Vito – A Generic Agent for Multi-Physics Model Personalization

Application to Heart Modeling

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Introduction

Clinical: Heart failure

Major cause of morbidity and mortality [1,2]

Important need to **better stratify patients**

➔ **Computational models** could help
- Advanced information from clinical data
- Prediction of therapy outcome / disease course

➔ Clinical applications require precise **model personalization**

Technical: Individualized computational model

Adjust model parameters such that model fits patient data

Various personalization techniques have been explored [3,4]
➔ Applied blindly / unsupervised: **prone to failure**
➔ Complex algorithms necessary: tedious design, **not generic**

Human experts almost **always succeed** (manual personalization)
➔ **Intuition**, **experience**, ability to generalize

Contribution: Intelligent machines personalize biophysics models

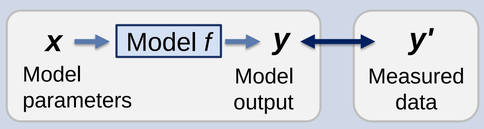
Vito, an artificial agent, learns by itself cardiac physiology and how to personalize complex models

Vito is generic: It can learn multiple biophysics – no handcrafted optimization functions and algorithms

Method

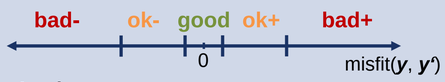
Personalization problem reformulation

Computational model



Personalization objective
Minimize misfit(***y***, ***y'***)

Markov decision process (MDP) [5]
Framework for modeling decision making
- **S**: States

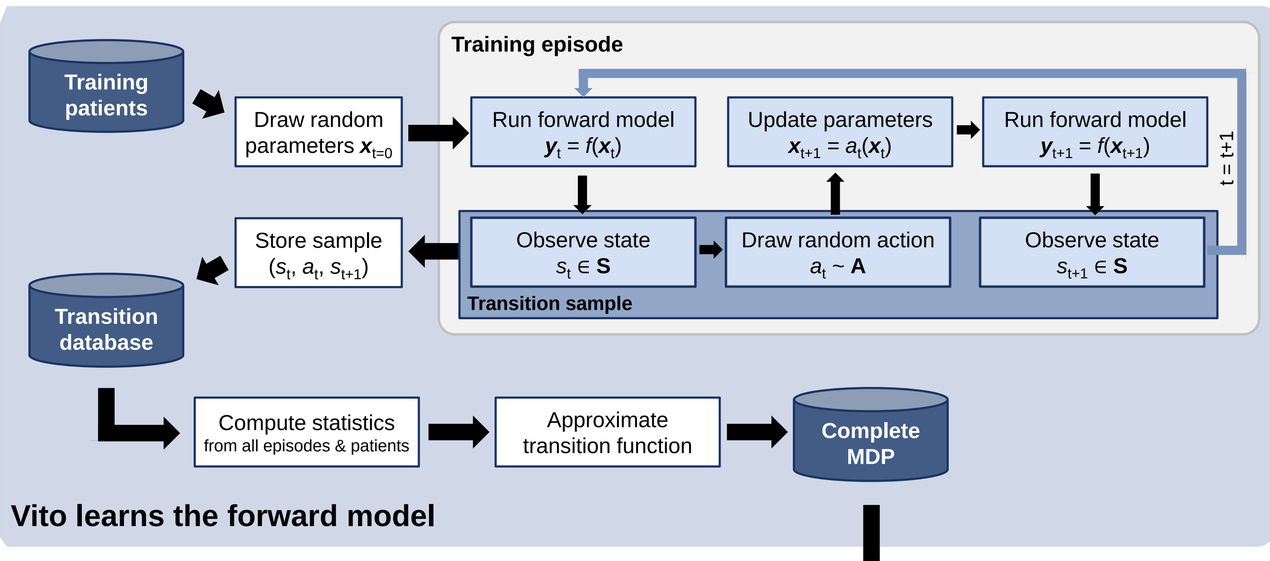


- **A**: Actions
  Modify ***x***
- **T**: Transition function
  Learned
- **R**: Rewards
  0 if state is **good**
  -1 otherwise

Solution
- π: Policy
  Maximizes cumulative rewards

Off-line phase

Assimilate model behavior



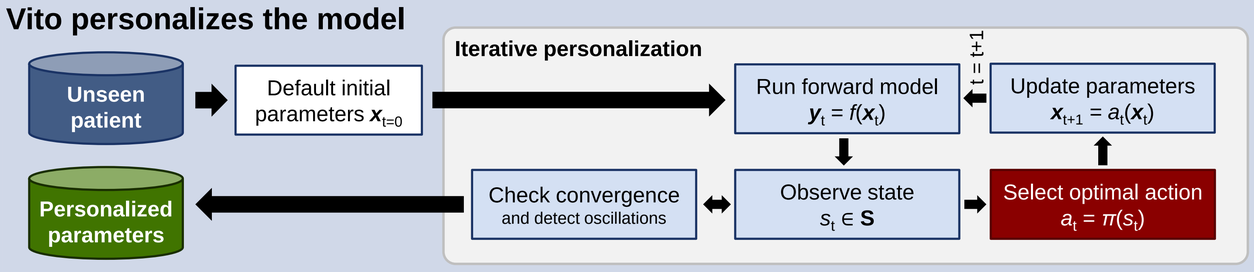
Learn optimal strategy

Vito learns how to personalize the model
to decide which action to take given any possible state of a personalization (**reinforcement learning** [5,6])

On-line phase

Personalize new patient

Vito personalizes the model



Evaluation

Same framework applied to two different biophysics models
28 patients without severe cardiac arrhythmias (8 for hyper-parameter tuning; 20 for testing)

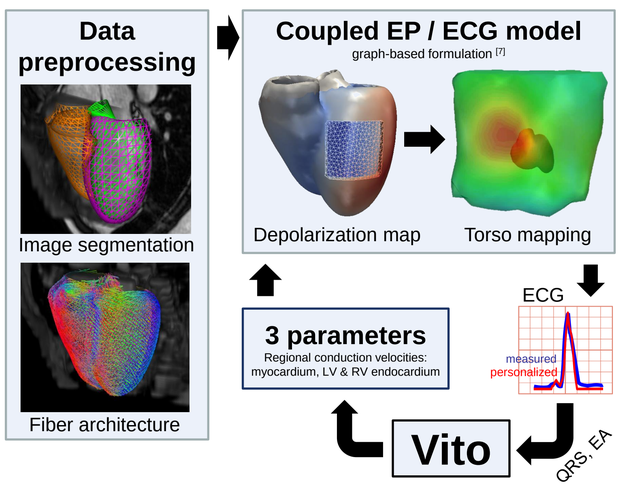
Cardiac electrophysiology

Calculates electrical signal controlling heart function
- Potential use: arrhythmia treatment
- Personalization: from 12-lead ECG

Results

Method	Vito	Reference (Gradient-free optimization)
#Fail-cases	2	7
QRS error	3 ± 2 ms	1 ± 3 ms
EA error	9 ± 10 deg	10 ± 15 deg
#Iterations	37 ± 33	31 ± 7

➔ 70% less fail-cases!



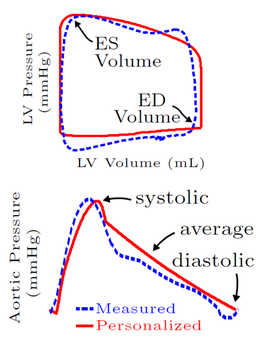
Whole-body circulation

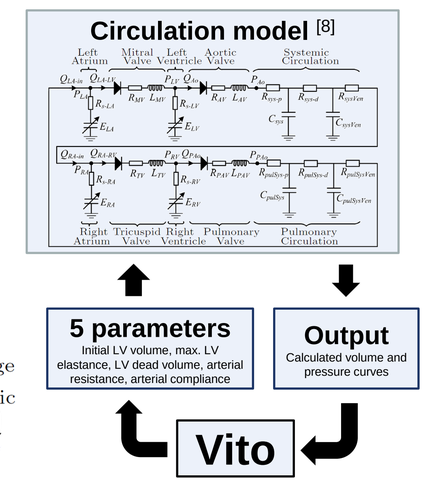
Calculates blood flow in cardiovascular system
- Potential use: new insights in cardiovascular function
- Personalization:
  - from volume (MRI) and
  - pressure (catheterization) data

Results

Method	Vito	Reference [8]
#Fail-cases	2	3
Volume errors	9 ± 7 mL	9 ± 6 mL
Pressure errors	5 ± 5 mmHg	5 ± 5 mmHg
#Iterations	16 ± 30	48 ± 30

➔ Three times faster!





Conclusions

- New **generic** personalization method
  ➔ No need to design & engineer cost function
- **Patient-** and **model-independent**
- **Fast** and **robust**

Perspectives

- Data-driven state-space quantization
  ➔ Continuous, approximate RL
- Improve data efficiency [6]
- Investigate convergence, stability, …

References

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