimizing industrial microalgae production processes

Microalgae (Phytoplankton)

Photosynthetic micro-organisms, 2-50 micrometers







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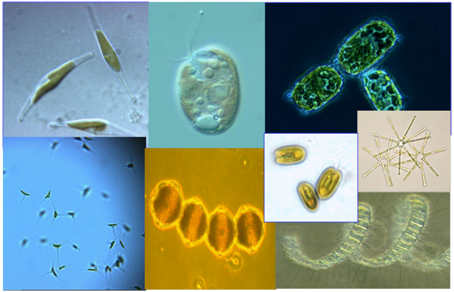
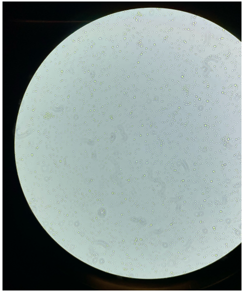
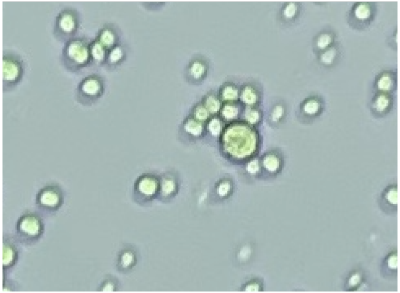

Natural aquatic environment: ocean, lake, river, backyard swimming pool

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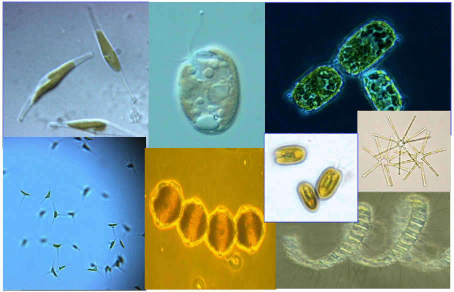

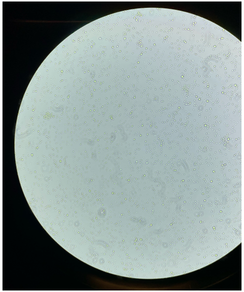

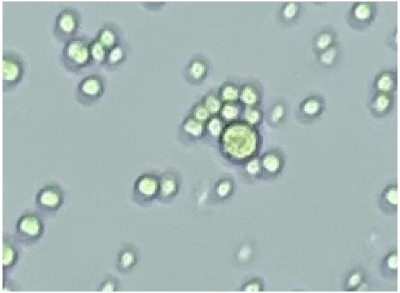

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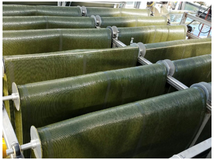
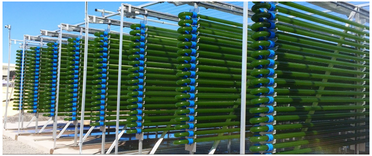
Purposes: wastewater treatment, biomass production, high-value secondary products (cosmetics, food complements, pharmaceuticals, etc)

Microaglae production

Photobioreactors:

- technology: rotating biofilm, chemostats, raceway pond, tubular, etc
- scale: lab / industrial
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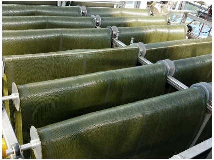   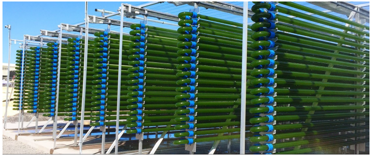

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- macro / micro levels
- light, temperature, nutrient, pH, etc
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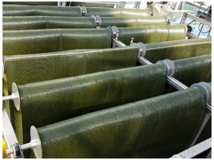


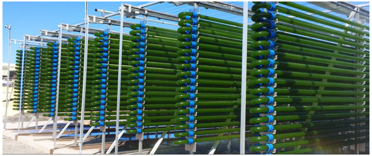

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Not a one-man job — Collaborations !

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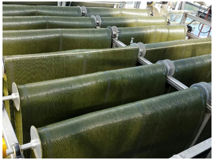


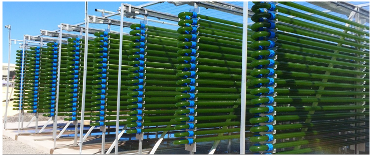

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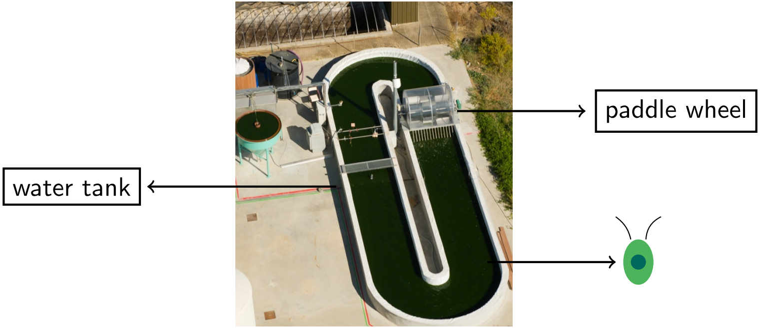
Optimize microalgae growth in raceway ponds



Raceway pond

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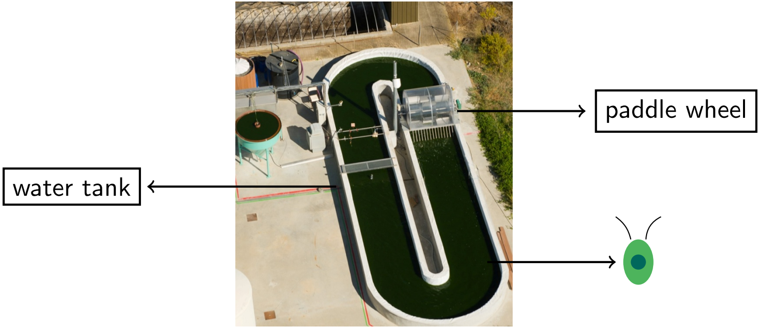
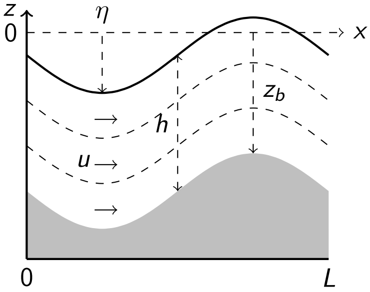


Raceway pond

Optimization strategies:

- Far from paddle wheel: optimize the "shape" of the **topography**
- Close to paddle wheel: optimize the **mixing**

- hydrodynamics: static Shallow water equations;

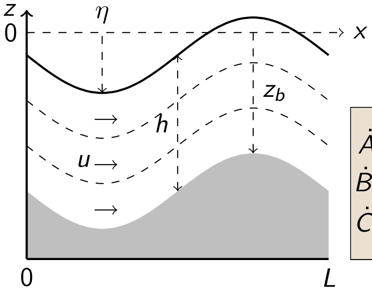


$$\partial_x hu = 0$$
$$\partial_x(hu^2 + g\frac{h^2}{2}) = -gh\partial_x z_b$$

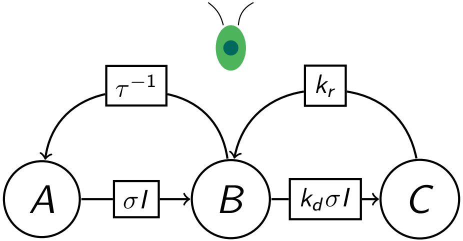
Raceway pond

Optimize topography in raceway ponds

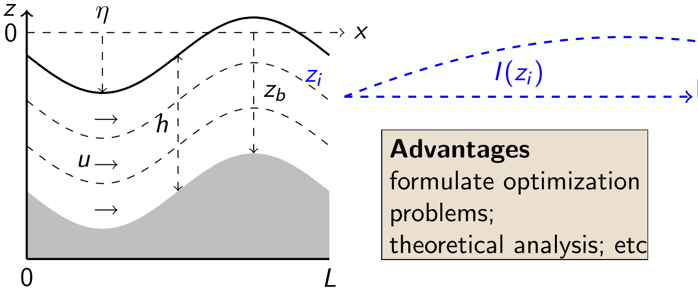
- hydrodynamics: static Shallow water equations;
- photosynthesis: Han dynamics accounts for photoinhibition.



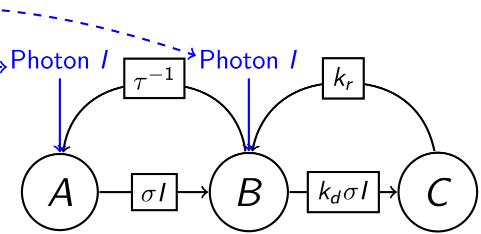
$$\dot{A} = -\sigma I A + \frac{B}{\tau}$$
$$\dot{B} = \sigma I A - \frac{B}{\tau} + k_r C - k_d \sigma I B$$
$$\dot{C} = -k_r C + k_d \sigma I B$$



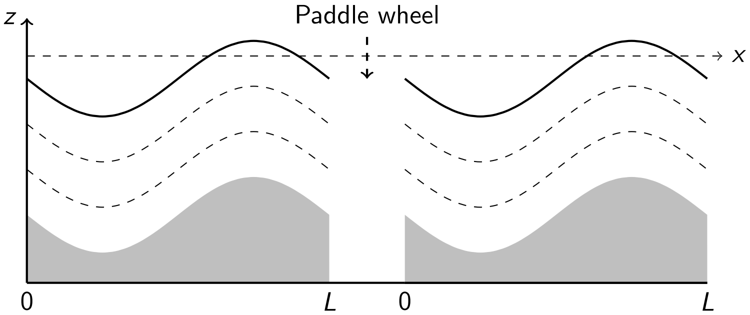
- hydrodynamics: static Shallow water equations;
- **coupling:** light intensity I from Lagrangian trajectoires z_i with radiative transfer models $I(z_i)$;
- photosynthesis: Han dynamics accounts for photoinhibition.



Advantages
formulate optimization problems;
theoretical analysis; etc



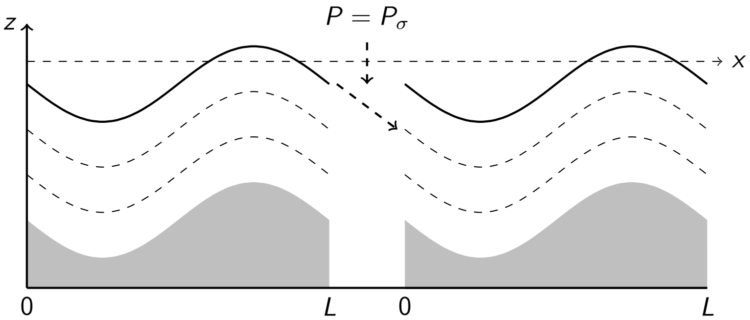
Optimize mixing in raceway ponds



Optimize mixing in raceway ponds

Idea: Model the paddle wheel by permutation matrices P

Example: A "paddle wheel" with permutation $\sigma = (1\,2\,3\,4)$



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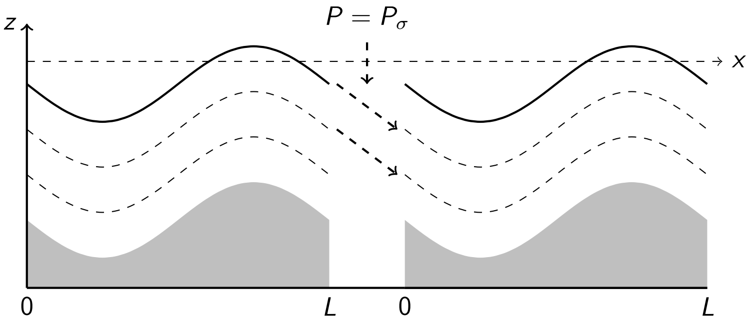

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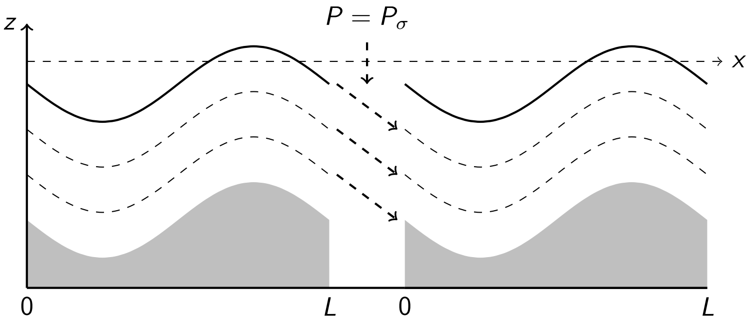

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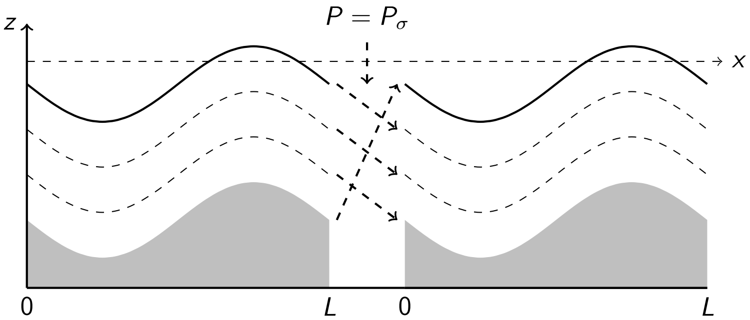
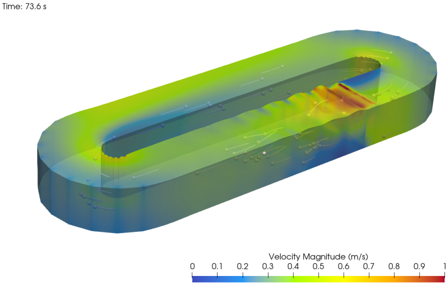
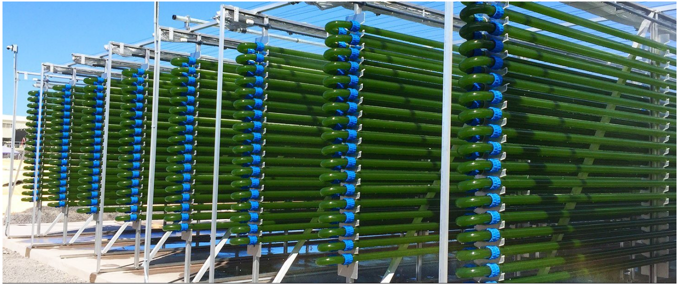


Test all combinations, $N!$ cases.

Conclusion





Conclusion

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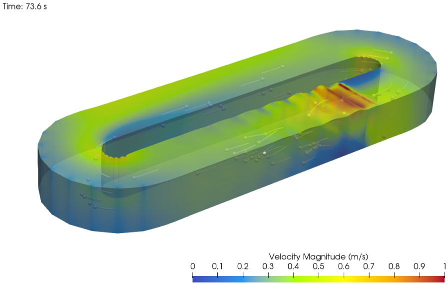

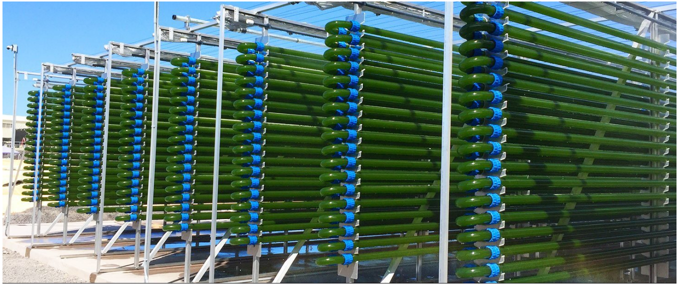

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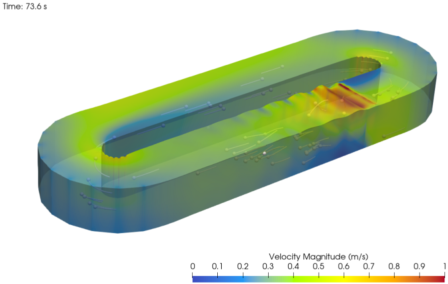

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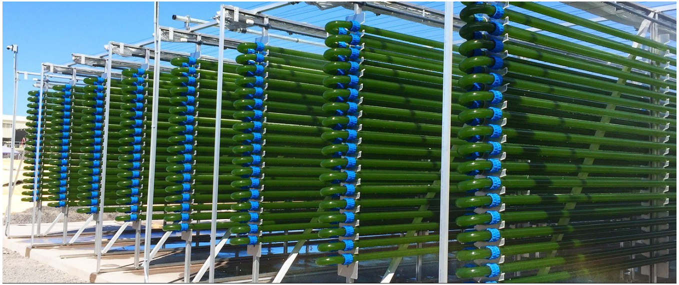
- Simplify the task
- Remove less relevant information
- Bring to your "comfort zone"
- Simple vocabulary, efficient bridge



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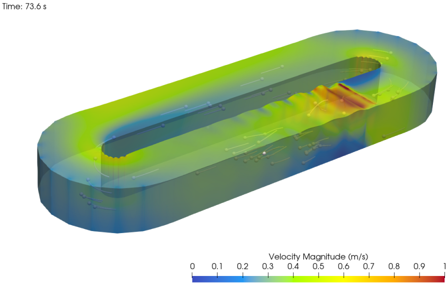

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Thank you for your attention !