Bayesian Optimization of 2D Echocardiography Segmentation

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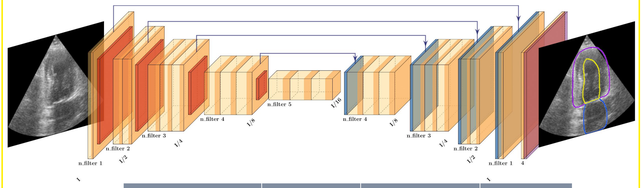
MOTIVATION & BACKGROUND

- Echocardiography is a ubiquitous modality for diagnosing cardiomyopathy.
- Time-consuming if segmented manually.
- Previously published state-of-the-art convolutional neural network (CNN) model [1] used heuristically-chosen hyperparameters.
- **Goal: Use Bayesian Optimization on hyperparameters for CNN-based multi-structure echo segmentation.**

METHOD - BAYESIAN OPTIMIZATION (BO)

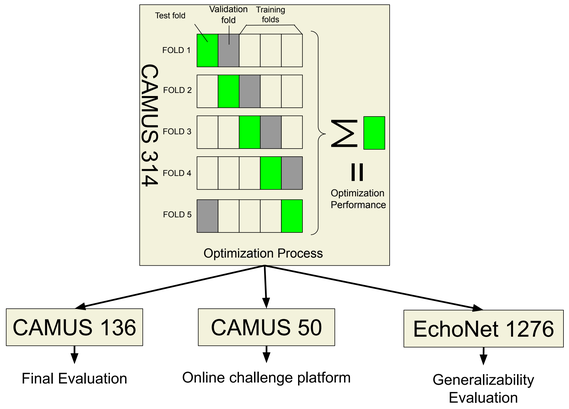
- Noisy Constrained Expected Improvement [2].
- Objective: Mean validation (MV) performance on test set.
- Constraint: GPU capacity.
- Heteroskedastic Gaussian Processes (Matérn 5/2 kernel) to model objective.
- Usual Gaussian Process (Matérn 5/2 kernel) to model constraint.



	Hyperparameter	Range	Previous [1]	AP 2&4
Architectural	n_filter #1	[16, 32]	32	21, 19
	n_filter #2	[57, 128]	64	94, 77
	n_filter #3	[153, 256]	128	225, 157
	n_filter #4	[281, 512]	256	427, 490
	n_filter #5	[537, 1024]	512	811, 915
	group vs. batch num. groups	[0,1] [2,24]	0 16	1, 1
Training	lg learning rate	[-9, 2]	-6.22	-8.0, -7.6
	lg weight decay	[-9, -2]	-13.8	-7.9, -8.7
	batch size	[2, 10]	16	7, 6

EXPERIMENTAL SETUP

- CAMUS dataset [3].
- Apical two and four chamber views (AP2/AP4) each patient.
- End-diastolic and end-systolic (ED/ES) phases each view.
- K-fold splits are stratified on both patient EF range (≤45%, ≥55%, else) and reported image quality.
- Run BO asynchronously, each node runs single GeForce RTX 2080 Ti.
- Optimize each view independently, 100 candidates for each view.
- EchoNet [4] test set for generalizability test.



RESULT

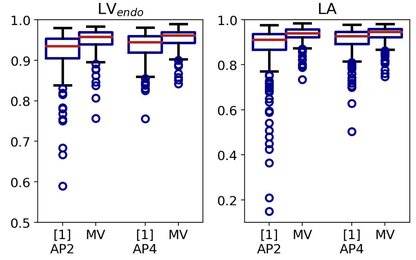


Fig 1: Boxplot of LVendo and LA performance

RESULTS

- Higher Dice score, less outliers (Fig. 1 & 2 & 3), and narrower clinical index limit of agreement (LOA) (Fig. 4).
- Deeper feature maps and thus more trainable parameters (40M vs 13M).
- Generalizes to independent Stanford-EchoNet [4] data, achieves statistically significant improvement, with median Dice overlaps of 0.921/0.895 on ED/ES.
- Consistent results on 50 left-out CAMUS patients [3], obtain mean ED/ES overlaps of 0.948/0.928 on LV_{endo}, 0.962/0.955 on LV_{epi}, and 0.899/0.932 on LA.

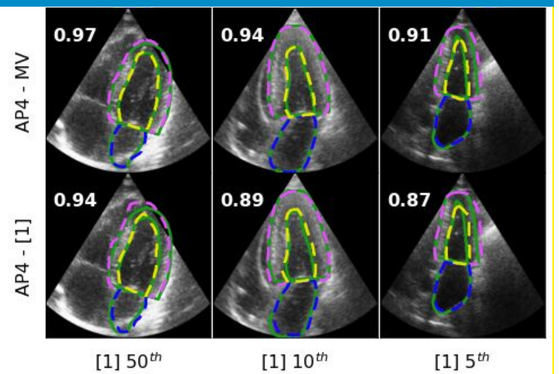


Fig 2: Segmentation performance on AP4 of MV, or optimized, (above) and published [1] (below). Green contour denotes manual segmentation.

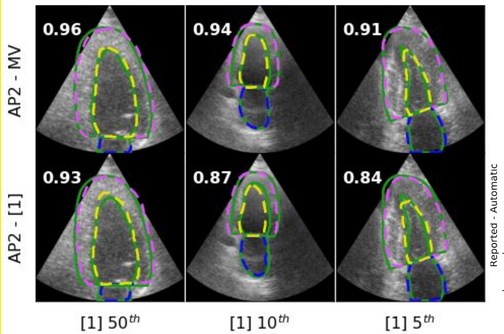


Fig 3: Segmentation performance on AP2 of MV, or optimized, (above) and published [1] (below). Green contour denotes manual segmentation.

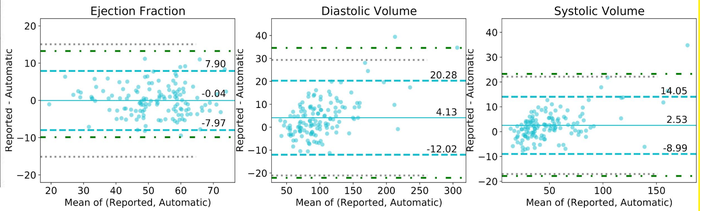


Fig 4: Bland-Altman plot. ***Blue dash***: LOA of optimized model. ***Green dash-dotted***: LOA of published [1] model. ***Gray dotted***: inter-rater variability.

CONCLUSION & FUTURE DIRECTION

- BO significantly improved recent state-of-the-art multi-structure segmentation in echocardiography.
- Potential absence of catastrophic failures makes more feasible limited auditing in future large-scale historical analyses.
- Model performance further generalized to a large independent clinical database.
- Continue to assess generalizability to other historical clinical data.

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