TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

*Public summary of PhD-thesis of Andreia Moço*

*PhD defense date: 16 May 2019*

## Video camera assesses vascular health

**The skin is the body's biggest organ and a barrier against the outside world. From an engineering perspective, the skin has interesting features. Subtle color variations are one of them. The skin becomes transiently darker and "reddish" with every heartbeat due to arterial blood-volume variations at the skin's vasculature. A video camera can monitor these variations, which enable a technique called photoplethysmography (PPG). Researcher Andreia Moço from Eindhoven University of Technology has studied and explored potential applications for PPG imaging.**

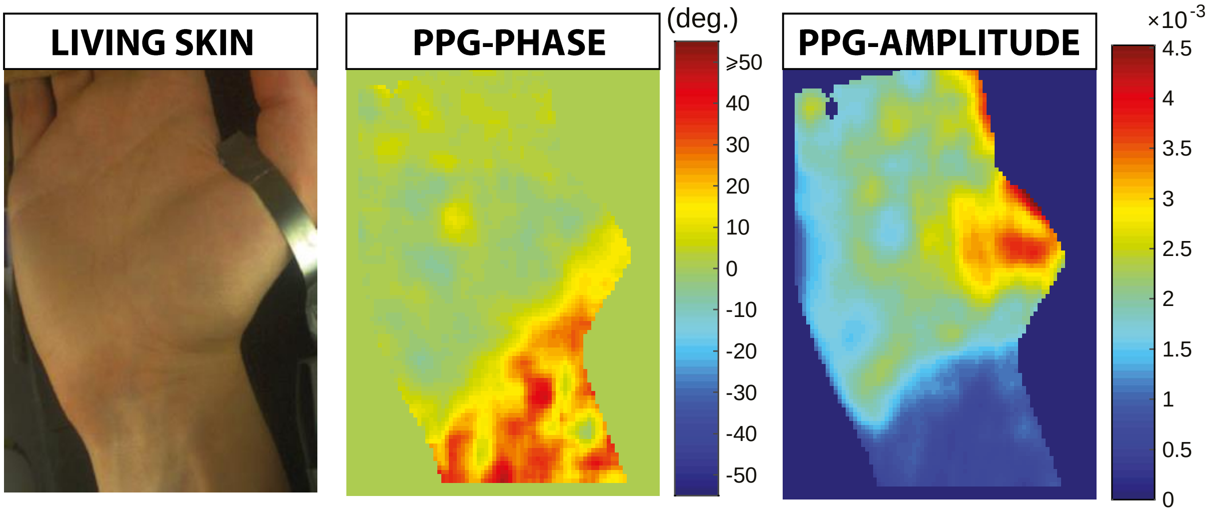
*Remote PPG signals are simply obtained from video recordings of the skin such as the palm of the hand (on the picture: PhD candidate Andreia Moço). Photo: Andreia Moço*

Remote photoplethysmographic (PPG) signals are measured by shining light at the skin and are a means to monitor the vital signs without cables and uncomfortable contact sensors. Thanks to the developments and ubiquitous access to regular cameras, remote PPG bas become an enabler of application-scenarios for contactless pulse-rate monitoring, including the clinically-oriented.

Remote PPG signals are often hidden by motion artifacts and noise. It was only over the last decade that the means to acquire PPG signals robustly was discovered and refined, hence enabling technical developments as impressive as the estimation of the oxygen saturation in the arteries. In her PhD, Moço had the opportunity to work on remote PPG, with an emphasis on imaging.

By modeling and experiments, Moço's work led to an improved understanding of the fundamentals of PPG imaging. Her research resulted in an imaging pipeline for exploratory micro- and macro-vascular assessments and for overall video-health monitoring. The PPG imaging framework she developed provide surface maps which describe the pulsatile status of the living skin tissue with macroscopic resolution. Possible applications are perfusion estimations and skin characterization.

The developed simulations, models and measurements offer an impression of the opportunities and challenges of measuring vital signs beyond the pulse-rate with remote-PPG signals. Moço's thesis project started by methodological improvements which ensured motion-robustness. Eventually, her focus shifted to the interpretation of measurements performed using visible light, with a priority on understanding the origin of the remote PPG signals. She developed a skin-model which enabled the living skin to be simulated.




*Representation of imaging PPG at the palm of the hand. Left-side figure: sample video frame; center: PPG-phase image. Right-side: PPG-amplitude image. Interpreting these type of images was not trivial. Photo: Andreia Moço*

Moço used the Monte Carlo method to perform these skin simulations. At multiple layers of the vascular bed of the skin tissue, she calculated the trajectories of the photons coming from light sources hitting the skin and being scattered by blood in pulsating vessels. The simulations helped to predict the relative intensities of the remote PPG signals that can be measured at different wavelengths, skin locations and physiological conditions. The wavelengths of red and green are, for example, used to study the effect of a change in posture for the relative amplitude of PPG signals.

*This PhD project was conducted by Andreia Moço at the Electronic Systems Group, Eindhoven University of Technology (TU/e), in partnership with Philips Research, Eindhoven and Catharina Ziekenhuis. The scientific outcomes of this project include 7 journal papers as first author and 1 patent application with Philips Research. Title of PhD-thesis: Towards Photoplethysmographic imaging: modeling, experiments and applications. Supervisors: prof. dr. Gerard de Haan (TU/e) and dr. Sander Stuijk (TU/e).*