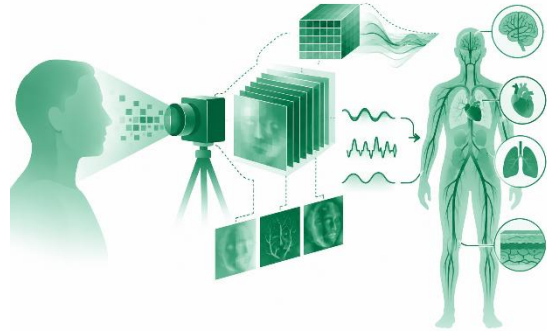


# VIDEO-BASED HEALTH ASSESSMENT

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## Background

Video-based health assessment is a contactless approach to monitoring physiological parameters by analyzing video recordings of the human body. Subtle changes in skin color, tissue reflectance, and motion caused by cardiovascular and respiratory activity can be used to estimate vital signs such as heart rate, respiratory rate, and blood oxygen saturation. Advanced image processing, signal analysis, and machine learning techniques enable the extraction of physiological information from conventional RGB videos as well as multispectral and hyperspectral imaging. This technology offers promising opportunities for unobtrusive, continuous, and remote patient monitoring in clinical settings, at home, and in everyday environments.



DSENS applies and further develops available algorithmic solutions for video-based health assessment in multiple fields and using different hardware solutions.

## Possible works (examples)

- Analysis or development of algorithms for the non-contact assessment of local perfusion from videos (P,S,T)
- Usage of hyperspectral reconstruction for vital parameters assessment (P,S,T)
- GPU-based video processing for vital parameter assessment
- Modelling and simulation of light-tissue interaction by Monte-Carlo simulations (P,S,T)
- Conception and implementation of experimental studies invoking fluidic phantoms and healthy volunteers (P,T)
- Event-camera usage for health assessment (P,S,T)

(exemplary topics suitable for seminar (S), project (P) and/or thesis (T); details will be discussed)

## Literature

- [1] S. Zaunseder, A. Trumpp, D. Wedekind, and H. Malberg, "Cardiovascular assessment by imaging photoplethysmography – a review," Biomed. Eng. / Biomed. Tech., vol. 63, no. 5, pp. 617–634, Oct. 2018, doi: 10.1515/bmt-2017-0119.
- [2] T. Vogelsang, V. Fleischhauer, A. Woyczyk, M. Wellnhofer, S. Rasche, and S. Zaunseder, "Hyperspectral imaging photoplethysmography: insights into the signals' origin and usage," Biomed. Opt. Express, vol. 17, no. 10, p. 5062, Oct. 2026, doi: 10.1364/BOE.605828.

# LLM/SLM FOR MEDICAL PREDICTION TASKS

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## Background

Large Language Models (LLMs) and Small Language Models (SLMs) are increasingly being explored as tools for clinical prediction. Beyond their ability to generate and understand natural language, language models can be adapted to identify patterns in complex medical data and estimate the likelihood of clinically relevant outcomes. In particular, clinical notes, longitudinal patient records, laboratory results, physiological measurements, and other structured or unstructured information can provide valuable input for predictive models. A central research question is how general-purpose or medically specialized language models can



be trained, adapted, or fine-tuned for specific prediction tasks. This creates a broad research space ranging from model and dataset development to clinical evaluation. Possible research questions include how much task-specific data is required, whether smaller models can achieve comparable performance to larger models, which fine-tuning strategies are most effective, and how model predictions can be evaluated with respect to accuracy, calibration, generalizability, and clinical usefulness.

## Possible works (examples)

- Fine-tuning LLMs/SLMs for predictions and evaluation of model calibration (P,S,T)
- Comparison of LLMs and/or SLMs for specific clinical prediction tasks (P,S,T)
- Comparison and combination of LLM/SLM predictions with conventional machine-learning approaches (P,S,T)

(exemplary topics suitable for seminar (S), project (P) and/or thesis (T); details will be discussed)

## Literature

- [1] Y. Yildiz et al., "Will large language models transform clinical prediction?" *Diagnostic and Prognostic Research*, 2025.
- [2] Y. Qin, T. Yan, M. Y. H. Wong, S. Srinivasan, H.-Y. Zhou, R. Eils, Y.-C. Tham, N. H. Shah, J. Wu, H. Wang, and T. Y. Wong, "Small language models in medicine," *Nature Biomedical Engineering*, vol. 10, pp. 1519–1523, 2026, doi: 10.1038/s41551-026-01734-3.
- [3] S. Gebreab, A. Musamih, K. Salah, and R. Jayaraman, "Enhanced medical diagnostic reasoning in small language models using reinforcement learning," *International Journal of Cognitive Computing in Engineering*, vol. 7, pp. 400–411, 2026, doi: 10.1016/j.ijcce.2026.02.002.

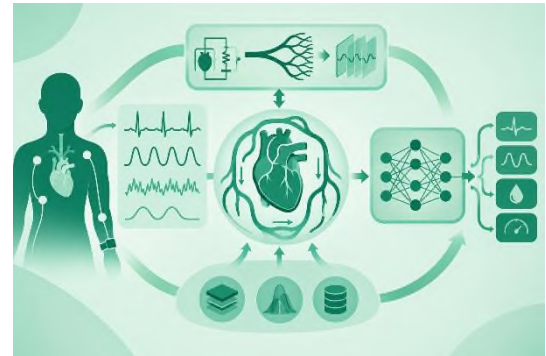
# MODELING AND MODEL-BASED ASSESSMENT OF THE CARDIOVASCULAR SYSTEM

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## Background

The cardiovascular system follows well-understood physical processes. Mathematical models describe these processes at very different levels of detail, from simple lumped models, through models of pulse wave propagation in the arterial tree, to closed-loop simulations of the heart and the circulation. Such models let us understand how physiological signals arise, generate large synthetic datasets, and derive parameters that cannot be measured directly.



At the same time, non-invasive biosignals such as the photoplethysmogram (PPG), camera-based PPG, Electrocardiogram, bioimpedance and continuous blood pressure are becoming widely available, from wearables to the intensive care unit. Combining physiological models with signal processing and neural networks opens up new possibilities.

DSENS develops and applies cardiovascular models, model-based signal analysis and physics-informed neural networks to infer wide information on the cardiovascular system.

## Possible works (examples)

- Closed-loop cardiovascular simulator for generating synthetic biosignals (P,T)
- Digital twin: personalization of a cardiovascular model to measured blood pressure and cardiac output (P, T)
- Sim-to-real: training estimation networks on simulated pulse waves and transferring them to real recordings (P,T)
- Arterial stiffness from multi-site PPG and ECG using pulse wave propagation (P,S,T)
- Physics-informed vs. purely data-driven cardiac output estimation (e.g. using transformers, S4 architecture, ...): a benchmark on public intensive care data (P,S,T)
- Literature review: cardiovascular models of different complexity and their use in machine learning (S)

(exemplary topics suitable for seminar (S), project (P) and/or thesis (T); details will be discussed)

## Literature

- [1] Y. Shi, P. Lawford, and R. Hose, "Review of zero-D and 1-D models of blood flow in the cardiovascular system," Biomed. Eng. Online, vol. 10, art. 33, 2011, doi: 10.1186/1475-925X-10-33.
- [2] H. Crandall et al., "Cuffless hemodynamic monitoring with physics-informed machine learning models," Nat. Commun., vol. 17, art. 6429, 2026, doi: 10.1038/s41467-026-72693-1.

# SEX-SENSITIVE AND INCLUSIVE CARDIOVASCULAR RESEARCH

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## Background

Cardiovascular disease is the leading cause of death in both men and women, yet it does not affect them in the same way. Sex, meaning biological factors such as genetics, hormones and anatomy, shapes how the disease develops, presents and responds to treatment. Women have smaller coronary arteries and hearts, even after correcting for body size, along with a higher resting heart rate and higher resting myocardial perfusion. Their overall heart rate variability is lower, but a larger share of it is vagally mediated. Oestrogen supports endothelial function until menopause. Women are more prone to microvascular dysfunction and to ischaemia without obstructive coronary disease, while men more often develop focal obstructive plaques. Some risk factors, such as pre-eclampsia and premature menopause, exist only for women, and others, such as diabetes and smoking, weigh more heavily in women.



DSENS investigates sex-specific differences in cardiovascular signals and hemodynamics. We combine model-based analysis and bias-aware machine learning with openly available datasets and our own measurement studies using multi-site PPG, camera-based PPG and ECG.

## Possible works (examples)

- Bias in machine learning for cardiovascular monitoring: sex-balanced training, reweighting, and sex as an input feature vs. separate models (P,S,T)
  - Sex differences in pulse wave morphology and pulse wave velocity in multi-site PPG and ECG recordings (P,T)
  - Sex-specific parameterization of cardiovascular models (P,T)
  - Autonomic regulation in women and men: heart rate variability and baroreflex responses during stress tests (P,S,T)
  - Review on reporting of sex and gender in biosignal datasets and wearable studies (S)
- (exemplary topics suitable for seminar (S), project (P) and/or thesis (T); details will be discussed)

## Literature

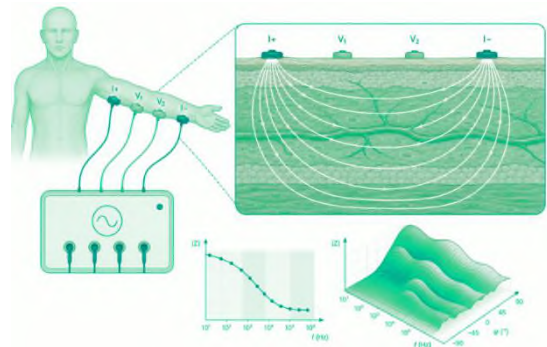
[1] O. Manfrini et al., "Sex and gender differences in coronary pathophysiology and ischaemic heart disease: A Scientific Statement of the ESC Working Group on Coronary Pathophysiology & Microcirculation, the Association for Acute CardioVascular Care, and the European Association of Percutaneous Cardiovascular Interventions of the ESC," Eur. Heart J., vol. 47, pp. 2727–2749, 2026, doi: 10.1093/eurheartj/ehaf1059.

# IMPEDANCE MEASUREMENTS FOR NON-INVASIVE MONITORING AND DIAGNOSTICS

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## Background

Impedance plethysmography (IPG) and electrical impedance tomography (EIT) are non-invasive sensing techniques that characterize physiological processes by measuring changes in the electrical properties of biological tissues. By injecting a weak, imperceptible electrical current, these methods can capture variations associated with blood volume changes, fluid distribution, and organ function. Their ability to probe deeper tissues and provide information beyond surface-level measurements makes them promising for a broad range of applications, including cardiovascular monitoring, respiratory assessment, fluid management, and wearable sensing. However, challenges related to signal quality, measurement robustness, and physiological interpretation remain.



DSENS addresses these challenges through a two-pronged strategy that enables algorithm development and training using both in vivo and phantom data. Potential research questions center around the recording and analysis of IPG signals to assess central hemodynamics as well as the implementation of dynamic phantom components to generate artificial data.

## Possible works (examples)

- Localization of superficial arteries for IPG signal enhancement (P, S, T)
  - Electrical and mechanical characterization of fluid phantom components (P, T)
  - Model-based parameter estimation from participant study data (P, S, T)
  - Impedance tomographic applications (respiratory and blood volume changes) (P, S, T)
- (exemplary topics suitable for seminar (S), project (P) and/or thesis (T); details will be discussed)

## Literature

- [1] S. Jung et al., "Differential sensitivity of impedance plethysmography and photoplethysmography sensors to temperature-induced peripheral vasoconstriction," *Sci Rep*, vol. 16, no. 1, p. 6828, Jan. 2026, doi: [10.1038/s41598-026-36563-6](https://doi.org/10.1038/s41598-026-36563-6).
- [2] I. Karpiel, M. Richter-Laskowska, D. Feige, A. Gacek, and A. Sobotnicki, "An Effective Method of Detecting Characteristic Points of Impedance Cardiogram Verified in the Clinical Pilot Study," *Sensors*, vol. 22, no. 24, p. 9872, Jan. 2022, doi: [10.3390/s22249872](https://doi.org/10.3390/s22249872).
- [3] J. Hoffmann, D. Hruschka, L. Fueller, R. Kusche, and S. Zaunseder, "Dynamic fluid phantoms for impedance plethysmography - a proof-of-concept study," *Curr. Dir. Biomed. Eng.*, vol. 12, no. 1, pp. 207-210, Oct. 2026, doi: [10.1515/cdbme-2026-0153](https://doi.org/10.1515/cdbme-2026-0153).

# ASSESSMENT OF THE AUTONOMOUS NERVOUS SYSTEM FROM BIOSIGNALS

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## Background

Assessment of the autonomous nervous system (ANS) using biosignals holds enormous potential to transform how we monitor and understand health. By analyzing physiological signals such as heart rate variability (HRV), QT variability (QTV) blood pressure, or respiratory patterns - from wearable devices in everyday life to high-resolution monitoring in intensive care - we can move beyond describing the current state toward identifying subtle changes that precede clinical deterioration. Intelligent algorithms can recognize individual patterns, detect deviations from a patient's baseline, and provide early risk predictions. This opens the door to truly personalized, proactive monitoring: systems that continuously learn from physiological dynamics and support timely intervention, while reducing the burden on clinicians and enabling more efficient use of healthcare resources.



DSENS applies and further develops available algorithmic solutions for autonomous assessment in multiple fields. Beyond, our works also include novel/adjusted hardware and clinical application scenarios.

DSENS applies and further develops available algorithmic solutions for autonomous assessment in multiple fields. Beyond, our works also include novel/adjusted hardware and clinical application scenarios.

## Possible works (examples)

- QTV analysis to predict deterioration (P,S,T)
- Ultra-short term ANS assessment (HRV and QTV)(P,S,T)
- Respiration-enhanced HRV analysis (P,S,T)
- Optimization of a proprietary QTV algorithm (GPU processing)(P,T)

(exemplary topics suitable for seminar (S), project (P) and/or thesis (T); details will be discussed)

## Literature

[1] C. Maldonado-Veas, P. León, C. Lerma, and J. C. Echeverría, "Application of heart rate variability in clinical practice and research: A systematic review of recent years," *Auton. Neurosci. Basic Clin.*, vol. 266, no. April 2025, 2026, doi: 10.1016/j.autneu.2026.103450.

[2] M. Baumert et al., "QT interval variability in body surface ECG: measurement, physiological basis, and clinical value: position statement and consensus guidance endorsed by the European Heart Rhythm Association jointly with the ESC Working Group on Cardiac Cellular Electroph," *Europace*, vol. 18, no. 6, pp. 925–44, Jun. 2016, doi: 10.1093/europace/euv405.