DII INFORMA

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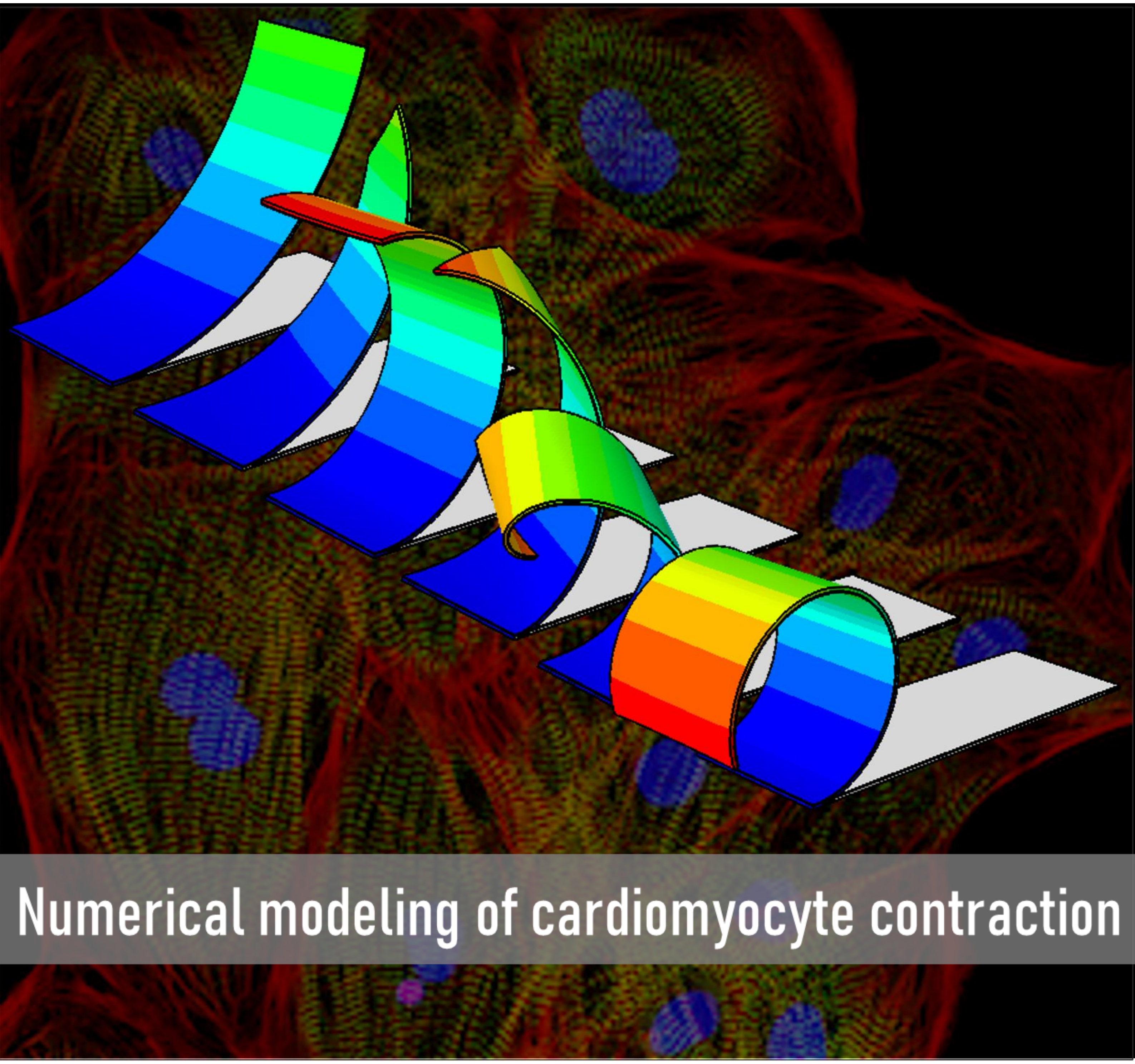
NEWSLETTER DEL DIPARTIMENTO DI INGEGNERIA INDUSTRIALE DELL'UNIVERSITÀ DEGLI STUDI DI PADOVA



Numerical modeling of cardiomyocyte contraction

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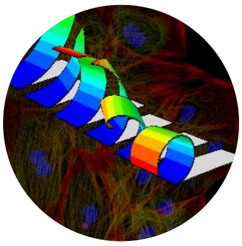

C O P E R T I N A

Modellazione numerica della contrazione dei cardiomiociti
Numerical modeling of cardiomyocyte contraction

PAGINA

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Il saluto del Direttore

Il Direttore Prof. Fabrizio Dughiero

Cari colleghi, care colleghe,
studenti, studentesse,
amici e personale tecnico amministrativo
del Dipartimento di Ingegneria Industriale,

con grande gioia e orgoglio celebriamo oggi il decimo anniversario della pubblicazione della nostra rivista, DIInforma. Nel 2014 abbiamo intrapreso un percorso per migliorare la comunicazione e la collaborazione all'interno del nostro dipartimento e per condividere con il mondo esterno la vitalità scientifica e didattica del nostro istituto.

In questi anni, DIInforma è diventato uno strumento fondamentale per diffondere le nostre ricerche innovative e grazie al quale abbiamo potuto valorizzare il lavoro di dottorandi, ricercatori e docenti, contribuendo alla crescita professionale e al rafforzamento della nostra comunità accademica.

Ricordo le pubblicazioni iniziali, in cui abbiamo presentato i primi contributi dei gruppi di ricerca, i risultati del lavoro di studenti e studentesse, dottorandi e assegnisti e la presentazione dei nostri corsi di laurea. Da allora, DIInforma si è evoluto, presentando una vasta gamma di tematiche che spaziano dall'ingegneria dei sistemi meccanici ed elettrici alla bioingegneria e biotecnologia, dai materiali avanzati alla mobilità sicura e sostenibile.

Guardando al futuro, ci attendono sfide e opportunità straordinarie. L'intelligenza artificiale (AI) sta trasformando rapidamente ogni aspetto della nostra vita, dalla sanità all'industria, dall'istruzione alla mobilità. Il nostro Dipartimento è determinato a rimanere all'avanguardia, riconoscendo il ruolo cruciale dell'AI nel migliorare la qualità della vita delle persone e rendere i processi industriali più efficienti e sostenibili.

Le innovazioni tecnologiche svolgeranno un ruolo chiave anche nella lotta contro il cambiamento climatico; siamo consapevoli della responsabilità che abbiamo nei confronti del pianeta e delle generazioni future. Attraverso la ricerca su energie rinnovabili, materiali sostenibili e processi industriali a basso impatto ambientale, il nostro Dipartimento continuerà a contribuire attivamente alla mitigazione degli effetti del cambiamento climatico.

Anche le sfide in termini di salute pubblica sono una nostra priorità. Le recenti pandemie hanno evidenziato l'importanza di tecnologie avanzate per la prevenzione, diagnosi e trattamento delle malattie. L'ingegneria biomedica e le biotecnologie rappresentano settori chiave nei quali intendiamo investire ulteriormente, per sviluppare soluzioni innovative che possano migliorare la salute e il benessere della società.

Infine, la space economy: le tecnologie spaziali non solo stanno rendendo l'esplorazione dello spazio più accessibile, ma stanno anche creando nuove opportunità per applicazioni terrestri, dalla comunicazione alla gestione delle risorse naturali. Il nostro Dipartimento è entusiasta di esplorare queste nuove frontiere e di contribuire allo sviluppo di tecnologie che possano espandere le capacità umane nello spazio e migliorare la vita sulla Terra.

Questo anniversario non è solo un momento di riflessione sul passato, ma anche un'opportunità per guardare al futuro con rinnovato entusiasmo e interesse. Continueremo a promuovere l'eccellenza nella ricerca, nella formazione e nella terza missione, mantenendo sempre alta l'attenzione alla valorizzazione dei giovani e alla collaborazione interdisciplinare.

Ringrazio tutti voi, membri del Dipartimento, per il vostro impegno e la vostra dedizione. Un ringraziamento particolare va a tutti coloro che hanno contribuito in questi anni alla redazione e alla diffusione di DIInforma, rendendola una pubblicazione di qualità e di estremo interesse.

Un saluto,

Fabrizio Dughiero

Bioingegneria, biotecnologia e tecnologie per la salute

Bioengineering, biotechnology and health technologies

DII research groups

Chemical bioengineering

Mechanical bioengineering

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The research has been carried out in collaboration with the Department of Cardiac, Thoracic and Vascular Sciences of the University of Padua (Prof. Gino Gerosa)

Main research topics:

- Biomaterials
- Biomedical devices
- Mechanical behavior of biological tissues
- Computational biomechanics

In vitro and *in vivo* assessment of hybrid membranes for vascular applications

Synthetic grafts, e.g. polytetrafluoroethylene and polyethylene terephthalate, and chemically treated biological tissues, such as glutaraldehyde-fixed pericardium, are used to overcome the limitations of autologous vascular substitutes. These materials possess adequate features in terms of impermeability and deformability, but present the chronic risk of infection, thrombogenicity, and intimal hyperplasia formation; moreover, they are non-viable and they cannot be endothelialized in vivo; they are not prone to remodeling and regeneration, thus hampering the process of integration with the recipient's organism. The decellularization procedure offers a new approach to minimize these drawbacks: it removes nuclear and cellular components from biological tissues, but preserve their original extracellular matrix. Thus, the acellular scaffold is prone to be repopulated by patient's own cells and can integrate with the host's body. To improve mechanical resistance, impermeability and patency of decellularized tissues, hybrid membranes (HYMEs) were produced by coupling decellularized porcine pericardium (DPP) with a polycarbonate urethane (Chronoflex AR, with and without silica microparticles). HYMEs were assessed in vitro by direct contact test with HUVECs; biocompatibility was preliminarily investigated in vivo in the rat model. Experiments were carried out as stated in authorization No. 782/2021-PR (protocol number 965E9.41) and animal were treated following the UNI EN ISO 10993-2.

In vitro, HYMEs did not cause any cytotoxic effect and were able to promote cell proliferation 7 days after seeding (Fig. 1). In vivo, HYMEs showed neither inflammation nor rejection, allowing a perfect wound healing (Fig. 2A), and integrated with the host organism without polymer degradation (Fig. 2B). These preliminary results are encouraging but further investigations are required to evaluate eventual calcification and to assess their ability to properly interact with blood under physiological pressures.

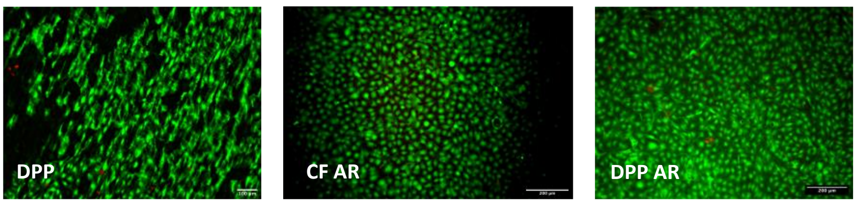


Figure 1. Live and Dead assay 7 days from seeding on decellularized pericardium (DPP), on the polymer (CF AR) and on the HYME (DPP AR).

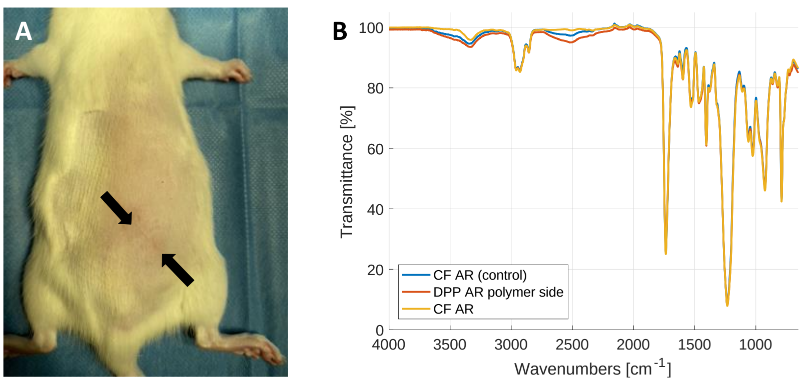


Figure 2. A) rat's back 4 weeks after implantation: arrows indicate the surgical wound; B) FTIR-ATR spectra of CF AR and DPP AR (polymer side).

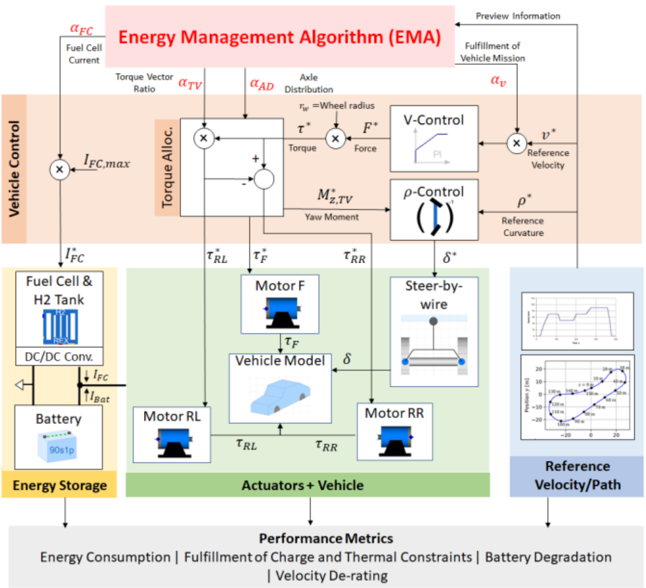
VTS Motor Vehicle Challenge 2023: The Winning Multi-physical Energy Management Algorithm

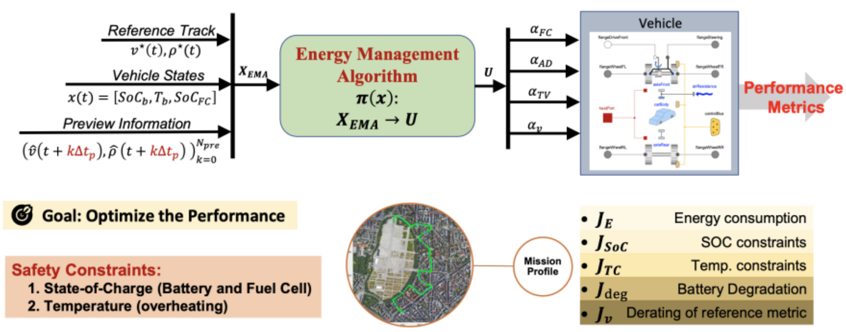
The IEEE Vehicular Technology Society (VTS) Challenge is an annual competition that aims to promote innovation in the field of vehicular technology since 2016. In recent years, the competition has grown, proposing increasingly challenging problems based on the design and optimization of an energy management system of a hybrid vehicle.

The topic of this year's edition was the optimization of a set of parameters which control the energy management system of a vehicle with multiple energy sources and electric motors. The vehicle was characterized by two in-wheel electric motors installed in the rear axle and one central front motor and was powered by a hybrid energy storage system with a fuel cell and battery.

Energy consumption, battery degradation, safety constraints and derating of the vehicle performance are the main metrics of the given cost function to be minimized. The developed algorithm aims at increasing vehicle range and enhancing performance. Torque vectoring control was also exploited.

The algorithm was validated with an extensive simulation stage. Different driving cycles which contain typical operating conditions for the vehicle were used. The effectiveness of the proposed approach is further corroborated by winning the IEEE VTS Motor Vehicle Challenge 2023.





Sistemi elettrici

Electrical systems

DII research group

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https://github.com/DLR-VSDC/IEEE-MVC-2023

Main research topics:

- Control of electric drives
- Control of grid connected converters
- Design of electric machines
- Vehicle and machinery electrification

Bioingegneria, biotecnologia e tecnologie per la salute

Bioengineering, biotechnology and health technologies

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PARLAB

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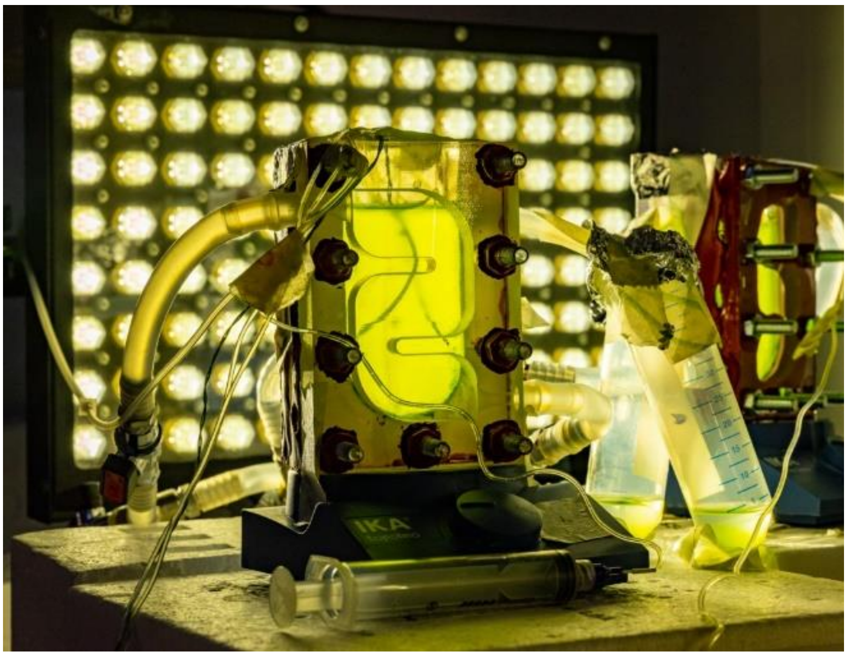
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 955520 "DigitAlgaesation".

Main research topics:

- Microalgae cultivation processes
- Bioprocess design and optimization
- Mathematical modelling
- Photosynthesis
- Sustainable production

Combined effect of temperature and light intensity on microalgae growth in small scale photobioreactors

Temperature and light intensity are the main factors affecting microalgae growth in unlimited nutrient conditions. Quantifying their effects and interaction is essential to the design and optimization of sustainable large-scale production of microalgae. Typically, temperature and light intensity are described as two independent factors – however, a weak coupling between the two variables can be observed at low light intensities, while limited data about the joint effect of temperature and light intensity are available under photoinhibiting light intensities. Decreasing the scale of photobioreactors (PBRs) can accelerate the process of data acquisition while easing the control of the manipulated variables and reducing the experimental effort, while working in continuous reactors allows the acclimation of microalgae to the set operating conditions. In this work, two milli-PBRs with a working volume of 45 mL and a thickness of 15 mm have been exploited to study the potential correlation between temperature and light intensity on microalgae growth with the strain Acutodesmus obliquus. The interactions between light and temperature were observed at steady state and both limiting and saturating light levels were applied to assess their combined effect with temperature. Experimental results showed that temperature has an effect on the level of light intensity at which light-saturation conditions are reached. Under light-limited conditions, the rate of photon supply is the limiting factor for photosynthesis rate, which is considered to be independent of temperature. However, for light-saturated conditions, the threshold for light saturation depends on the rate of dark reactions, which are dependent on temperature. A new modelling approach that accounts for the interaction of these two variables is being investigated to predict in a more accurate way microalgal biomass production in continuous systems for a broader range of light and temperature conditions. The results pave the way to the possibility of optimizing light and temperature conditions for industrial microalgae biomass production.



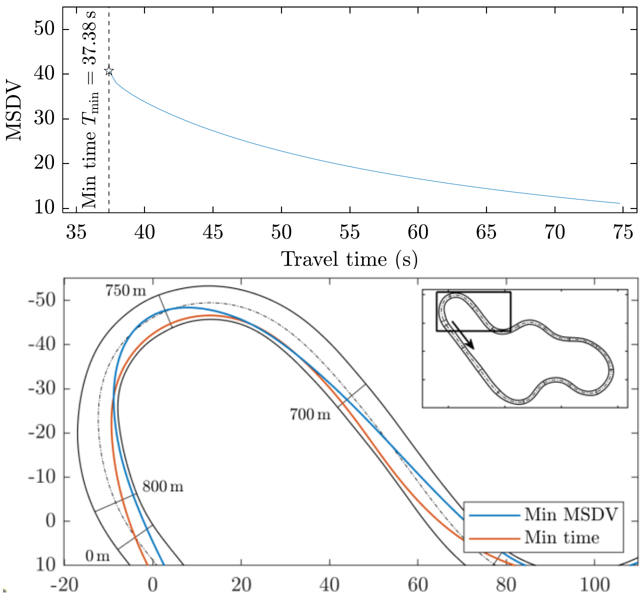
Mitigation of motion sickness in autonomous driving

Autonomous driving is expected to significantly affect future mobility. While the focus is often on the technological aspects, various subjective challenges such as perceived comfort and safety need to be addressed as well. One of the key aspects is the motion sickness, whose incidence and severity is increased in autonomous vehicles due to the shit from driver to passenger. In this context, a human-centred design is important, in order to maximize the user acceptance of the new technology.

Trajectory planning, consisting in the planning of both the vehicle path and speed profile, is one of the most challenging functionalities to design since it affects the driving style. On the one hand, trajectory planning may lead to an 'aggressive' driving style when aiming at minimizing the travel time. On the other hand, to improve the motion comfort, the trajectory should have 'smooth' characteristics. However, going more slowly can increase traffic congestions and passenger's dissatisfaction. Finding the ideal balance between travel time and passenger motion comfort is essential to meet customer expectations.

A possible approach is to use the Motion Sickness Dose Value (MSDV) as the objective function of an optimization problem, which aims to search for a trade-off between the MSDV and the travel time. The MSDV is an index computed from the vertical, longitudinal, and lateral accelerations, with a frequency weighting filter which makes some frequency bands more 'sick' for the passengers. The most sensible bands are 0.1-0.3Hz, 0.02-0.3Hz and 0.1-0.3Hz for the longitudinal, lateral, and vertical directions, respectively.

Simulations of a 180kW SUV running on a testing circuit showed the capability of the approach to mitigate the motion sickness, while accounting for possible different driving styles by balancing the travel time and MSDV. The minimum-time simulation gives travel time of 37.38s, with a MSDV of approximately 40.8. When increasing the travel time by 50%, the MSDV reduces to approximately 18.5. As the travel time increases, the MSDV decreases, with also evident changes in the optimal path followed by the vehicle. Experimental testing for the validation of the approach are planned for spring 2024.



Sistemi meccanici

Mechanical systems

DII research group

Mechanism and Machine
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Main research topics:

- Industrial and service robotics
- Mechanical drivers and control
- Mechanical vibrations
- Mechanisms and automated machines
- Road vehicles
- Robotic systems for human interaction

Processi e prodotti industriali

Industrial processes and products

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The research activity has been carried out in collaboration with Lgem (Achterweg 65, 1424 PP De Kwakel, Netherlands) and Algreen B.V. (Bronland 10 6708 WH Wageningen The Netherlands).

Main research topics:

MICROALGAE CULTIVATION

- Effect of light and operating variables on continuous cultivation of microalgae in Photobioreactors
- Optimization of sustainable nutrient and CO_2 supply for industrial autotrophic cultivation
- Exploitation of microalgae for Wastewater treatment and CO_2 capture
- Modelling of microalgae growth for process design and optimization
- Optimization of artificial light supply and reactor design
- Process simulation and technolo-economic analysis of algal biomass production

ENERGY AND DECARBONIZATION

- Chemical or biological carbon capture and sequestration/utilization (CCUS)
- Production of hydrogen and carbon-neutral fuels
- Biofuels and biomass-derived products

Cyanobacterial chromatic adaptation to widen the light spectrum exploitation: a new concept of microalgal consortia

Phototrophic cultivation of microalgae represents a potential sustainable process to obtain valuable commercial products, but the industrial cultivation is still hampered by low energy-to-biomass conversion efficiency. However, a certain number of cyanobacteria species evolved the ability to adapt to the prevailing light spectrum exploiting phycobiliproteins and Complementary Chromatic Adaptation (CCA). Spectral properties of such accessory pigments can be, hence, used to cover the green gap and possibly use light energy more efficiently.

In our work, the green microalgae *Tetradesmus obliquus* and the chromatically adapting cyanobacterium *Tolypothrix tenuis* were co-cultivated in continuous LEDs illuminated photobioreactors. With this new cultivation strategy, higher areal productivity (38 g m-2 d-1) and overall conversion efficiency (21%) were recorded under low red-light regime, thanks to a wider absorption of photons with different wavelengths by the two species. The consortium lab-scale performances were then validated in 16 L and 160 L continuous photobioreactors as well.

Hence, we found that is possible to efficiently convert light energy supplied to photobioreactors through a rationale use of light and widening wavelengths absorption spectrum thanks to co-existing species. Such results indicate that innovative consortia establishment can be advantageous for future research and industrial microalgae cultivation.

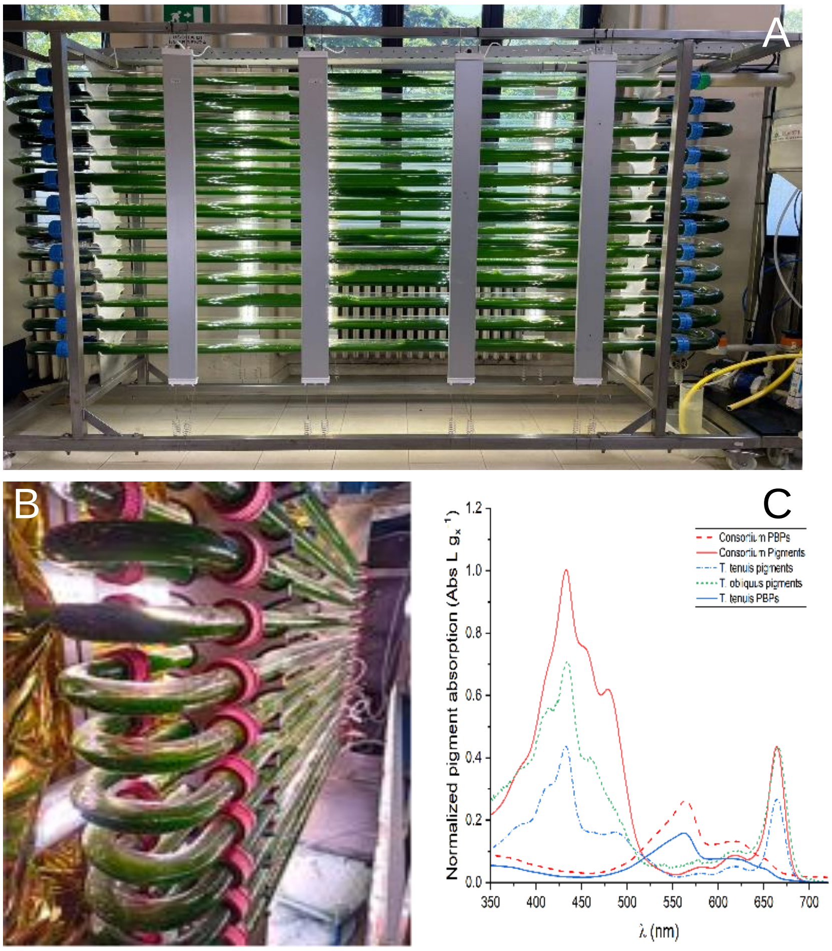

Figure 1. Consortium cultivation in 275 L (A) and 25 L (B) pilot scale PBRs. (C) Consortium whole-pigments absorption spectra and "green gap" covering.

Sustainability in the construction sector: the case study of selective demolition of a building in Milan

In the construction sector, the Circular Economy model represents a precious opportunity for sustainable waste management: the selective demolition technique allows for carrying out procedures for recycling building materials.

The final aim of “strip-out demolition” is the identification, through a series of checks and analyses of buildings, of dangerous substances and recyclable materials. Although there are numerous studies relating to the environmental performance of selective demolition, the convenience of this technique also in terms of health and safety risk reduction is still unexplored.

The research has two main objectives:

1. Create a set of economic, environmental and health and safety indicators to evaluate the sustainability of demolition waste management;
2. Test sustainability indicators and obtain evidence of the convenience of CE practices in managing CDW.

The case study of building renovation in Milan, allows to compare the performances of selective and traditional demolition, quantifying the convenience of circular practices in construction sites, such as minimization of resource consumption and emissions, demolition and disposal costs saving, better health and safety conditions of workers.

The results demonstrate several benefits related to selective demolition compared with the traditional one. In fact, most of the materials can be recycled, avoiding environmental impacts and assuring economic advantages; furthermore, better working conditions reduce health and safety risks related to waste management.

Conclusions encourage the scientific community to deepen the evaluation of sustainability performance, integrating environmental and economic measures already widely explored, with social evaluations, no less important but still little treated. Research findings can direct the market towards greater awareness of the benefits associated with sustainable practices.

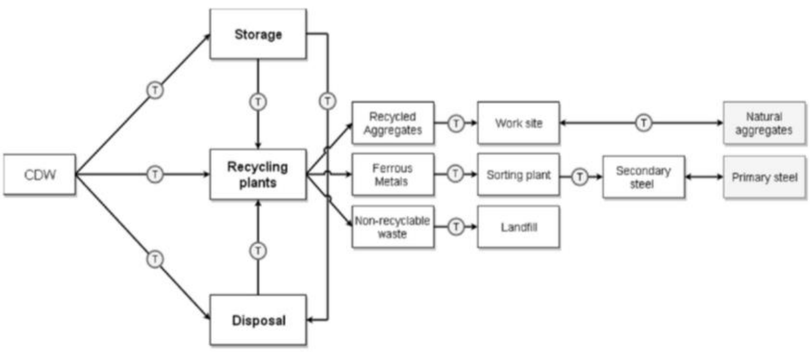

Figure 1. Reference system for the LCA analysis of CDW management in Lombardia (https://doi.org/10.1016/j.jcl)

Figure 2. Strip out demolition applied in the case study.

Sicurezza ambientale e industriale

Environmental and industrial safety

DII research group

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Valentina Vangi, Università Bocconi Infrastructures, Sustainability & Facility Management, Italy
Cooperates to the research with: design of assessment method, data collection, data analysis and interpretation of results.

Main research topics:

- Circular economy and waste minimization
- Sustainable performance indicators
- Environment, Health and Safety

Materiali

Materials

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This work was funded by EU– Next Generation EU PROJECT #2022T4LPER and SID-BIRD 2022.

Main research topics:

- Additive Manufacturing
- Polymer Derived Ceramics
- Materials for the environment
- Biomaterials

Room temperature extrusion of multi-material core-shell structures

The application of 3D printing for creating multi-material structures presents a complex set of challenges and opportunities. Integrating materials such as metallic alloys and ceramics introduces complexities in managing processing parameters, from the initial printing phase to post-processing. Nevertheless, this complexity also opens up a wide range of possibilities, as combining different metals and ceramics can result in components with enhanced structural and functional properties [1].

This study is focused on the use of room temperature extrusion of specifically designed inks to 3D print core-shell filaments in 3D shapes .

The combination of metallic core and ceramic shell, will be analyzed in terms of processing parameters (ink's rheology, de-binding and sintering conditions), microstructure, mechanical and functional behavior.

As first case-study a biocompatible alloy (AISI316L) will be tested as core, and an in-situ synthesized bio-ceramic will be used as shell, with the aim of producing 3D scaffolds for bone-replacements [2].

We expect that the introduction of a metallic core will improve the material toughness keeping unalterd its bioactivity [3].

3D modeling of the thermo-mechanical stress that will rise upon debinding and sintering will be performed in collaboration with Politecnico di Milano so as the mechanical behaviour of the sintered core-shell strucutures with Laboratori Nazionali di Legnaro. The main objective is the definition of a design guide for the combination of different materials in a core-shell configuration.

Further development will consist in the combination of conductive core and insulating inks for specific thermo-electrical applications.

[1] A. Nazir et al., Materials & Design, 226 (2023) 111661 DOI: 10.1016/j.matdes.2023.111661
[2] H. elsayed et al, appl Ceram Tech DOI: 101111/IJAC.14168
[3]J. Mueller et al, Adv Mat, 30 (2018) 1705001, DOI: 10.1002/adma.201705001

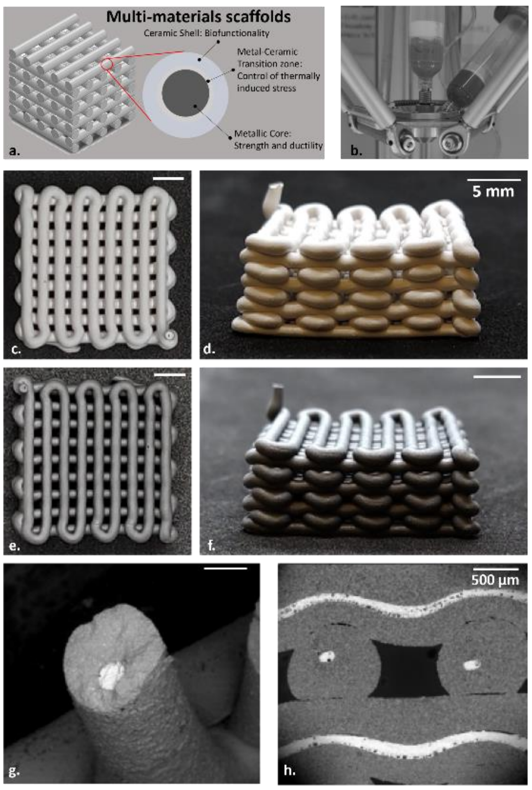

Figure 1. a) Graphical representation of core-shell structures; b) printing set-up with coaxial nozzle; c), d) core-shell scaffold after printing; e), f) core-shell scaffold after sintering; g), h) SEM images of scaffold sections after sintering process.

Exploiting the potential of electrified chemical processes in the decarbonisation route. Insights from the EU Eretech project

Hydrogen is an essential molecule for the chemical industry used both as pure in refineries and ammonia synthesis or as syngas for methanol and in other industrial applications.

Within 2030, the hydrogen demand is expected to increase to 90 Mt per year. Forecasts expect that, in the best-case scenario, electrolysis will be able to supply 45% of this. The remaining 55% will have to be produced differently, e.g. via steam methane reforming, which currently emits 9-10 $kgCO_2$ per kgH_2 if based on the conventional fuel-fired route.

Inside the Eretech Horizon Europe project, we combine direct resistive heating with electrical element wires into a catalytic macrostructure to avoid fossil fuel combustion and reduce carbon dioxide emissions by up to 50 %. Moreover, the carbon dioxide produced is present in the syngas at moderate pressures, facilitating total carbon capture. The reforming technology based on electric heating developed within the Eretech project is in line with the new paradigm of process manufacturing based on electrification, intensification (volumetric reduction factor of 250 compared to traditional route), emission reduction and operational flexibility (35 % turn-down ratio, hot standby with minimal energy requirement and fast startup and shutdown).

Now, we are finalizing the construction of a pilot plant for electrified reforming (e-SMR) to test a directly electrified reformer of 250 kW, which is scaled up from the laboratory prototype of 22 kW. The pilot plant is supposed to be fully installed and tested by the first semester of 2024. The proposed concept can be applied, for example, to the biogas market. In collaboration with Sypox GmbH, we are implementing two skids for converting waste biogas into green hydrogen with a productivity of 200-400 kgH_2 per day. The solution is fully containerized and ready for a concept of decentralized production.

Another application consists of implementing this new technology in centralized hydrogen production. The Eretech project is looking into the development of the basic engineering of a centralized 6 MW electrified steam reforming plant that converts natural gas into hydrogen with tail gas integration and carbon capture.

Independently on the application, there is detailed attention to developing inherent safe processes. In this light, the research activity is also focused on updating and implementing risk assessment techniques to accommodate emerging risks and new scenarios. Within the consortium, there are different milestones related to developing new certification schemes to improve the current regulatory framework. Unconventional safety-related features include non-standard heating strategies, fast transients and hazardous operations in confined spaces with potentially strong ignition sources.

Figure 1. Container for the installation of the pilot plant for e-SMR.

Processi e prodotti industriali

Industrial processes and products

DII research group

Safety group

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The research activity is carried out in collaboration with the Technische Universität München (TUM) – CRC and the other partners of the European project Eretech.
The Eretech project is based on electrically heated reactor technology developed by SYPOX.
This research has been funded by the European Union's Horizon Europe Research and Innovation Program under grant agreement No 101058608.

Main research topics:

- Risk analysis and process safety
- Electrification of the chemical industry
- Design of inherent safe processes

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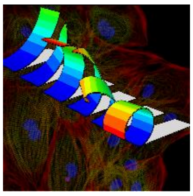
Cover story



Valutazione della contrazione di cardiomiociti ricavati da cellule staminali pluripotenti umane seminati su uno scaffold di polidimetilsilossano (PDMS).

L'obiettivo di questa ricerca è quello di valutare le capacità contrattili delle cellule muscolari cardiache su substrati di diversa forma e dimensione con la finalità di utilizzare i modelli ad elementi finiti per sviluppare e affinare tecniche di ingegneria tessutale che portino ad una possibile rigenerazione del tessuto cardiaco.

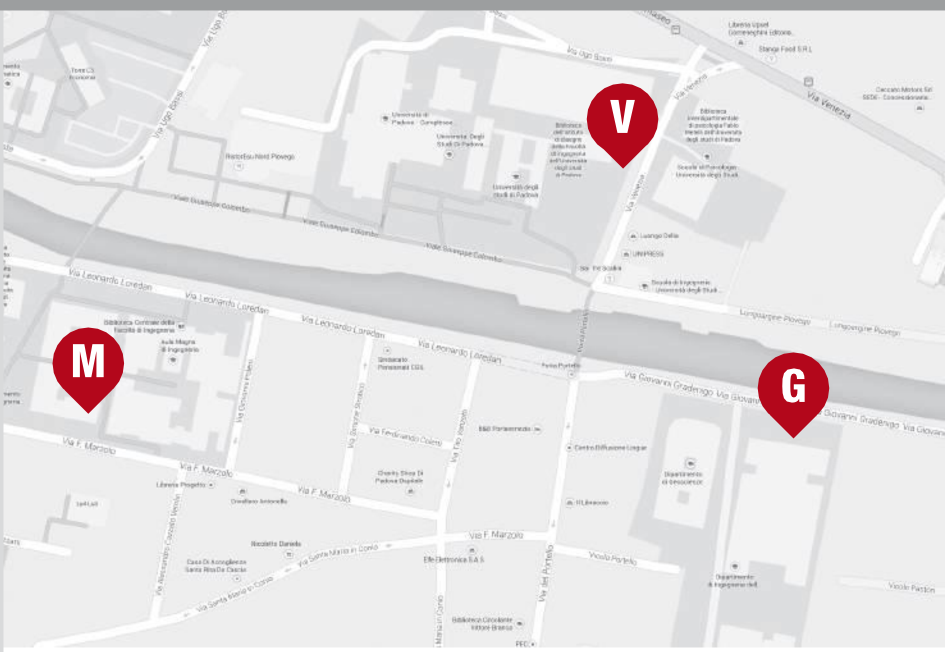
In particolare, nelle immagini proposte, viene valutata l'influenza della dispersione delle fibre durante la contrazione muscolare di uno strato di cellule cardiache seminate su una membrana sottile di PDMS.

Silvia Spadoni

Laureata in Ingegneria dell'Informazione e successivamente in Bioingegneria presso l'Università degli Studi di Padova, è stata Assegnista di Ricerca presso il Dipartimento di Ingegneria Industriale all'interno di un progetto volto a sviluppare un modello a elementi finiti di testa e in seguito Borsista di Ricerca con una ricerca per lo sviluppo di hydrogel per viscosupplementazione.

Attualmente è Dottoranda in Industrial Engineering, curriculum Materials Engineering, e si occupa dello studio del comportamento meccanico di tessuti attivi tramite modellazione ad elementi finiti. Lavora sotto la supervisione del Prof. Piero Pavan e della Dott.ssa Silvia Todros.

SEDI



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