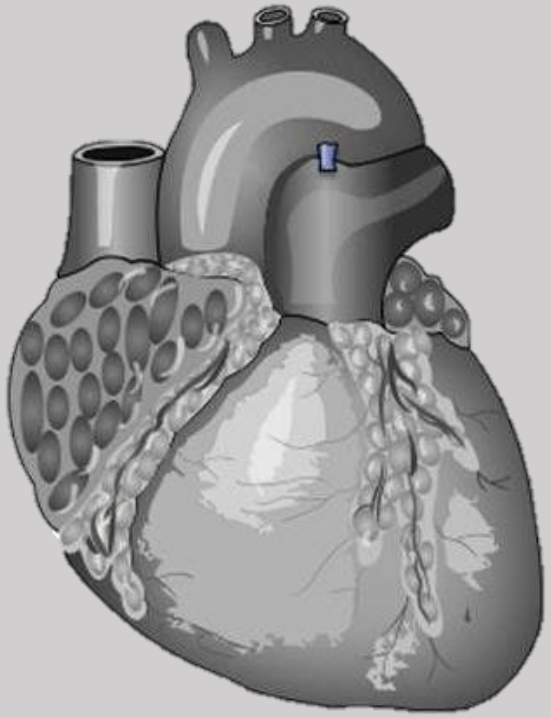
11th International Conference on Information Society and Technology (ICIST 2021)

Kopaonik, Serbia, March 7-10, 2021

Automatic Detection of Cardiomyopathy in Cardiac Left Ventricle Ultrasound Images



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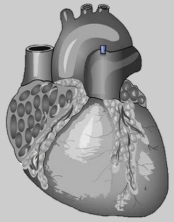


Motivation

- Eechocardiography is among different imaging systems preferred when it comes to the state evaluation of cardiac ventricles
- Segmentation of the heart **left ventricle (LV)** is a very important step when setting up an adequate diagnostic using quantitative measurements such as *ejection fraction*, *end diastolic and end systolic volumes*, *left ventricular mass* etc.

- Many authors tried to address the problem of segmentation using different approaches:
  - active shape, active contours, appearance methods (traditional methods)
  - machine learning-based methods (novel approach)

U-net in LV segmentation on apical view has not been applied to patients with cardiomyopathy, and only 2 papers exist regarding the M mode view analysis

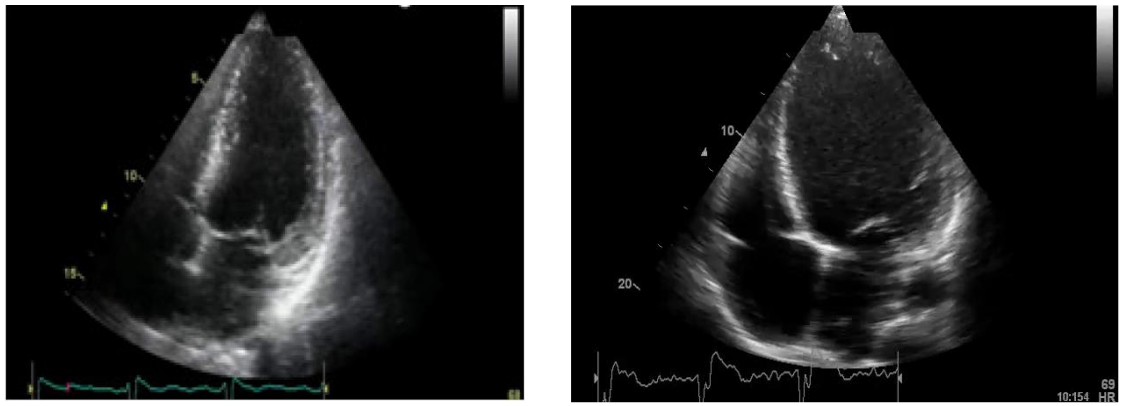
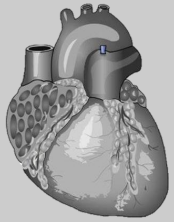


Figure 1. Ultrasound image with depicted left ventricle
(a) normal left ventricle
(b) dilated left ventricle, as a result of cardiomyopathy



Research questions

- On one hand, apical view (separately in diastole and systole phases) are necessary to estimate *Left Ventricular Length*, *Diastolic, 2D - LVLd* [cm] and *Left Ventricular Length, Systolic, 2D – LVLs* [cm]

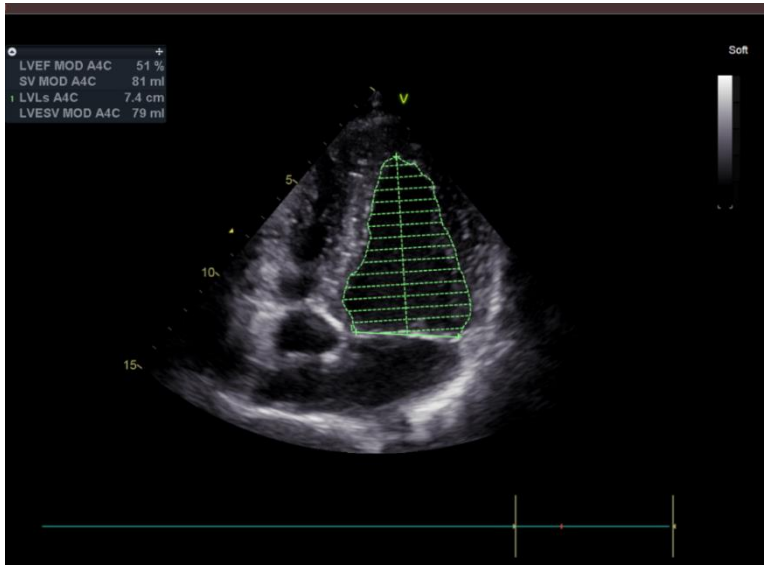


Figure 2. Apical view of the heart left ventricle

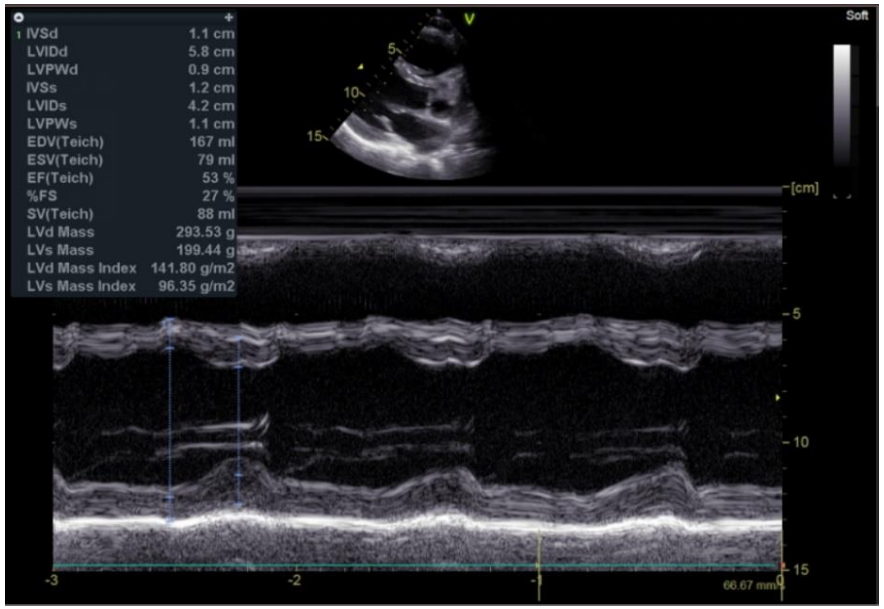
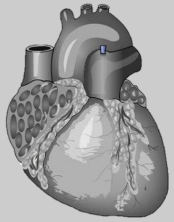


Figure 3. M-mode view of the heart left ventricle

- On the other hand, M-mode is crucial in estimating *Interventricular Septum Thickness, Diastolic, M-mode - IVSd* [cm], *LV Internal Dimension, Diastolic, M-mode - LVIDd* [cm], *Left Ventricular Posterior Wall Thickness, Diastolic, M-mode* - LVPWd [cm]



Materials and methods

Dataset

- Dataset was collected during the 2019 and 2020 in the Institute of Cardiovascular Diseases, Vojvodina – Sremska Kamenica (ICVDV - 12 patients) and Newcastle University and Newcastle upon Tyne Hospitals NHS Foundation Trust (UNEW - 6 patients) and Clinical Centre Kragujevac (CCKG – 53 patients).

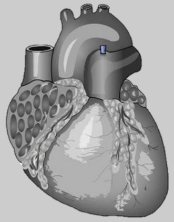
- 153 image ultrasound apical view and 53 image ultrasound M-mode view

- **Apical view:**
  - 120 images for training
  - 22 images for validation
  - 11 images for testing (no data augmentation)

- **M mode view:**
  - 53 images for training and testing

- All the images were in DICOM format, 8 bit images

Figure 4. Apical view of the heart left ventricle a) systolic phase, b) diastolic phase



Materials and methods

Apical view analysis

- U-net neural network architecture for LV segmentation was used
- In our network, all convolutions had the filter size of 3 × 3
- The network requires a fixed size input of 128×128 pixels (the level of details in images is not important (only one region is the region of interest)
- Neural network was implemented using Python Tensorflow
- The processing hardware were 8GB of RAM, a GPU Nvidia GeForce GTX960M, and an Intel (R) Core (TM) i7-6700HQ CPU @2.60GHz

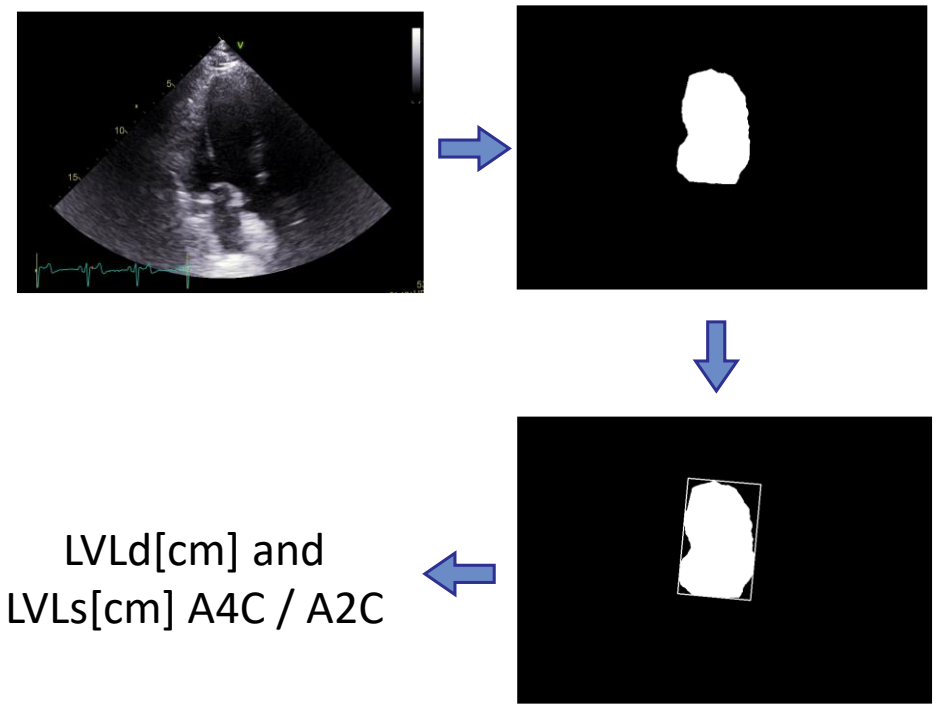


Figure 5. Methodology for Apical view analysis

Materials and methods

M mode view analysis

- Template matching
- Segmented area will be analysed using felsenszwalb's efficient graph-based method
- Additional erosion in 4 iterations and dilatation in 12 iterations are added
- Threshold binarization

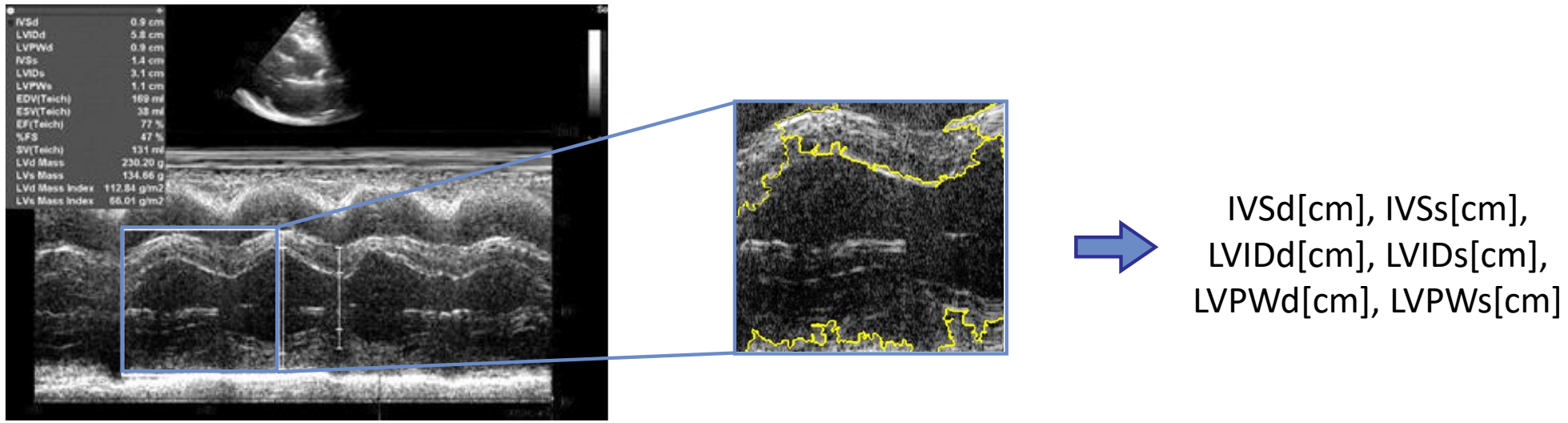
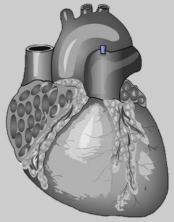


Figure 6. Methodology for M mode view analysis



Results and Discussion

- Deep convolutional neural network U-net can learn to recognise the heart left ventricle from ultrasound images
- In the good scenarios the network has performed very well, with some external additional areas, that were removed in a fine-tuning stage

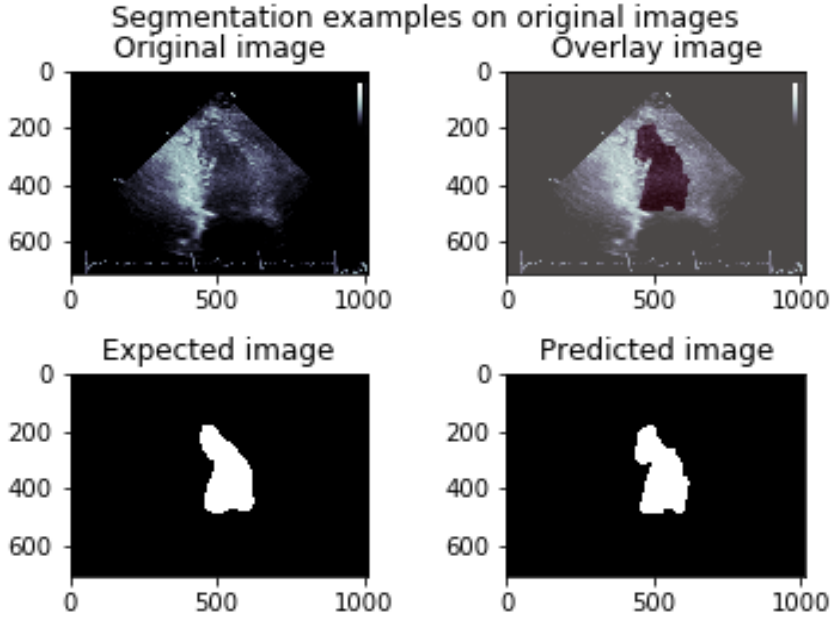


Figure 7. Comparison of the LV segmentation by U-net and manual segmentation (best case scenario)

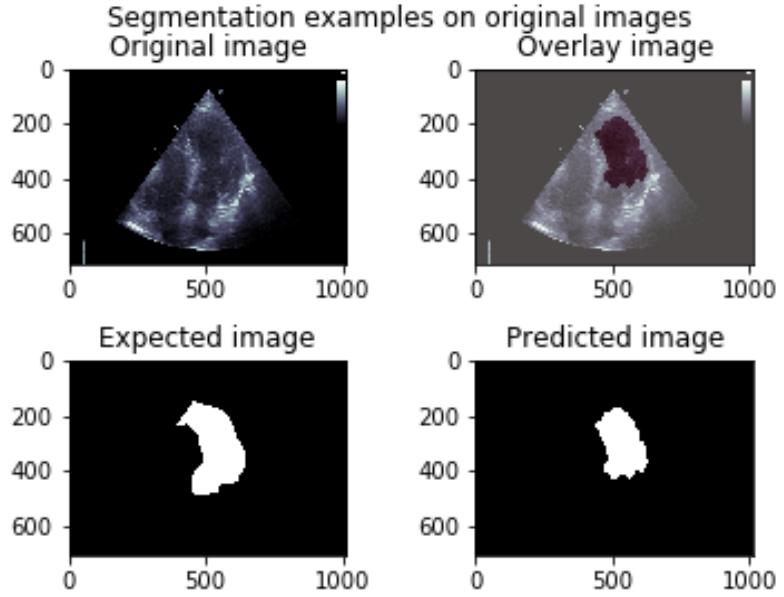
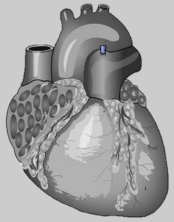


Figure 8. Comparison of the LV segmentation by U-net and manual segmentation (worst case scenario)



Results and Discussion

- The loss function had a falling trend as expected both in training and validation during the 5 epochs (Figure 9) and the accuracy of the training and validation data was increasing up to 88.79% and 80.35% respecively (Figure 10)
- **Test dataset**: dice similarity coefficient was 83.49% on 128x128 test images, 82.39% on 1016x708 images without kernel and 83.40% on 1016x708 images with kernel of size 10x10

Table 1. Results for mean absolute error (MAE) for automatic extraction of parameters on Apical view images

Parameter name	CCKG
Number of apical view images	98
MAE for parameter LVLd[cm] A4C	0.19995 cm
MAE for parameter LVLs[cm] A4C	0.29730 cm
MAE for parameter LVLd[cm] A2C	0.23356 cm
MAE for parameter LVLs[cm] A2C	0.20720 cm

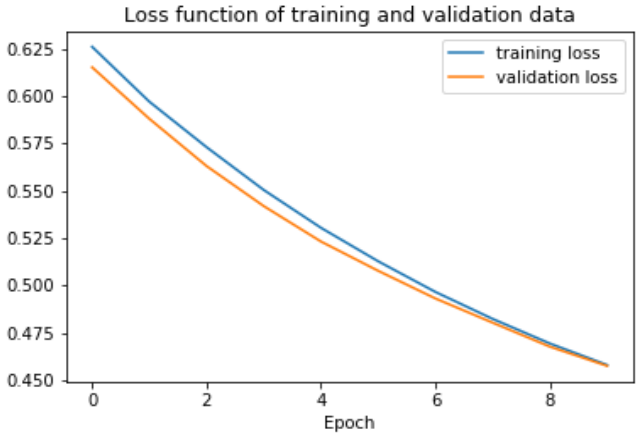


Figure 9. Loss function of training and validation data

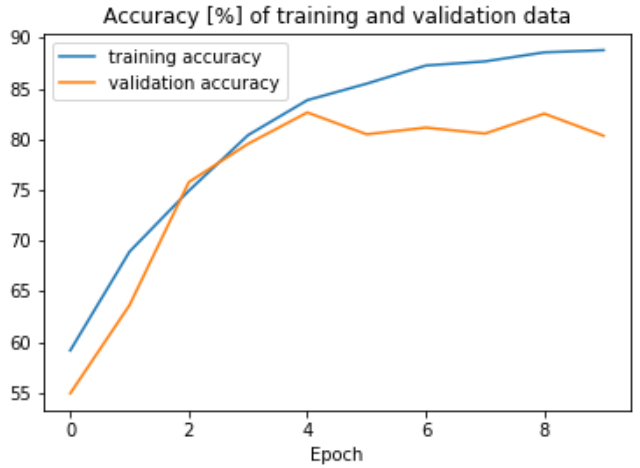
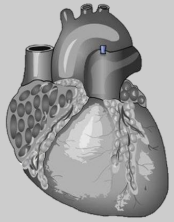


Figure 10. Accuracy of training and validation data



Results and Discussion

- Automatic extraction of the parameters IVSd[cm], IVSs[cm], LVIDd[cm], LVIDs[cm], LVPWd[cm], LVPWs[cm] are reported in Table 2 in the form of mean absolute error

Table 2. Results for mean absolute error (MAE) for automatic extraction of parameters on M mode view images

Parameter name	CCKG
Number of M-mode images	53
MAE for parameter IVSd[cm]	0.9 cm
MAE for parameter IVSs[cm]	1.5 cm
MAE for parameter LVIDd[cm]	1.7 cm
MAE for parameter LVIDs[cm]	1.1 cm
MAE for parameter LVPWd[cm]	1.8 cm
MAE for parameter LVPWs[cm]	2.2 cm

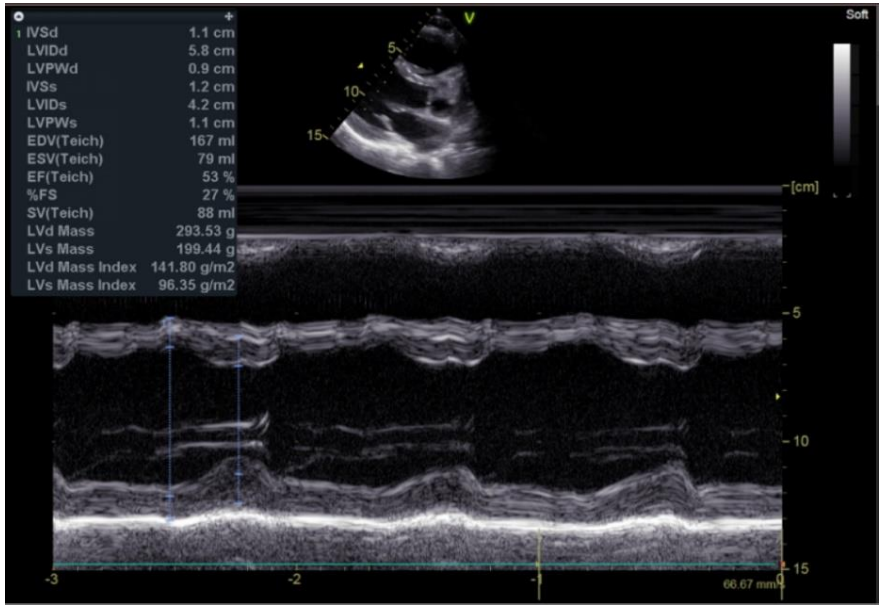


Figure 11. M-mode view of the heart left ventricle

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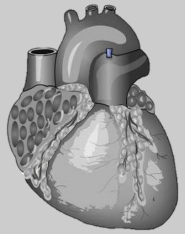
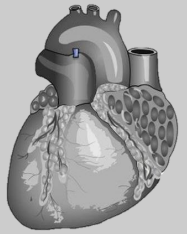


Thank you for your attention



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This paper is supported by the projects that have received funding from the European Union's Horizon 2020 research and innovation programmes under grant agreements No 777204 (SILICOFCM project). This article reflects only the author's view. The Commission is not responsible for any use that may be made of the information it contains.