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UNION EUROPÉENNE EUROPESE UNIE
GoToS3

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ALPO

Welcome to the Virtual workshop of the ALPO Project

biosciences
INSTITUT DE RECHERCHE EN BIOSCIENCES DE L'UMONS

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GoToS3

GoToS3
Catalyseur d'innovation
Katalysator van innovatie

GoToS3 : « For clever specializations »

17 projects

R & D (13)

SME competitivity development (4)

95 partners : research, technology transfer, accompaniment, competitivity clusters, ...

6 fields of **« S3 » common** to 3 regions

Health care

Agriculture and alimentation

Textile

Cultural and creative industries

Chemistry and new materials

Mechatronics and mechanical engineering

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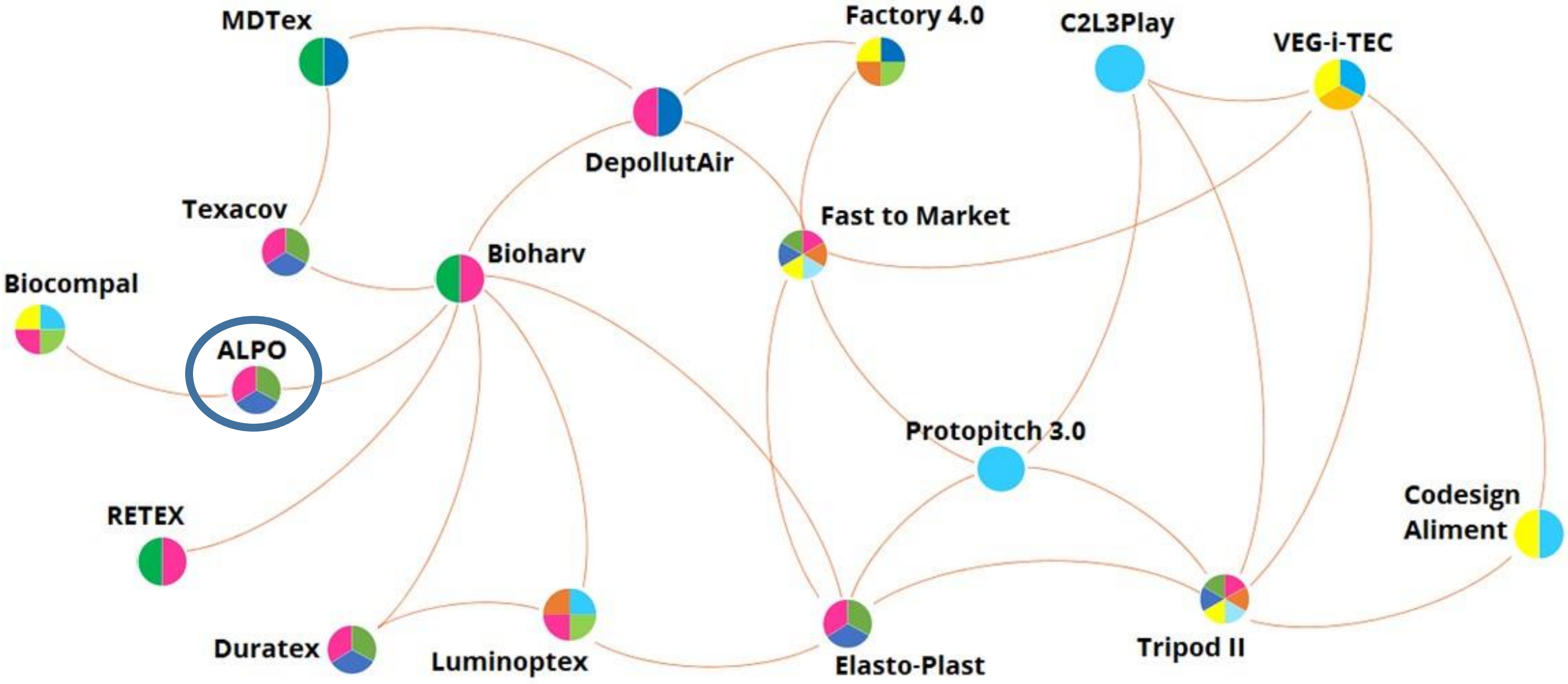

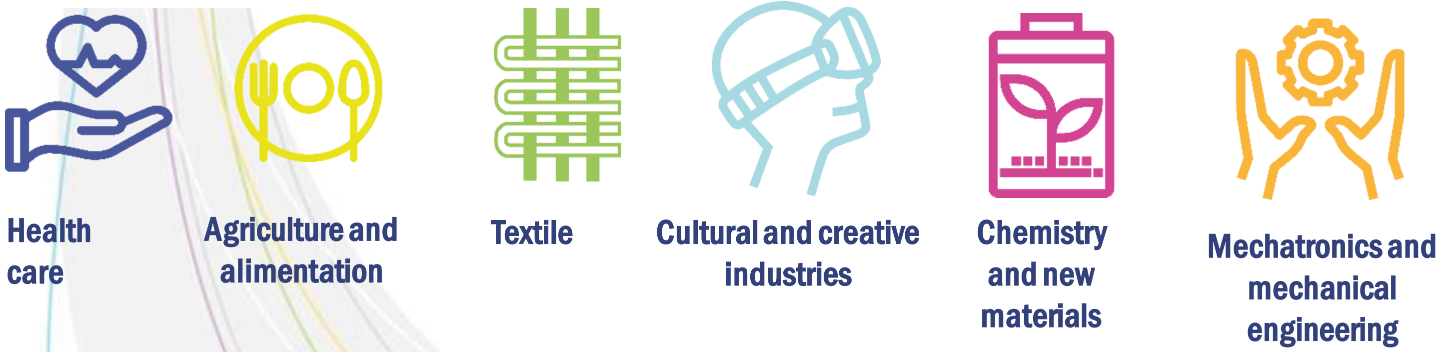

ALPO Project

Environmental and societal challenges (including global warming)

→ Use of renewable raw materials starts being generalized in the plastic field

→ New biodegradable plastic presenting interesting and well performing properties

Development is somewhat lagging in FWVL INTERREG

ALPO Project

Partners

- ✓ UMONS
- ✓ ULILLE
- ✓ UGent
- ✓ KULAK
- ✓ URCA
- ✓ AgroParisTech Innovation
- ✓ AQUIMER
- ✓ Euramaterials
- ✓ IAR
- ✓ POM West-Vlaanderen
- ✓ PCG asbl
- ✓ GreenWin

Budget

3.492.104 €

Contact UMONS

Research Institutes

matériaux
INSTITUT DE RECHERCHE EN SCIENCE ET INGENIERIE DES MATERIAUX DE L'UMONS

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Jean-Marie Raquez and Laurent Dewasme

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Dynamic optimization of continuous microalgae cultures

Laurent Dewasme
Systems, Estimation, Control and Optimization (SECO)

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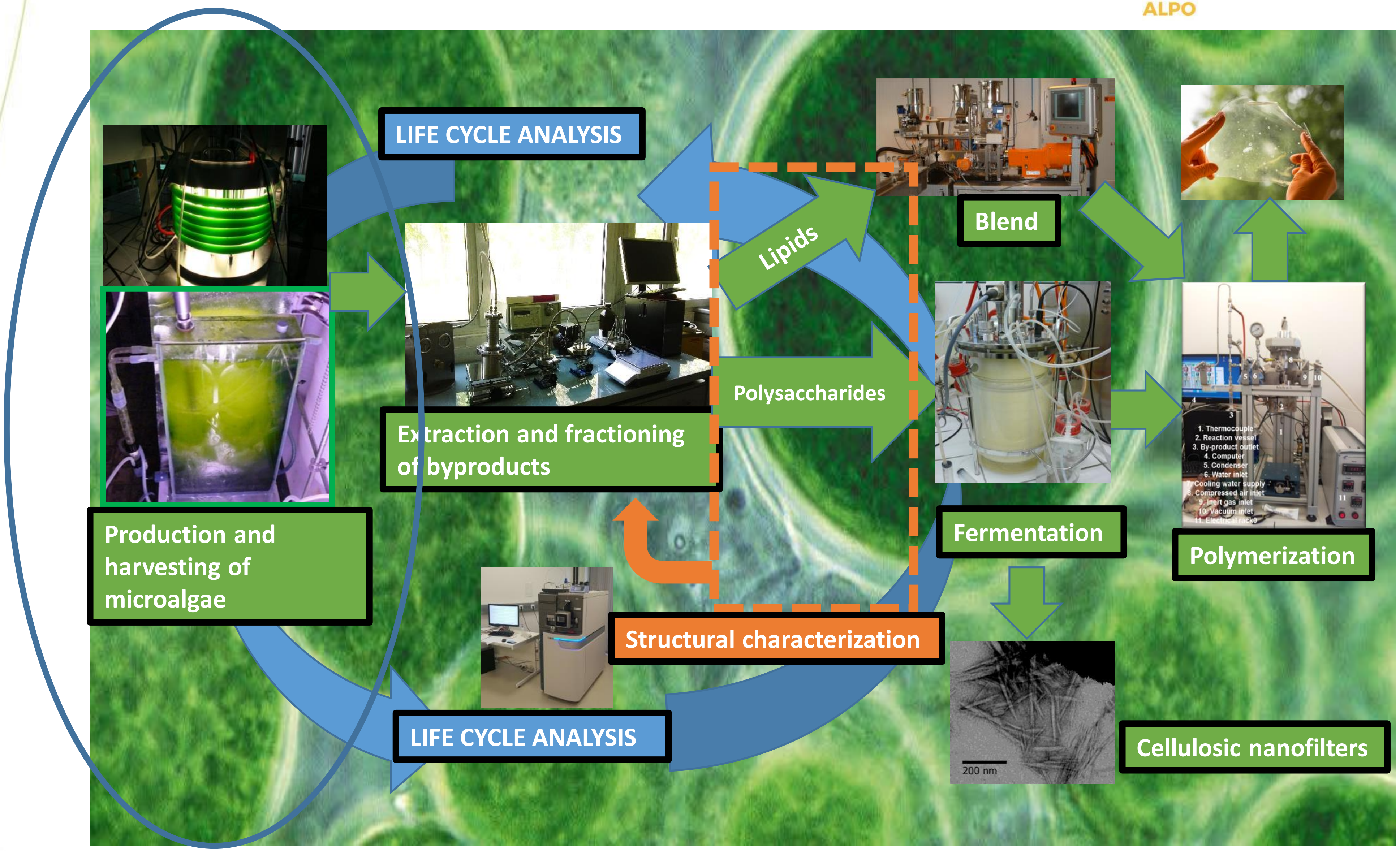

Outline

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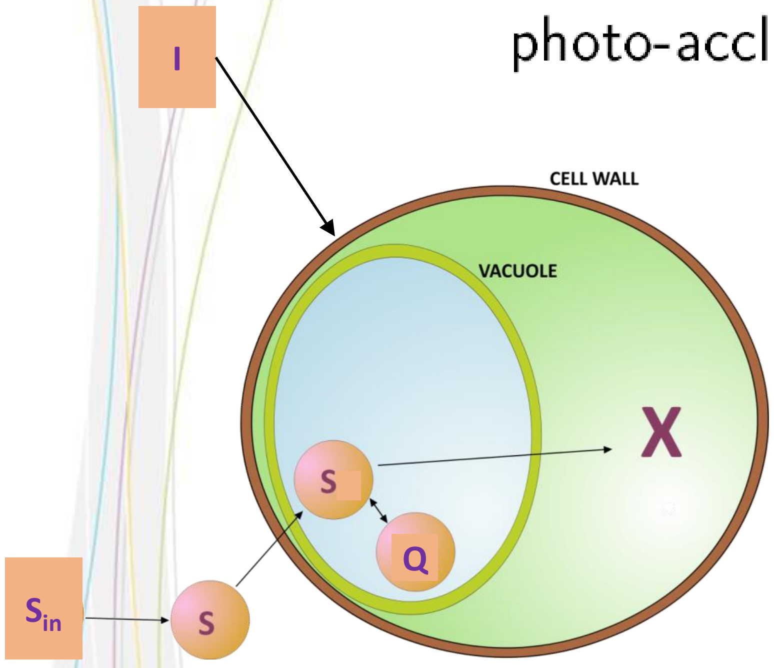
- Microalgae culture modeling
- Optimizing control – Extremum seeking
- Lab-scale validation
- Perpsectives

Microalgae culture modeling



(Bernard, 2011) discusses an extended Droop model (Droop, 1968) taking photo-acclimation and photo-inhibition into account:

$$\begin{cases} \frac{dX}{dt} = \mu X - DX - RX \\ \frac{dS}{dt} = -\rho X + D(S_{in} - S) \\ \frac{dQ}{dt} = \rho - \mu Q \\ \frac{dI^*}{dt} = \delta\mu(\bar{I} - I^*) \end{cases}$$

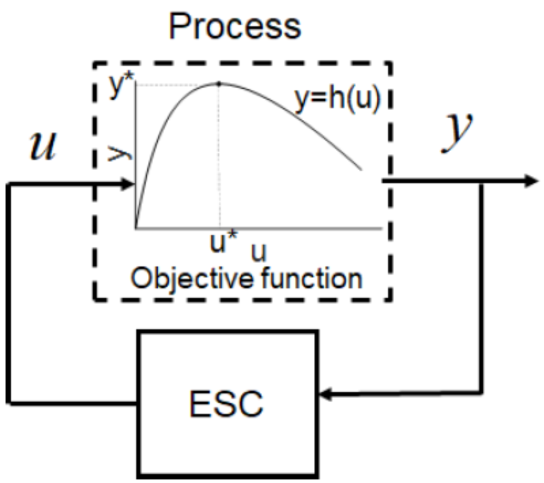
$$\rho(S, Q) = \rho_{max}\left(\frac{S}{K_S + S}\right)\left(1 - \frac{Q}{Q_{max}}\right)$$

$$\mu(Q, I, \theta) = \mu_{max}\frac{I}{K_{sI} + I + \left(\frac{I^2}{K_{iI}}\right)}\left(1 - \frac{Q_{min}}{Q}\right)$$

Optimizing control – Extremum seeking

- Real-time optimization (RTO):
  - Model parameter adaptation (Batch-to-batch)
  - Modifier adaptation (Gradient and constraint cost functions match with those of the plants)
  - ***Direct input adaptation (Extremum seeking)***

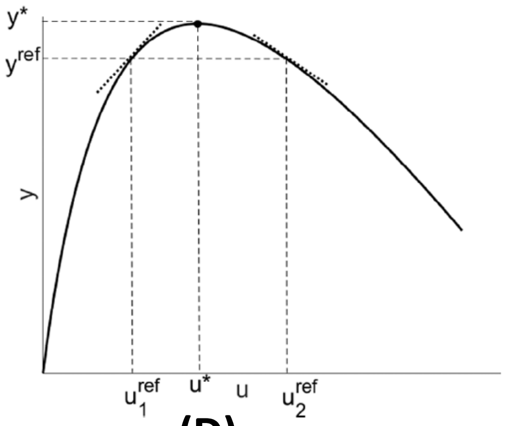
- Extremum seeking control
  - **Measurable** objective function
  - There exists an input *u* exponentially stabilizing the system to a steady-state **equilibrium**
  - The objective function is **convex** and unimodal



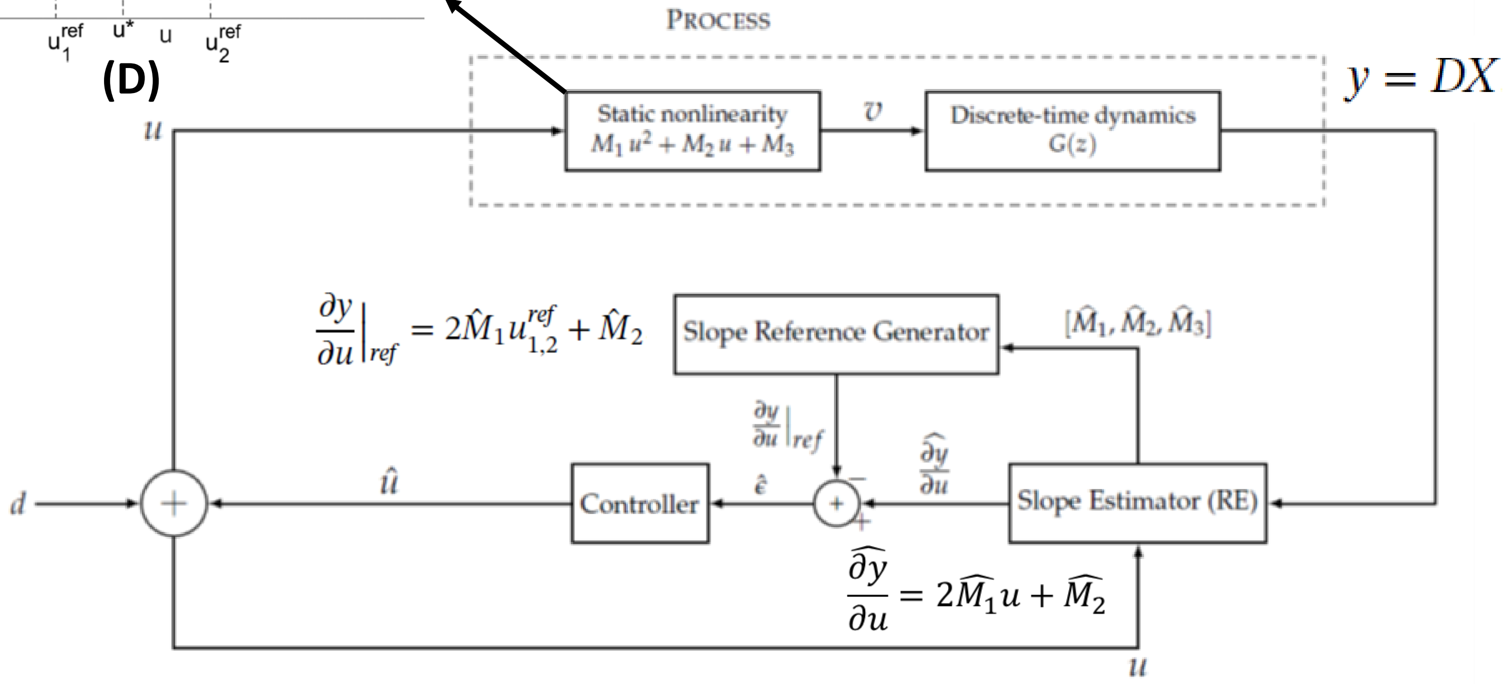
Optimizing control – Extremum seeking

- Goal: optimize the biomass production assuming:
  - ***Continuous process***
  - ***Convex static map***
  - ***Unimodal static map***
  - ***Stable neighborhood***

(P)

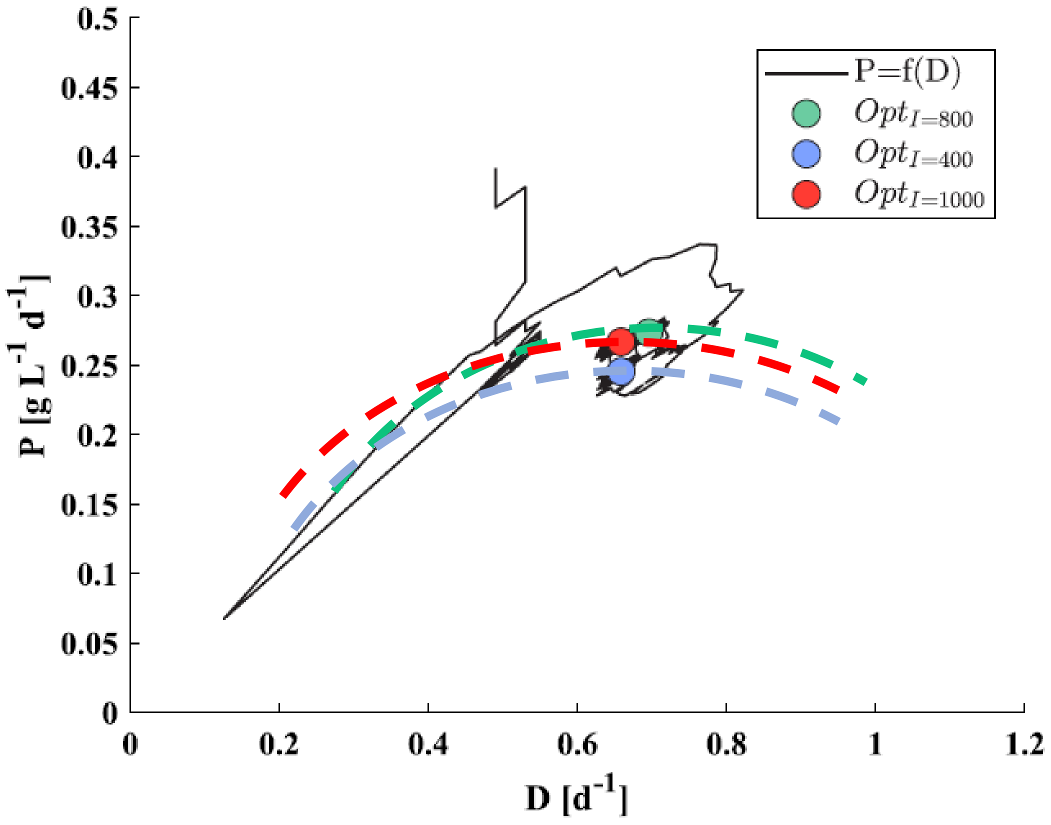


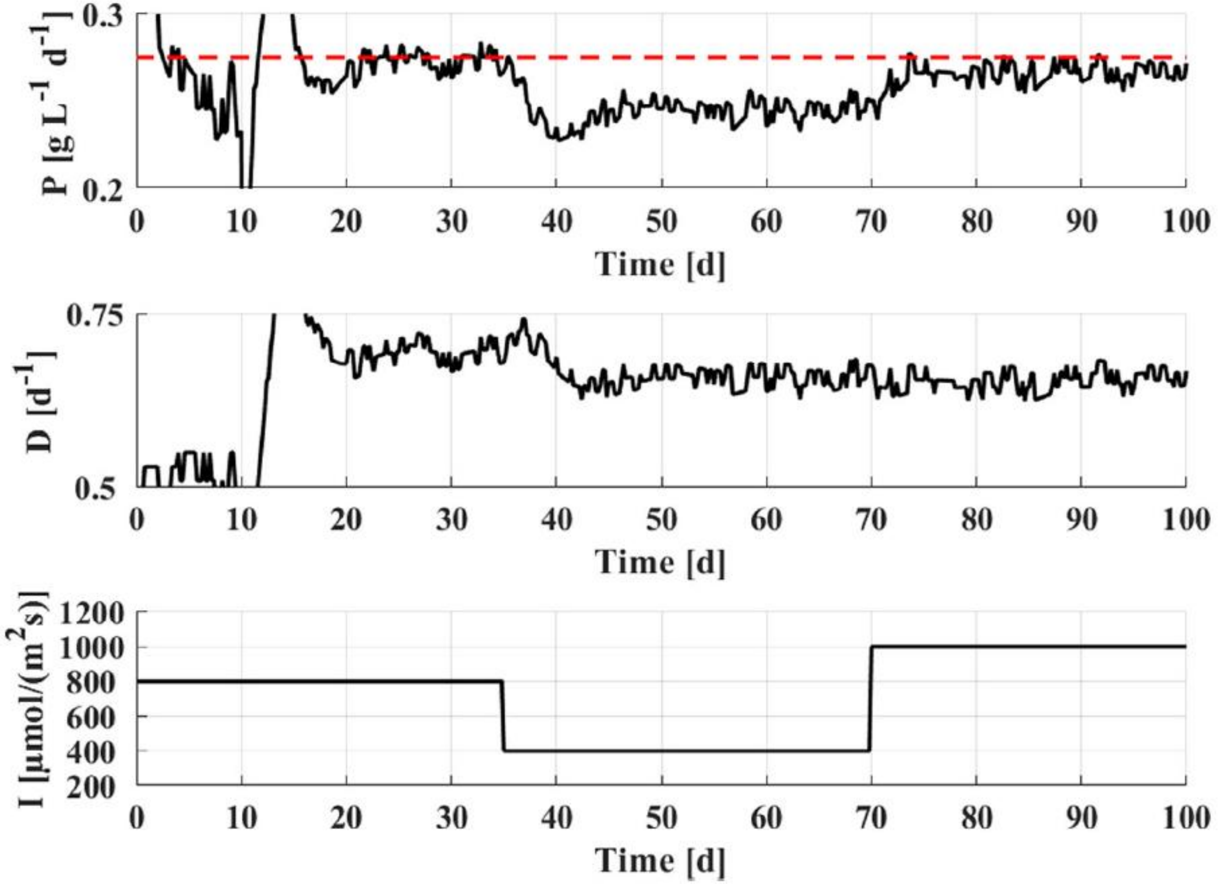
(D)



Optimizing control – Extremum seeking

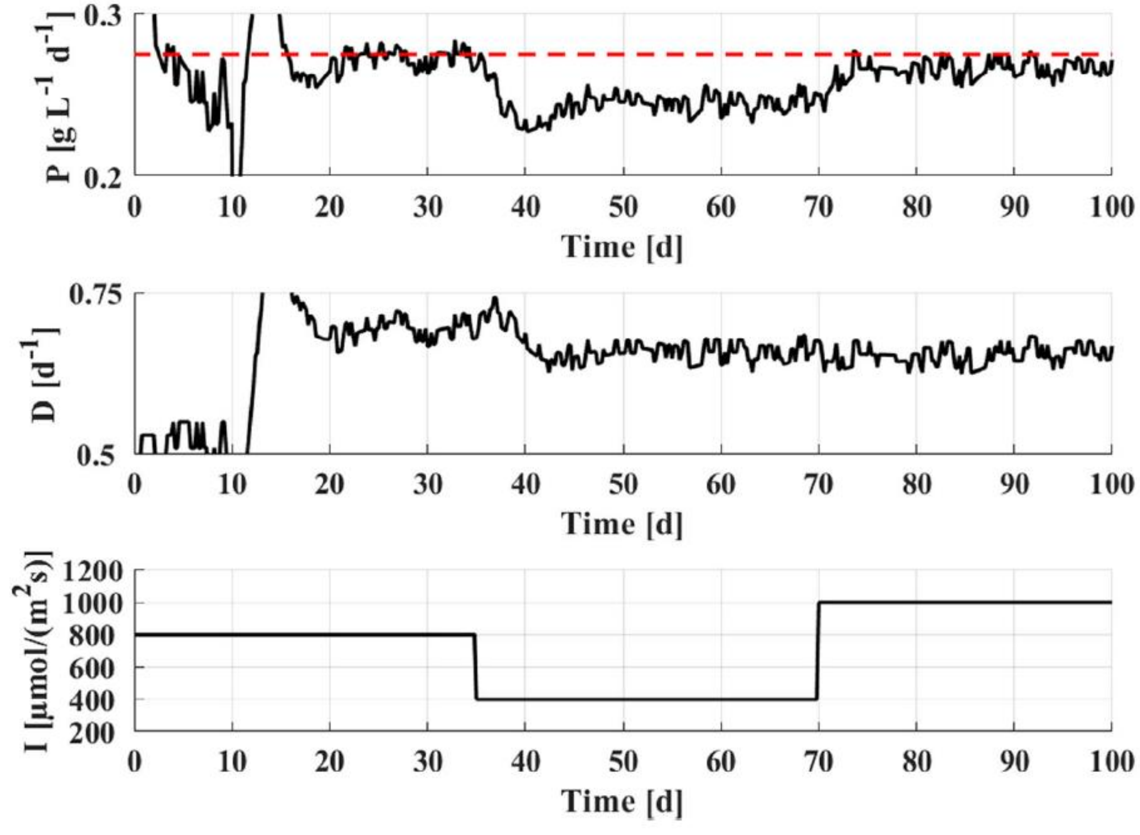
- Simulated experiments (*Scenedesmus obliquus*) applying light intensity changes (disturbance)



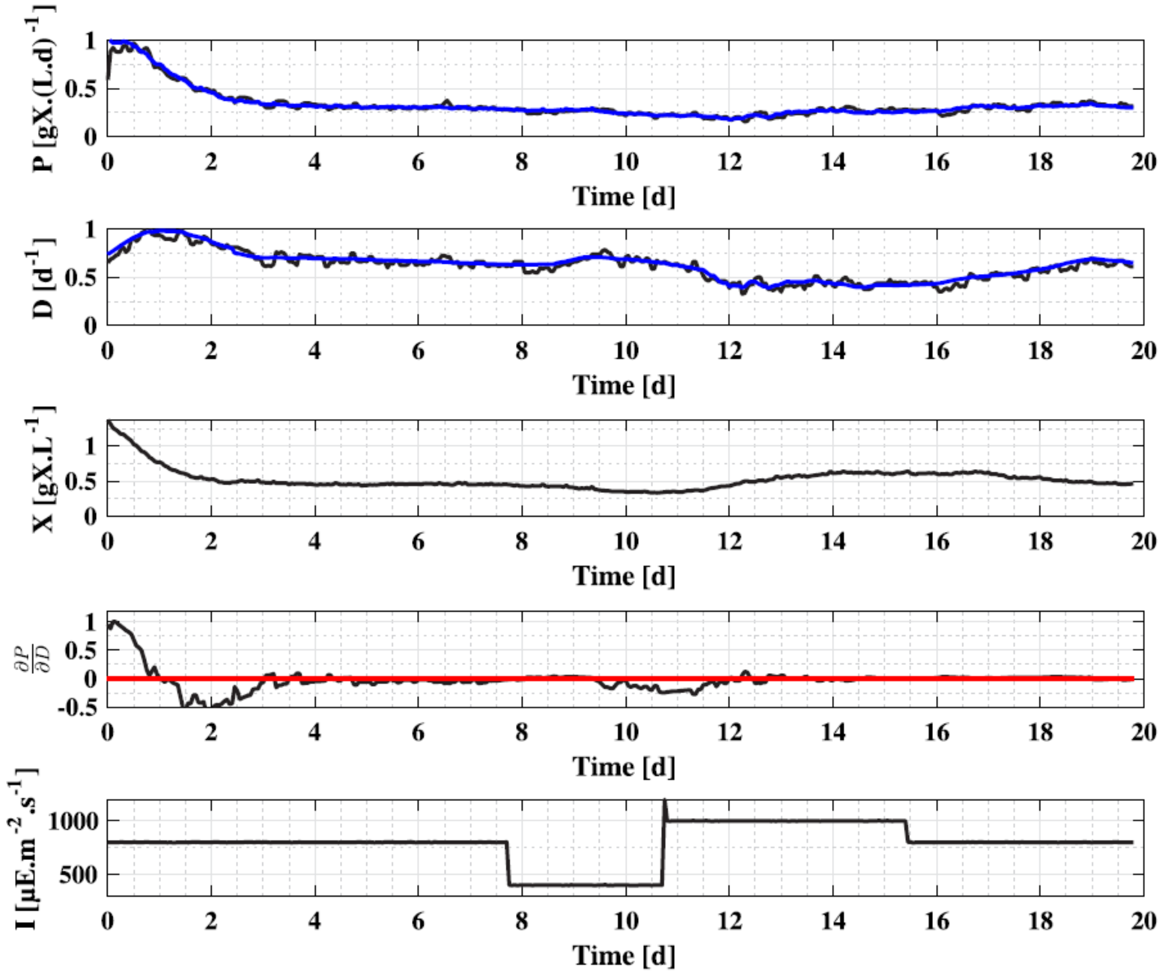


Optimizing control – Extremum seeking

- Experimental application (*Scenedesmus obliquus*) applying light intensity changes (disturbance)



Simulated experiment



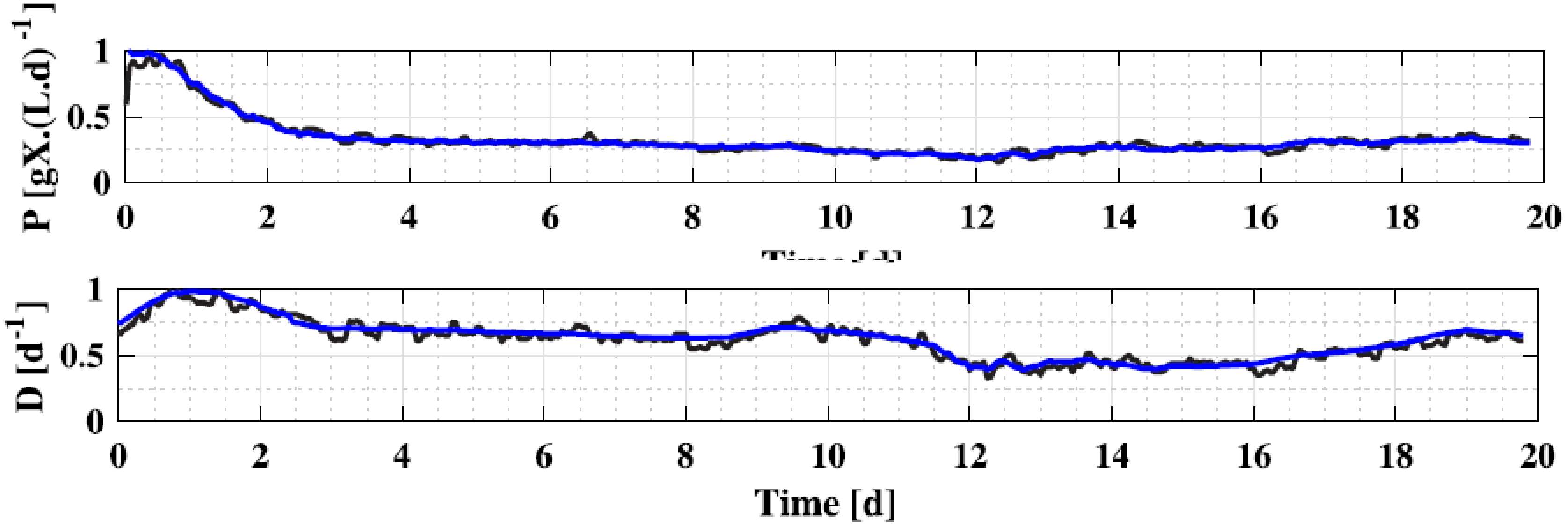
Experimental validation

Optimizing control – Extremum seeking

- Experimental application (*Scenedesmus obliquus*) applying light intensity changes (disturbance)

Max growth rate

Time period (d)	Light intensity (μ E m^{-2} s^{-1})	P (g L^{-1} d^{-1})	D (d^{-1})	X (g/L)	$\frac{D}{1-X}$
0 to 7.75	800	0.3	0.6	0.5	1.2
7.75 to 10.75	400	0.2	0.66	0.3	0.94
10.75 to 15.45	1000	0.25	0.4	0.65	1.14
15.45 to 19.75	800	0.3	0.6	0.5	1.2



Perspectives

- Optimizing control applied to microalgae cultures (ponds):
  - Convergence acceleration using Newton seeking or other recursive techniques (Max Likelihood ES);
  - Multivariable ES considering light intensity as a second input;
  - Application of nonlinear model predictive control (requires a well-identified model) to continuous/fed-batch cultures;
  - Other AI tools: neural controllers, software sensors, …

ALPO Project

Thank you for your attention!

Cofinanceurs
Medefinanciers

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