SenseMyHeart

A Validated Cloud Service for Heart Rate Variability

FUTURE CITIES PROJECT .EU

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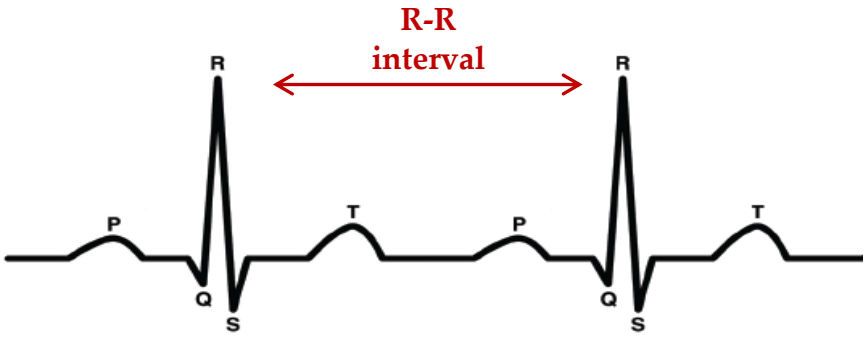
biodevices

Heart Rate Variability (HRV)

HRV - variations in time of the beat-to-beat intervals (R-R)

Clinical applications:

- HRV has been **linked to** certain states of **anxiety** and **occupational stress**. [1,2,3]



[1] - Hagit, C.; et al. (1998). "Analysis of heart rate variability in posttraumatic stress disorder patients in response to a trauma-related reminder". *Biological Psychiatry* **44** (10): 1054–1059.

[2] - Nickel, P.; F. Nachreiner (2003). "Sensitivity and Diagnostics of the 0.1-Hz Component of Heart Rate Variability as an Indicator of Mental Workload". *Human Factors* **45** (4): 575–590.

[3] - Jönsson, P. (2007). "Respiratory sinus arrhythmia as a function of state anxiety in healthy individuals". *International Journal of Psycho-physiology* **63** (1): 48–54.

HRV Measures

Relative measure of data quality: [4]

NN/RR – fraction of total RR intervals that are classified as normal-to-normal

Commonly used **time-domain** short-term measures:* [4]

AVNN	Average of all NN intervals
SDNN	Standard deviation of all NN intervals
rMSSD	Square root of the mean of the squares of differences between adjacent NN intervals
pNN50	Percentage of differences between adjacent NN intervals that are greater than 50 ms

* - Presented as last seen at http://www.physionet.org/tutorials/hrv-toolkit/, of 2nd April 2013

[4] - Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng C-K, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation* **101**(23):e215-e220 [Circulation Electronic Pages;http://circ.ahajournals.org/cgi/content/full/101/23/e215]; 2000 (June 13).

HRV Measures

Commonly used **frequency-domain** short-term measures:*[4]

TOTPWR	Total spectral power of all NN intervals up to 0.04 Hz
VLF	Total spectral power of all NN intervals between 0.003 and 0.04 Hz
LF	Total spectral power of all NN intervals between 0.04 and 0.15 Hz.
HF	Total spectral power of all NN intervals between 0.15 and 0.4 Hz
LF/HF	Ratio of low to high frequency power

* - Presented as last seen at http://www.physionet.org/tutorials/hrv-toolkit/, of 2nd April 2013

[4] - Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng C-K, Stanley HE. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation* **101**(23):e215-e220 [Circulation Electronic Pages;http://circ.ahajournals.org/cgi/content/full/101/23/e215]; 2000 (June 13).

Webservice

A simple definition of **webservice**:

> *An arbitrary **function** or set of operations that can be accessed by other programs over the web (HTTP).*

Characteristics:

- **Machine-to-Machine** communication.
- Promotes **cloud interoperability** between machines and OSs.

Motivation

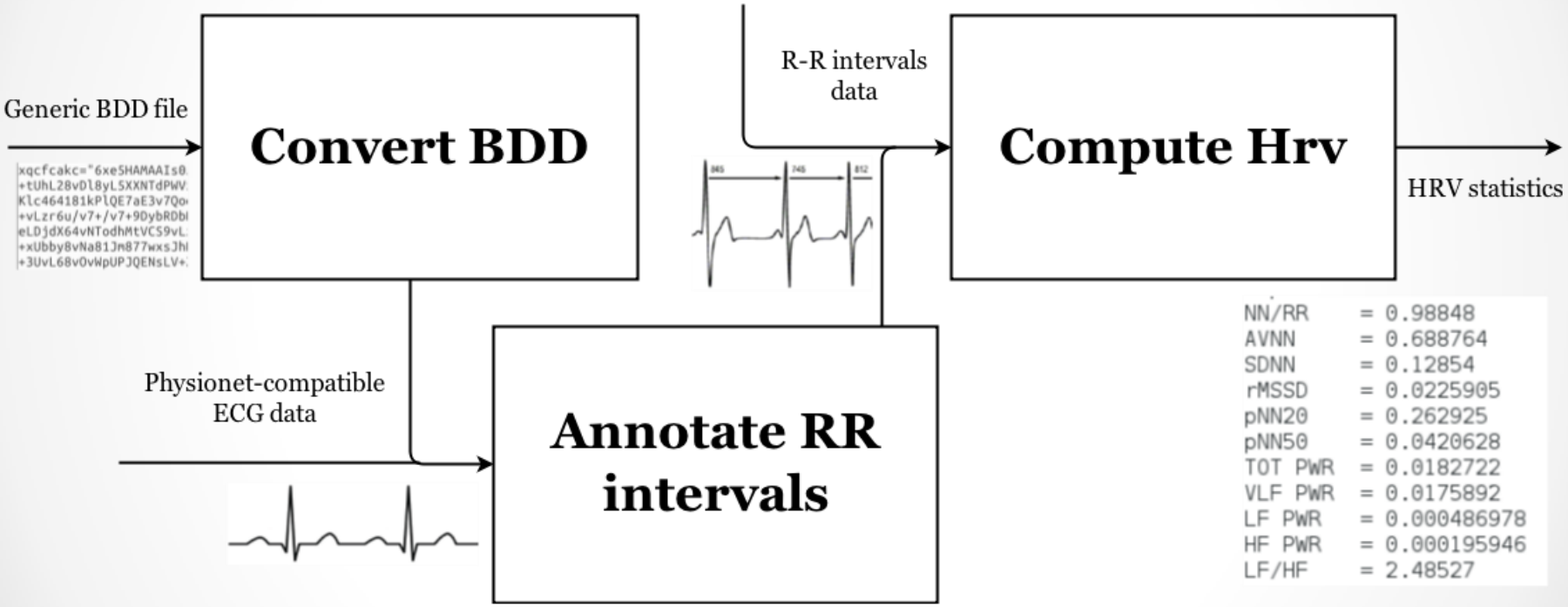
Why a HRV webservice?

- To provide a validated cloud **API** to applications that use **Vital Jacket** or other heart monitors.

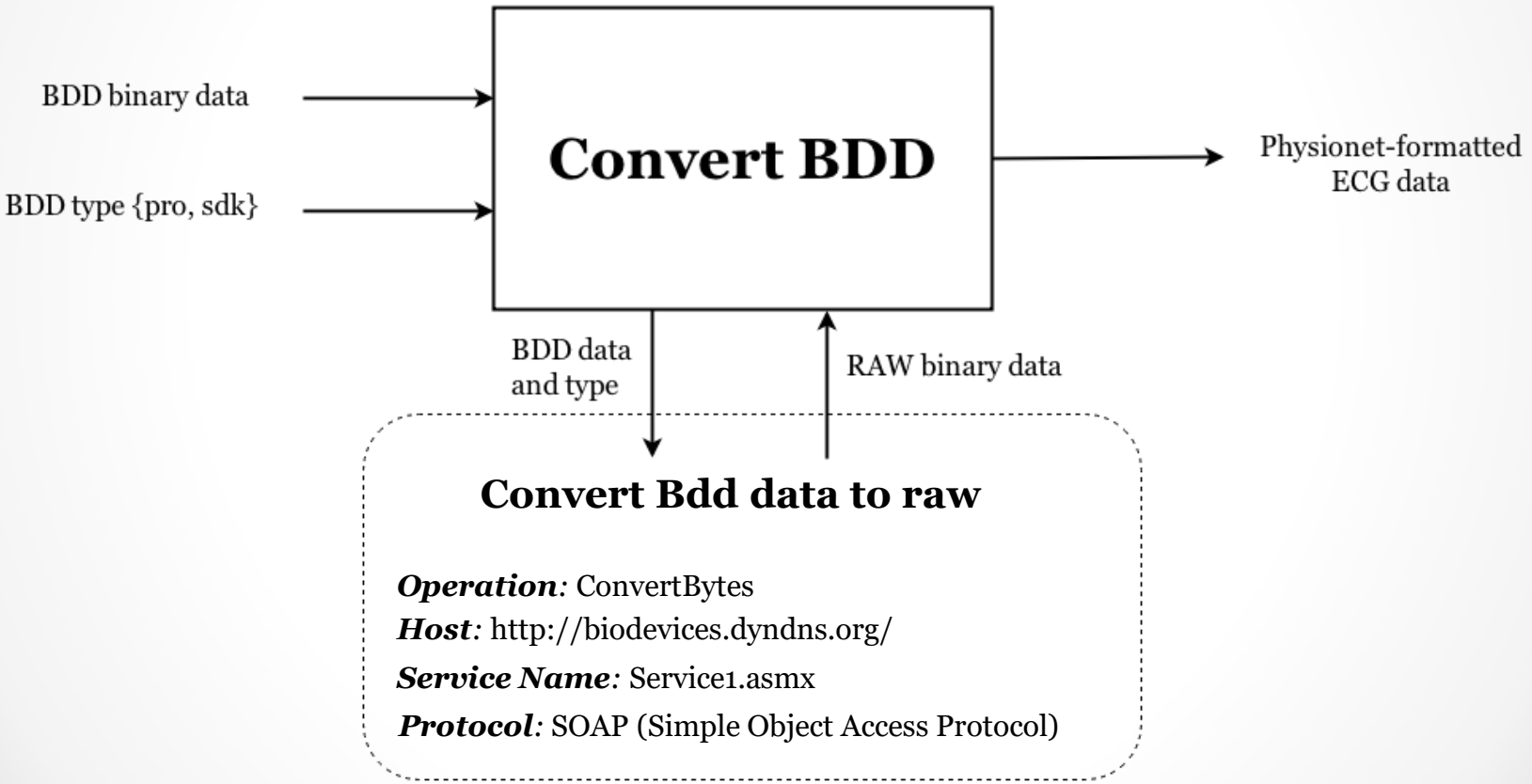
Main motivator:

- Cloud-based webservice made available to the FutureCities platform.

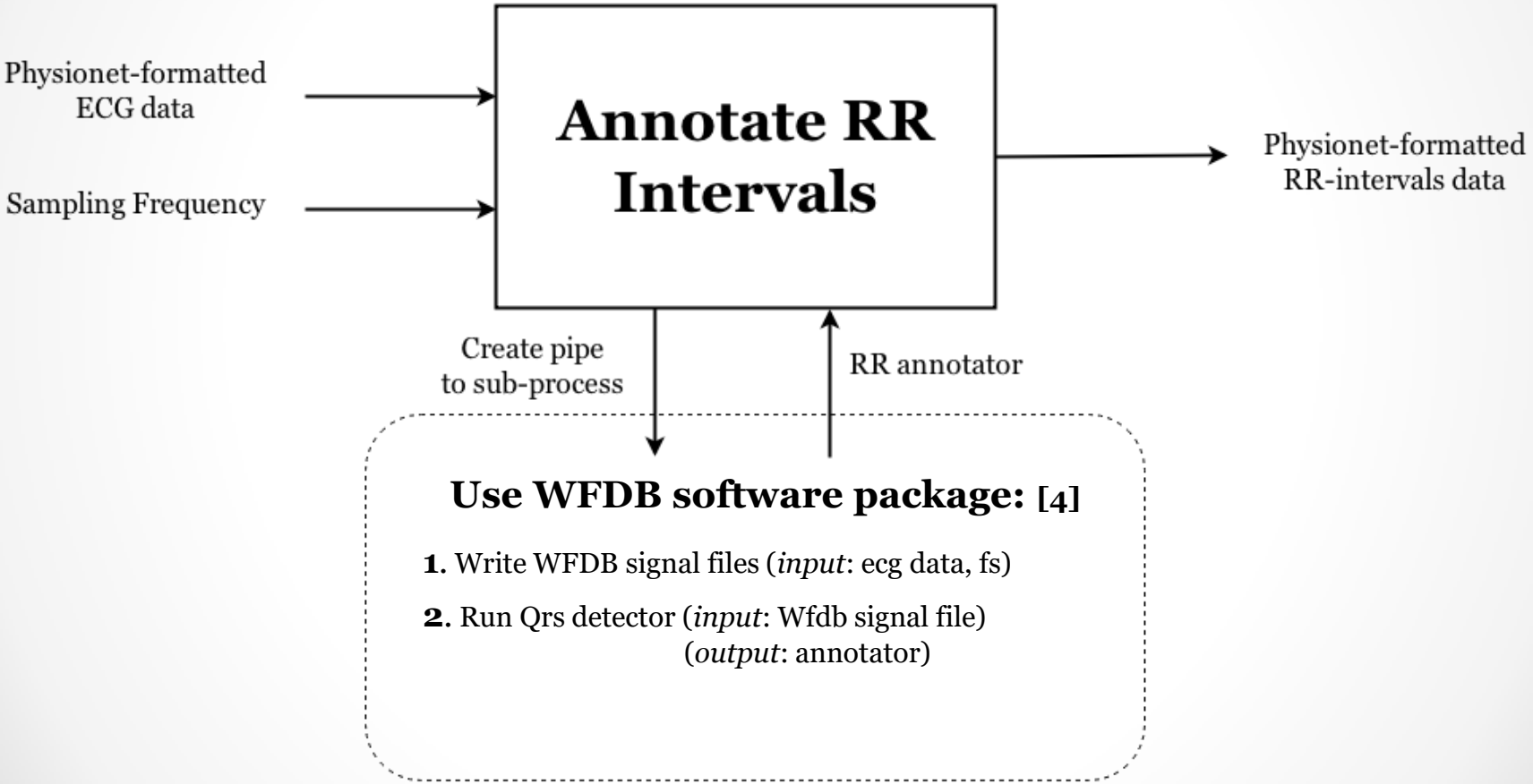
Process Diagram



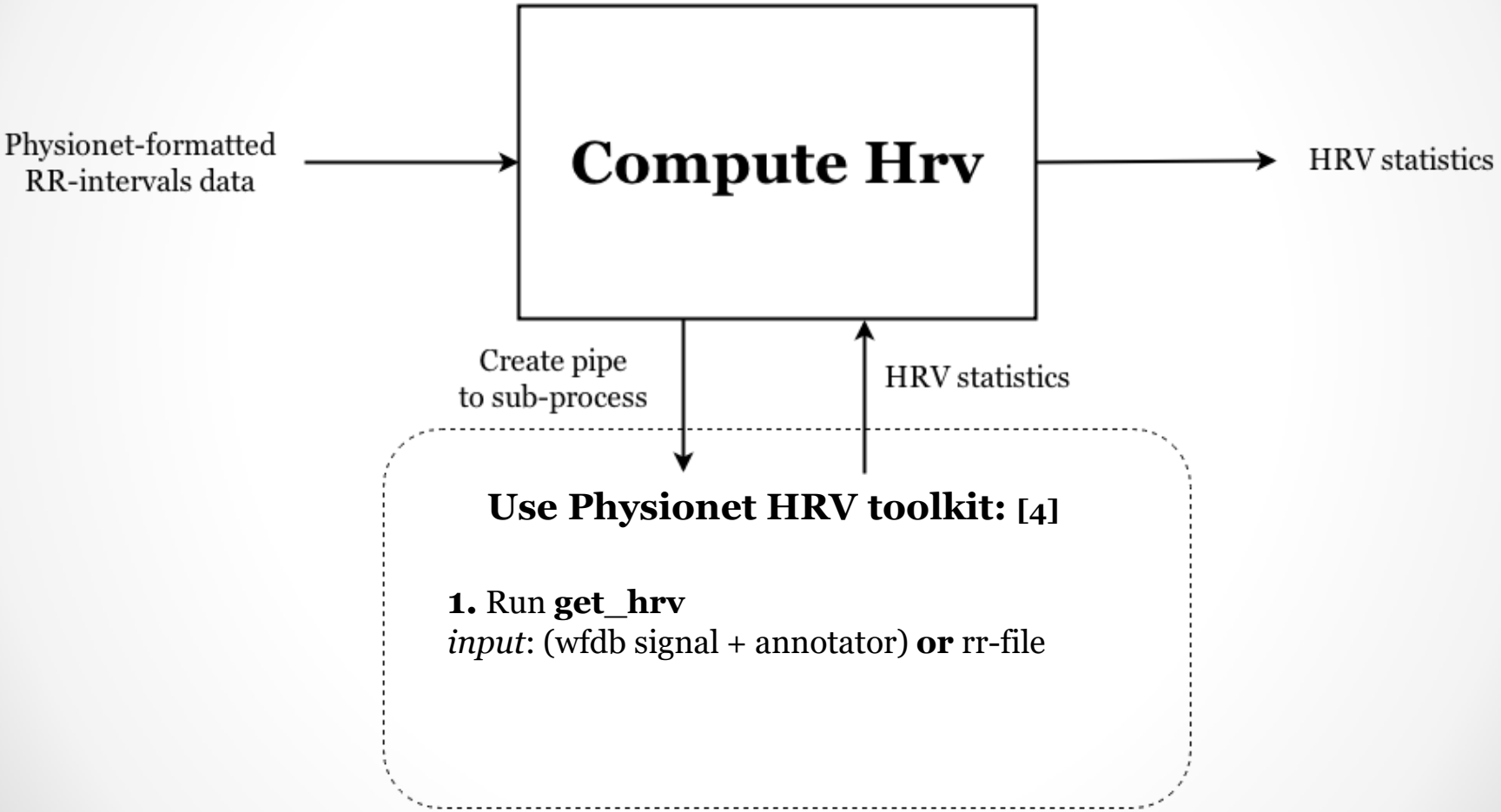
Modules: Convert BDD



Modules: Annotate RR

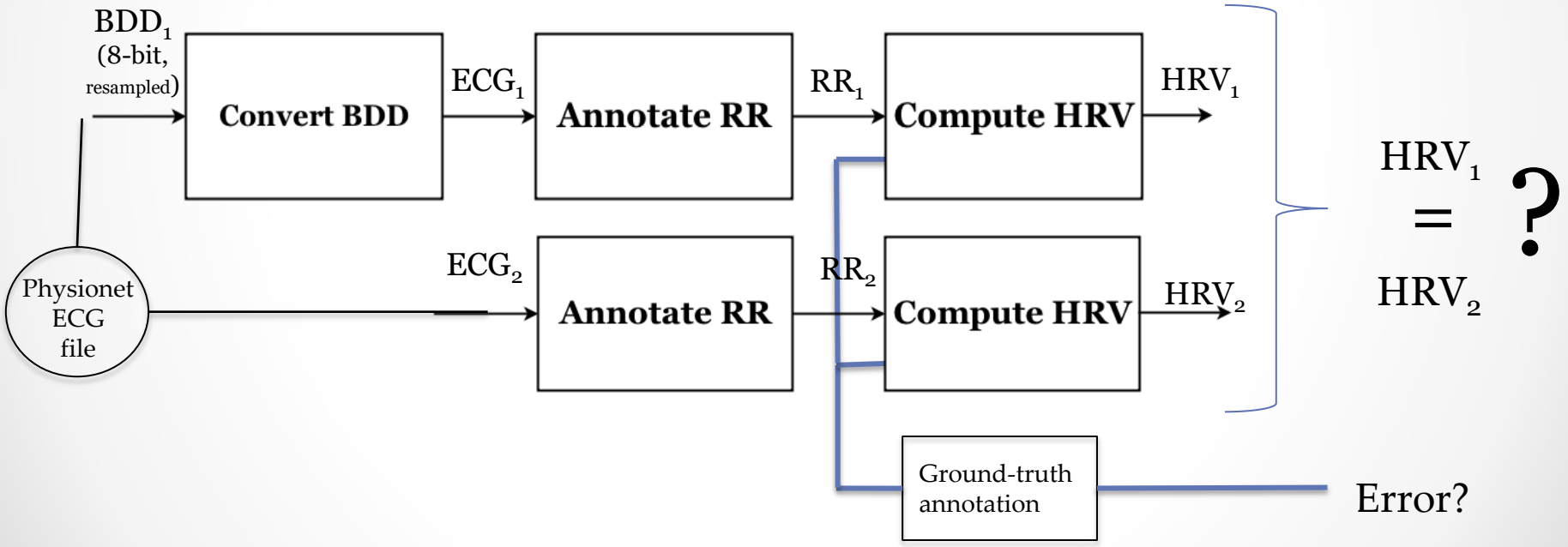


Modules: Compute Hrv



Validation

Question: *Given a Physionet ECG signal and its equivalent in bdd format, do they produce the same output, i.e. HRV statistics?*



Validation

Dabatase: The MIT-BIH Normal Sinus Rhythm Database (nsrdb)[4]

- 18 records of ≈ 24h of duration
- Sampled at 128 Hz

AVERAGE - ALL (18)			
SHORT HRV STATS	Ground Truth*	HRV_1 (BDD)	% ERROR
NN/RR	0.978113	0.978113	0.00%
AVNN	0.800968	0.800968	0.00%
SDNN	0.128432	0.128432	0.00%
rMSSD	0.037652	0.037652	0.00%
pNN20	0.475974	0.475974	0.00%
pNN50	0.141238	0.141238	0.00%
TOT PWR	0.020626	0.020626	0.00%
VLF PWR	0.002373	0.018642	685.47%
LF PWR	0.001323	0.001323	0.00%
HF PWR	0.000661	0.000661	0.00%
LF/HF	2.480736	2.480736	0.00%

* - available at http://www.physionet.org/tutorials/hrv-toolkit/hrstats/

[4] - Goldberger et all. PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. *Circulation* **101**(23):e215-e220 [Circulation Electronic Pages;http://circ.ahajournals.org/cgi/content/full/101/23/e215]; 2000 (June 13).

Validation: Fixing a bug

Default command: get_hrv -s -L -f "0.2 20 -x 0.4 2.0" -p "20 50" rec atr

New command:

get_hrv -s -L -f "0.2 20 -x 0.4 2.0" -p "20 50" -P "0 0.0033 0.0033 0.04 0.04 0.15 0.15 0.4" rec atr

AVERAGE - ALL (18)			
SHORT HRV STATS	Ground Truth*	HRV_1 (BDD)	% ERROR
NN/RR	0.978113	0.978113	0.00%
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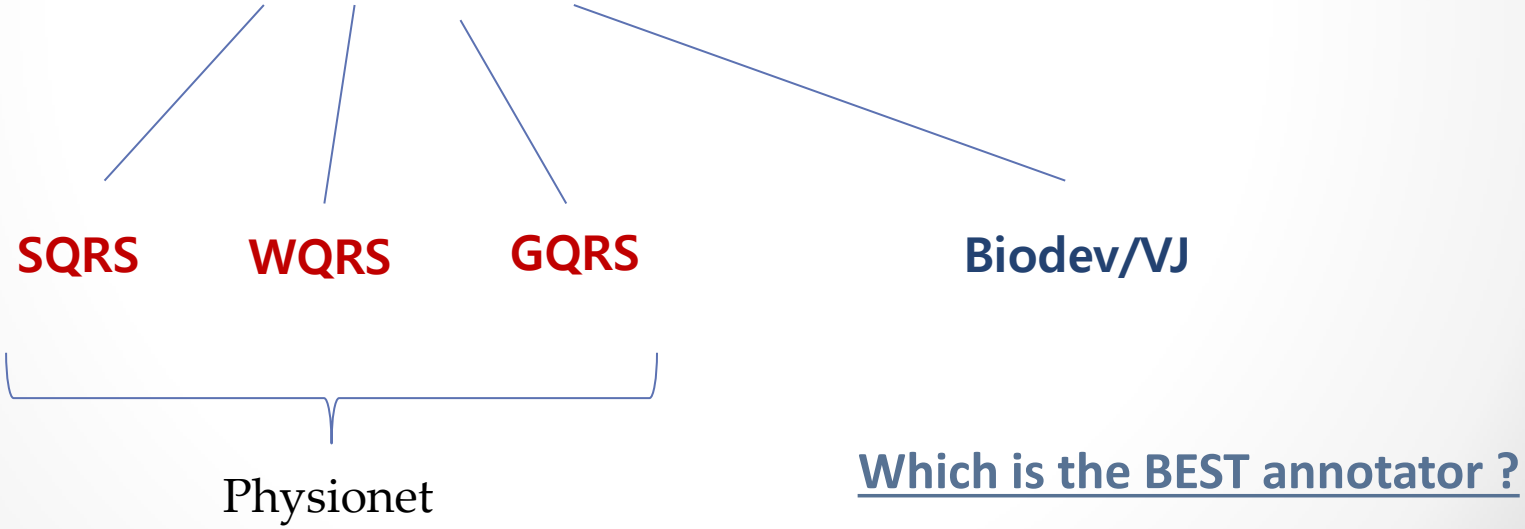
LF/HF	2.480736	2.480736	0.00%

* - available at http://www.physionet.org/tutorials/hrv-toolkit/hrstats/

Validation: Qrs detectors

Human agreement annotators (ground-truth) were used for previous validation…

But we need a **qrs detector** to annotate the RR intervals!



Which is the BEST annotator ?

VJ vs. each Physionet detector:

SQRS

AVERAGE - ALL (18)					
SHORT HRV STATS	Ground Truth	VJ as annotator	% ERROR	SQRS as annotator	% ERROR
NN/RR	0.978113	0.97620	0.20%	0.94391	3.50%
AVNN	0.800968	0.80027	0.09%	0.80365	0.33%
SDNN	0.128432	0.13106	2.04%	0.12973	1.01%
rMSSD	0.037652	0.03666	2.63%	0.03723	1.11%
pNN20	0.475974	0.44712	6.06%	0.45984	3.39%
pNN50	0.141238	0.13205	6.51%	0.13855	1.90%
TOT PWR	0.020626	0.02066	0.16%	0.02281	10.61%
VLF PWR	0.002373	0.00234	1.39%	0.00318	33.92%
LF PWR	0.001323	0.00124	5.93%	0.00150	13.13%
HF PWR	0.000661	0.00064	3.19%	0.00069	4.44%
LF/HF	2.480736	2.53294	2.10%	2.46488	0.64%

VJ vs. each Physionet detector:

WQRS

AVERAGE - ALL (18)					
SHORT HRV STATS	Ground Truth	VJ as annotator	% ERROR	WQRS as annotator	% ERROR
NN/RR	0.978113	0.97620	0.20%	0.91383	6.57%
AVNN	0.800968	0.80027	0.09%	0.80253	0.20%
SDNN	0.128432	0.13106	2.04%	0.12849	0.05%
rMSSD	0.037652	0.03666	2.63%	0.03699	1.76%
pNN20	0.475974	0.44712	6.06%	0.46135	3.07%
pNN50	0.141238	0.13205	6.51%	0.13541	4.13%
TOT PWR	0.020626	0.02066	0.16%	0.02258	9.48%
VLF PWR	0.002373	0.00234	1.39%	0.00347	46.24%
LF PWR	0.001323	0.00124	5.93%	0.00177	33.89%
HF PWR	0.000661	0.00064	3.19%	0.00078	17.50%
LF/HF	2.480736	2.53294	2.10%	2.42620	2.20%

VJ vs. each Physionet detector:

GQRS

AVERAGE - ALL (18)					
SHORT HRV STATS	Ground Truth	VJ as annotator	% ERROR	GQRS as annotator	% ERROR
NN/RR	0.978113	0.97620	0.20%	0.91222	6.74%
AVNN	0.800968	0.80027	0.09%	0.80683	0.73%
SDNN	0.128432	0.13106	2.04%	0.12699	1.12%
rMSSD	0.037652	0.03666	2.63%	0.03721	1.16%
pNN20	0.475974	0.44712	6.06%	0.46459	2.39%
pNN50	0.141238	0.13205	6.51%	0.13991	0.94%
TOT PWR	0.020626	0.02066	0.16%	0.02219	7.56%
VLF PWR	0.002373	0.00234	1.39%	0.00317	33.56%
LF PWR	0.001323	0.00124	5.93%	0.00187	41.25%
HF PWR	0.000661	0.00064	3.19%	0.00079	19.63%
LF/HF	2.480736	2.53294	2.10%	2.43525	1.83%

Validation: Qrs detectors

Results:

- There was not a Physionet annotator that was consistently better than the others.
- So, the Physionet annotator that produces the **highest NN/RR ratio** may be selected. However, its 3 times the computational cost of choosing one directly.

AVERAGE - ALL (18)					
SHORT HRV STATS	GROUND TRUTH	VJ as annotator	% ERROR	BEST annotator	% ERROR
NN/RR	0.978113	0.97620	0.20%	0.96930	0.90%
AVNN	0.800968	0.80027	0.09%	0.80107	0.01%
SDNN	0.128432	0.13106	2.04%	0.13081	1.85%
rMSSD	0.037652	0.03666	2.63%	0.03675	2.38%
pNN20	0.475974	0.44712	6.06%	0.45330	4.76%
pNN50	0.141238	0.13205	6.51%	0.13428	4.93%
TOT PWR	0.020626	0.02066	0.16%	0.02075	0.61%
VLF PWR	0.002373	0.00234	1.39%	0.00237	0.33%
LF PWR	0.001323	0.00124	5.93%	0.00133	0.40%
HF PWR	0.000661	0.00064	3.19%	0.00071	7.56%
LF/HF	2.480736	2.53294	2.10%	2.44600	1.40%

Only IF the bands are defined in the command!

Computing times

				Average Real Time Spent (seconds)		
File	**Size (initial)**	**Size after convertion**	**Duration**	**Convert Bdd**	**Compute Hrv (wfdb signal)**	**Compute Hrv (rrlist)**
16265.bdd	11.5M	45M	25h:06m:00s	220 s	9.79 s	4.91 s
30.bdd	220k	870k	15m:00s	4.10 s	0.311 s	0.207 s

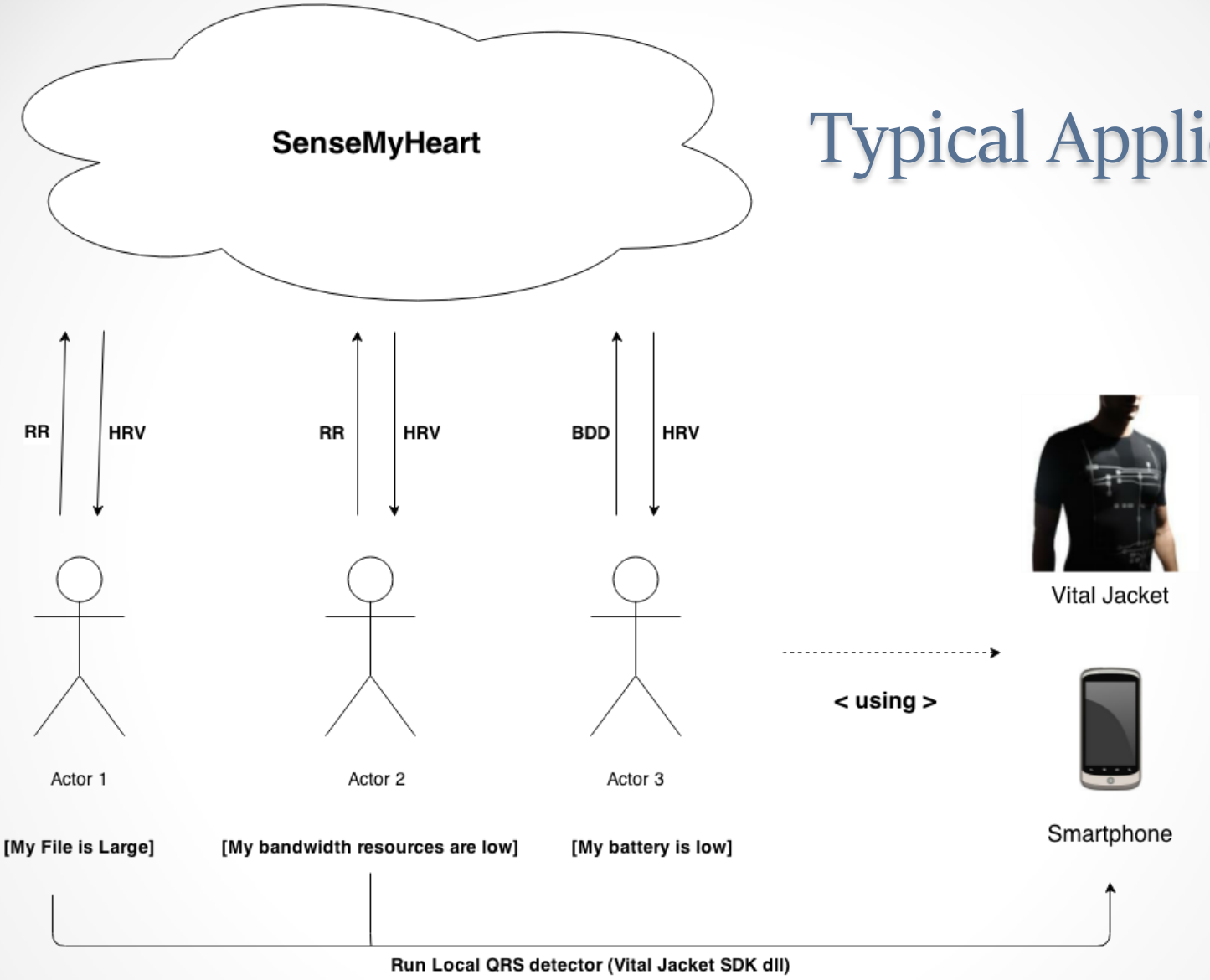
WebService: Operations

Operation	Description
getHrvFromBdd	Compute HRV short-term statistics from BDD encoded binary data
getHrvFromEcg	Compute HRV short-term statistics from ECG Physionet-formatted binary data
getHrvFromRR	Compute HRV short-term statistics from RR intervals Physionet-formatted binary data

Architecture: SOAP

- Stateful and complex operations
- Supports asynchronous processing and invocation
- Defines formal contracts

Typical Application



Future Directions

- **Deploy** the webservice**.**
- **Add operations** to compute stress/anxiety indicators from HRV measures, based on metrics presented in previous studies:
  - Decrease of HF activity under conditions of acute time pressure and emotional strain. [2]
  - Reduced HRV in individuals reporting a greater frequency and duration of daily worry. [5]

[2] - Nickel, P.; F. Nachreiner (2003). "Sensitivity and Diagnostics of the 0.1-Hz Component of Heart Rate Variability as an Indicator of Mental Workload". *Human Factors* **45** (4): 575–590.

[5] - Brosschot, J.F.; E. Van Dijk, J.F. Thayer (2007). "Daily worry is related to low heart rate variability during waking and the subsequent nocturnal sleep period". *International Journal of Psychophysiology* **63**

Thank you!

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