

University of Oslo, Department of Informatics [Impact case #3]

Institution: University of Oslo
Administrative unit: Department of Informatics (IFI)
Title of case study: Machine learning for improved cardiac ultrasound
Period when the underpinning research was undertaken: 2013-2022
Period when staff involved in the underpinning research were employed by the submitting institution: 2013-2022
Period when the impact occurred: 2014-2022

1 Summary of the impact

Echocardiography is the primary imaging tool for cardiologists to assess cardiac function and structures. Machine learning techniques to provide automatic measurements or interpretations from ultrasound imaging can contribute to efficient examinations and reduce inter-observer variability. By providing new machine learning tools for several tasks like suppressing noise, detecting cardiac valve events, mitral annulus segmentation we have contributed to more efficient examinations. In cooperation with GE Healthcare, these methods have been taken from published papers to results implemented in commercial ultrasound scanners deployed worldwide.

2 Underpinning research

Over the period 2013-2022, the DSB-group at IFI has partnered in a series of joint projects on image analysis and machine learning with GE Healthcare and their research department in Norway. This started with 3DUS-project (2013-16), and continued with INCUS (2016-201), the INIUS innovation project (2017-21), the EchoAI project (2020-2023) and the SFI Visual Intelligence from 2020. Over this decade, the following researchers have contributed to the impact:

- Anne Solberg (Professor, UiO)
- Eigil Samset (adjunct professor, UiO)
- Hani Nozari Mirar (phd. candidate to 2020)
- Sten Road Snare (postdoc to 2016)
- Tollef Jahren (phd. candidate to 2022)
- Andrew Gilbert (phd. candidate to 2021)
- Børge Solli Andreassen (phd. candidate to 2022)
- Christiana Tiago (phd. candidate to 2022)
- Sarina Thomas (postdoc from 2021).

The impacts are related to better image quality and more efficient ultrasound scanning across a range of normal and difficult-to-scan individuals examined using cardiac ultrasound scanners. Mirar and Snare contributed to improved image quality in the initial years of cooperation between UiO and GE Healthcare. Jahren, Andreassen, Gilbert, Tiago, and Thomas have been central in applying deep learning to cardiac ultrasound. The contributions are discussed more in detail in the next sections. It is worth noting that in addition to the image analysis and machine learning research highlighted in the current impact case, additional research collaborations related to image reconstruction and signal processing are conducted between GE Healthcare and DSB through the Centre for Innovative Ultrasound Solutions (CIUS) SFI.

The phd. candidates have also contributed to implementing their methods into GE Healthcare systems, and some of the most significant methods are also implemented into ultrasound scanners, so they can be of benefit to future patients.

3. References to the research

Jahren, Tollef Struksnes; Steen, Erik Normann; Aase, Svein Arne & Solberg, Anne H Schistad (2020). Estimation of End-Diastole in Cardiac Spectral Doppler Using Deep Learning. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*. ISSN 0885-3010. 67(12), s. 2605–2614. doi: 10.1109/TUFFC.2020.2995118.

Må legges i viten.

A. Gilbert, M. Marciniak, C. Roderio, P. Lamata, E. Samset and K. Mcleod, "Generating Synthetic Labeled Data From Existing Anatomical Models: An Example With Echocardiography Segmentation," in *IEEE Transactions on Medical Imaging*, vol. 40, no. 10, pp. 2783-2794, Oct. 2021, doi: 10.1109/TMI.2021.3051806. Fulltext:

Andreassen, Børge Solli; Veronesi, Federico; Gerard, Olivier; Solberg, Anne H Schistad & Samset, Eigil (2020). Mitral Annulus Segmentation Using Deep Learning in 3-D Transesophageal Echocardiography. *IEEE journal of biomedical and health informatics*. ISSN 2168-2194. 24(4), s. 994–1003. doi: 10.1109/JBHI.2019.2959430. Fulltext: <https://www.duo.uio.no/handle/10852/80775>

Andreassen, Børge Solli; Volgyes, David; Samset, Eigil & Solberg, Anne H Schistad (2022). Mitral Annulus Segmentation and Anatomical Orientation Detection in TEE Images Using Periodic 3D CNN. *IEEE Access*. ISSN 2169-3536. 10, s. 51472–51486. doi: 10.1109/ACCESS.2022.3174059. Fulltext: <https://www.duo.uio.no/handle/10852/101084>

Thomas, Sarina; Gilbert, Andrew; Ben-Yosef, Guy (2022). Light-weight spatio-temporal graphs for segmentation and ejection fraction prediction in cardiac ultrasound. *MICCAI 2022*. <https://doi.org/10.48550/arXiv.2207.02549L>. Available at <https://arxiv.org/abs/2207.02549>.

Tiago, C., Gilbert, A., Salem Beela, A., Aase, S.A., Snare, S.R., Sprem, J., and McLeod, K. "A data augmentation pipeline to generate synthetic labelled datasets of 3D echocardiography images using a GAN". In *IEEE Access*. Vol. 10, 2022. pp. 98803-98815. DOI: 10.1109/ACCESS.2022.3207177.

4. Details of the impact

The research referenced in section 3 contribute to tackling the following major challenges:

- Making automatic measurements of clinically relevant parameters available in close-to-real time (Jahren, Gilbert, Andreassen, Thomas).
- Enabling training deep neural networks with limited cardiac ultrasound data and limited labels by deriving new methods for generating synthetic labelled data or providing anatomically valid augmentations (Gilbert, Tiago).

Spectral Doppler recordings are frequently used for examining heart wall motion, flow parameters, and valve diseases. In the Doppler spectrograms, clinical parameters are typically measured separately in multiple cardiac cycles. Carciac cycles are available from ECG recordings,

but ECG is not always acquired. Jähren et al. present a method for automatic detection of end-diastoles in Doppler spectrograms without ECG.

The prevalence of valvular diseases is increasing with age, and more than 10% of the population above 75 years of age are affected. Mitral regurgitation is the most common valvular disease, and echocardiography is the most frequently used imaging modality to evaluate mitral valve diseases. Localization of the mitral annulus and leaflets is the first step in order to calculate clinical measures for diagnosing pathologies and planning interventions of the mitral annulus. Andreassen et al. present methods for mitral annulus segmentation using deep learning in 3D echocardiography.

Reduced left ventricle outflow is an important marker of heart failure, and it can be quantified from the ejection fraction. The ejection fraction describes the volumetric blood fraction pumped by the heart in each heart cycle. Methods for segmenting the left ventricle can be used to derive ventricular volume, ejection fraction, and other relevant measurements. Robust automation of left ventricle segmentation and ejection fraction estimation are high priority tasks for modern echocardiographic systems. Thomas et al. present a robust, fast, and accurate method for left ventricle segmentation and ejection fraction estimation based on graph convolutional networks.

The amount of cardiac ultrasound datasets with associated labels suitable for robustly training a deep learning model is limited, both due to privacy issues in acquiring data, and the laborious and error-prone human labelling of 2D and 3D image ultrasound recordings. Gilbert et al. and Tiago et al. have developed approaches for synthesizing 3D echocardiography images paired with corresponding anatomical labels suitable for input for training deep networks.

5. Sources to corroborate the impact

Website for SFI Visual Intelligence: <https://www.visual-intelligence.no/>

Website for SFI CIUS: <https://www.ntnu.edu/cius>

Website for INIUS project: <https://www.mn.uio.no/ifi/forskning/prosjekter/inius/index.html>

Website for INCUS project: <https://www.mn.uio.no/ifi/forskning/prosjekter/intelligent-cardiovascular-ultrasound-scanner/index.html>