HEARTVERIFY: MODEL-BASED QUANTITATIVE VERIFICATION OF IMPLANTABLE CARDIAC PACEMAKERS

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Valuable Artifact Prize Ceremony

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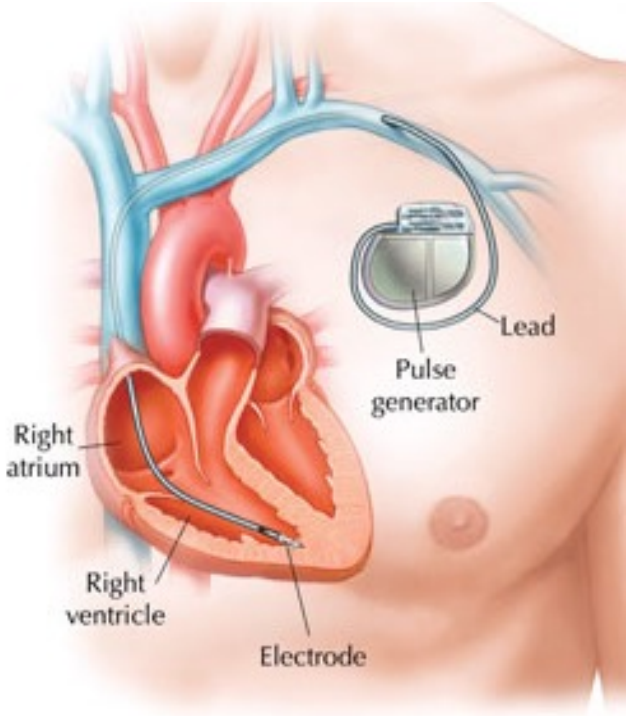
PURPOSES

- Cardiac pacemakers maintain a “correct” heart rhythm by sensing and stimulating heart beats
- One of the most common surgery procedures
- **Safety-critical system**
  (SW malfunctioning = severe adverse effects)
- Need for **quantitative verification**
- Personalised models for personalised treatments

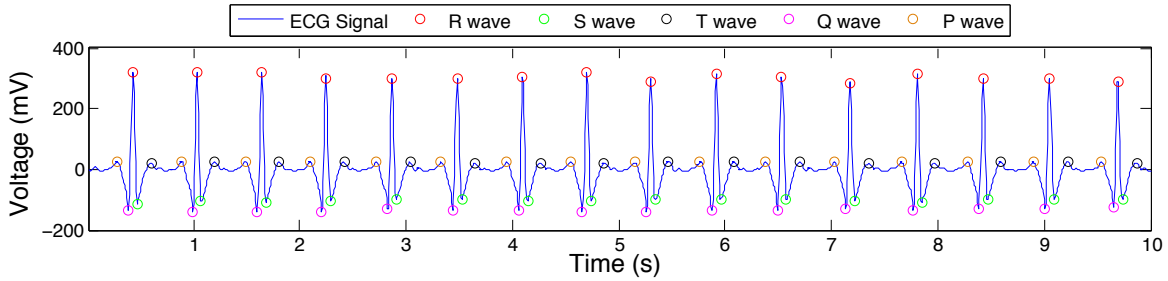


HEARTVERIFY IN A NUTSHELL

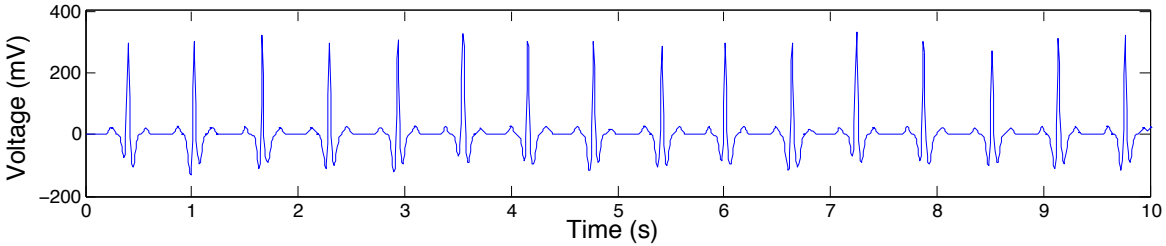
- **Model-based** framework for **quantitative verification** of **heart-pacemaker** systems
- Models are specified in **MATLAB Stateflow**
- Models are verified via **Statistical Model Checking** (Cosmos tool)
- **Modular** and **extensible**
- Supports **generic Stateflow models** (not just heart-PM)

FEATURES: **HEART MODELS**

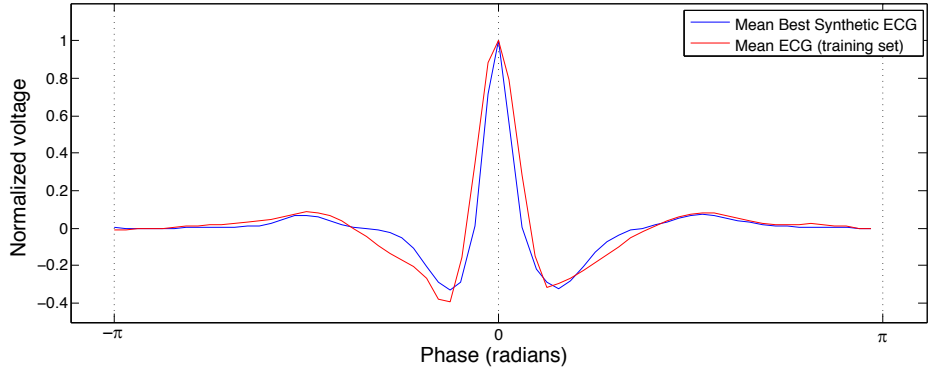
- Electrical conduction system as a network of automata
- Included models: deterministic, probabilistic, **personalised**



ECG detection and feature extraction



Model-based synthetic ECG signal generation



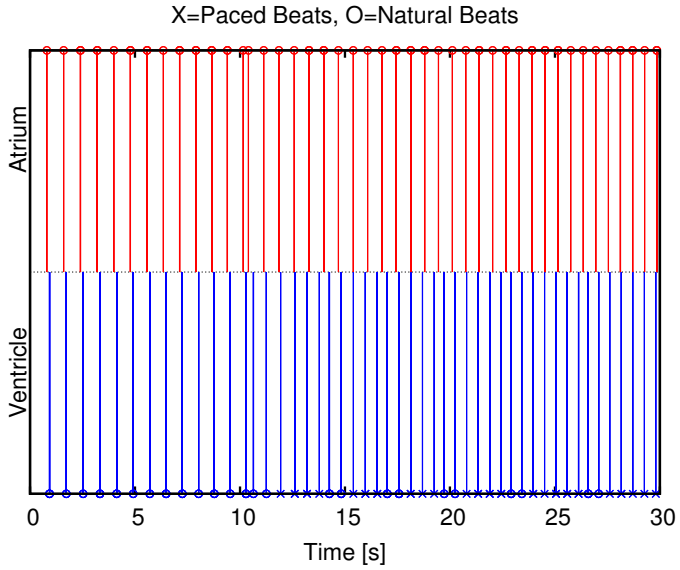
Find model parameters that minimise distance between input and synthetic signals

FEATURES: **PACEMAKER** and **PROPERTIES**

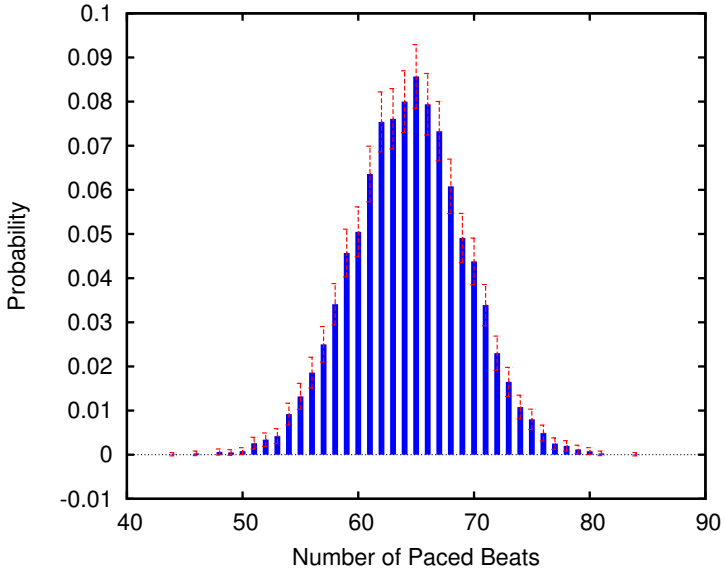
- Included pacemaker models: double chamber and rate-adaptive

- Verification properties:
  - Probability of **slow heart rate** or **conduction defects**
  - Probability of **sensor-induced heart conditions**

Additional analyses:

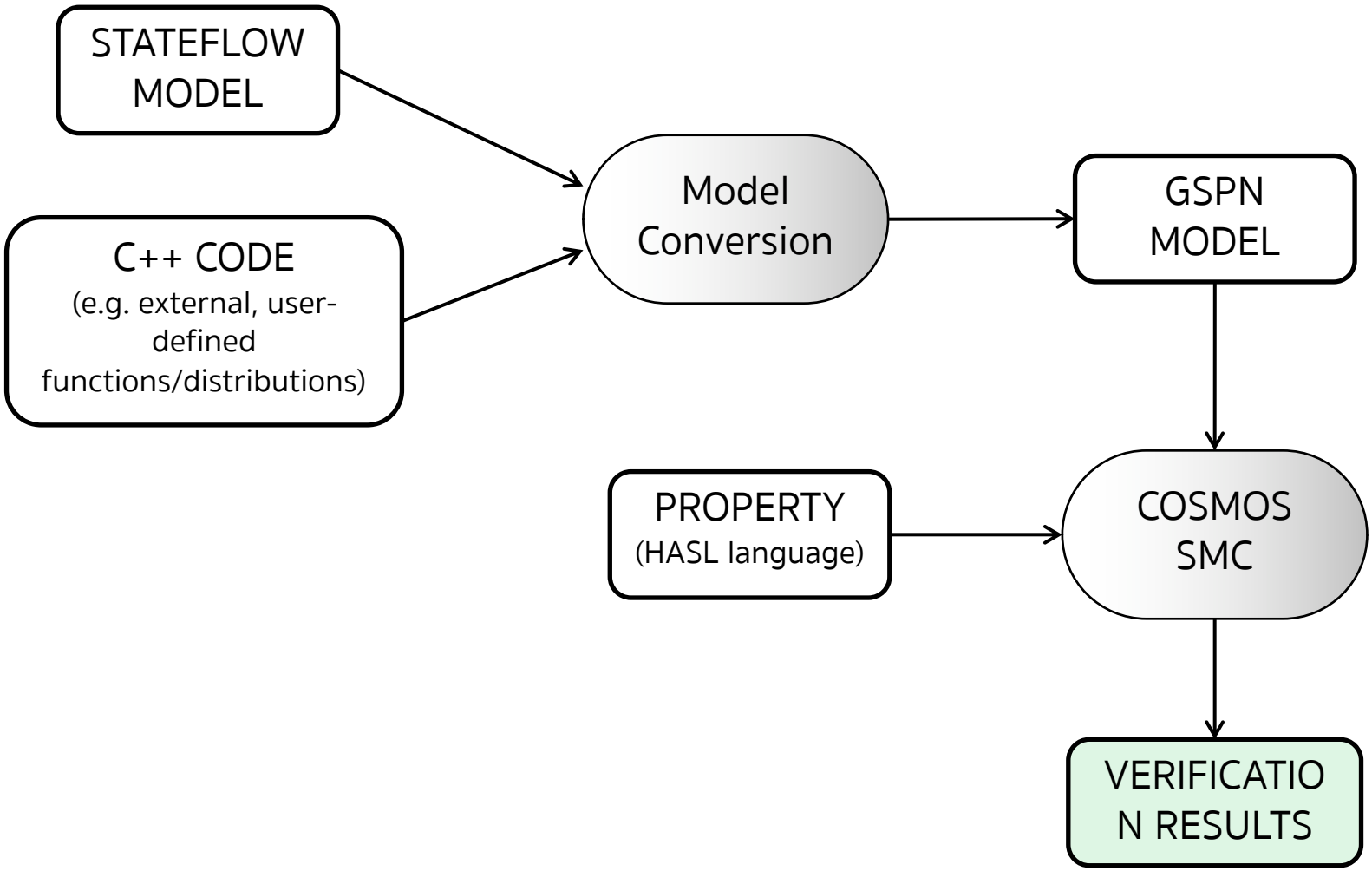



```
HeartVerify -m VVIR -c default
-p stem wait_VVIR.lha
```



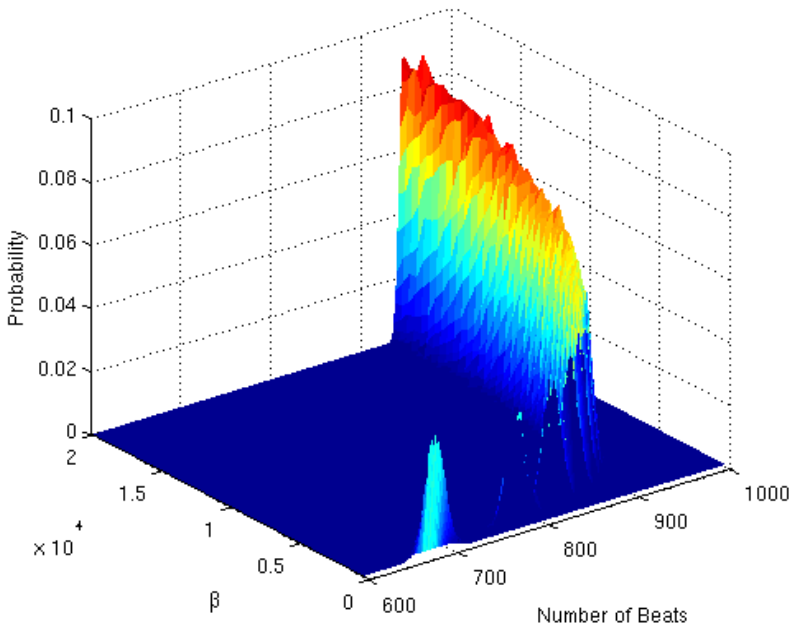

```
HeartVerify -m DDD –s stochastic -c default
-p pdf waitPDF_DDD_stochastic.lha
```

VERIFICATION WORKFLOW



IDEAS FOR EXTENSION

- Parametric analyses (easy)
- MATLAB toolbox (more involving)
- Any MATLAB Stateflow project!



e.g. how PDF of number of heart beats in 10 minutes changes at different levels of sensing noise?

THANK YOU FOR THIS PRIZE!

Acknowledgments:

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