Poster: Ontology-Based Heartbeat Classification for Mobile Electrocardiogram Monitoring

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1. INTRODUCTION
Recently, it has become possible to integrate a Holter monitor with mobile devices to supply the requirements of the monitoring function precisely to allow a person to continue with her/his normal routines. A person can lead a normal life while a sensor acquires electrocardiogram (ECG) data continuously and sends them to his/her mobile device using Bluetooth. Consequently, the individual's long-term ECG signal can be observed seamlessly.

We propose an ontology-based heartbeat classification method based on long-term observation of an individual's heart activity, which includes automatic ontology learning. Inspired by the fact that experts diagnose illness via their clinical experiences, as well as distinct individual characteristics, our classification system detects arrhythmia using *Arrhythmia/Profile Ontology* for distinct individual characteristics and *Universal Ontology* for clinical experience. Using these ontologies enables us to achieve analysis and systematic management for mobile ECG Holter monitoring.

2. ONTOLOGY-BASED CLASSIFIER
Decision trees constitute a non-parametric supervised learning method used for classification and can be converted to rules easily for inference. Learning a decision tree involves calculating the uncertainties of features and selecting the most general one. The uncertainty calculation is based on the concept of entropy, and the learning method selects the most general node of all the features. In our system, these steps are iterated until all heartbeats have been classified. Decision trees have three main components: a root node, leaf nodes, and branches. The root node is the starting point of the tree, and the leaf nodes represent the final result of a combination of branches. Thus, the root node is the most general feature, a branch is a condition, and a leaf node is a combination of feature values as an annotation (the result of classification). In the first stage of our system, the *Arrhythmia Ontology* has only an annotation set. After learning the decision tree, combinations of the values from a root node to the leaf nodes are converted into inference rules. If similar leaf nodes exist in the decision tree, combinations of these nodes are joined by the OR operator as a rule.

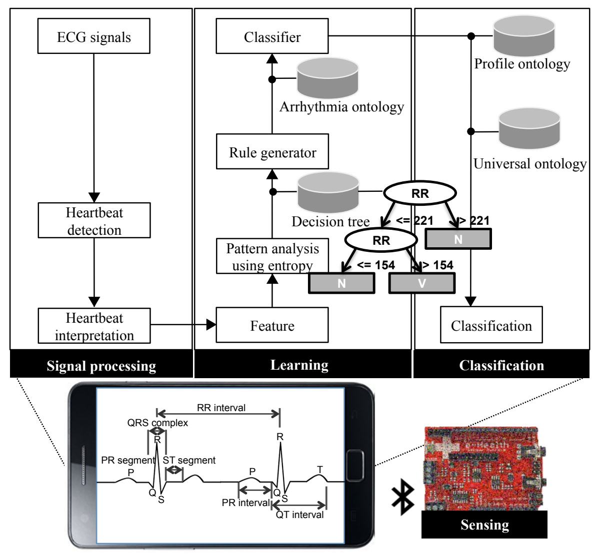

Figure 1. Functional architecture & example of a decision tree

3. CASE STUDY
As a case study, we applied a decision tree classifier to record ID 106 in the MIT-BIH Arrhythmia Database [1]. In our example of a decision tree (see Fig. 1), there are two branches that depend on the value of the RR interval I_{RR}, and there are three leaf nodes: two are for the normal heartbeat (N) class, and one is for the premature ventricular contraction (V) class. Thus, the decision tree is converted into two rules, one for each class:

$$\exists_x\{N(x) \equiv (I_{RR}(x) \leq 154) \sqcup (I_{RR}(x) > 221)\},$$

$$\exists_x\{V(x) \equiv (I_{RR}(x) \leq 221) \sqcap (I_{RR}(x) > 154)\}.$$

These rules are integrated into the *Arrhythmia/Profile Ontology* as individual characteristics. The *Universal Ontology* is used to verify the classification results using the *Arrhythmia Ontology* as reference and to classify a heartbeat in the absence of a rule in the *Arrhythmia Ontology* as clinical experiences.

4. REFERENCES
[1] G. B. Moody and R. G. Mark, "The impact of the MIT-BIH arrhythmia database," *IEEE Engineering in Medicine and Biology Magazine*, vol. 20, no. 3, pp. 45-50, May/Jun. 2001.

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