PhysmoNote: Simple Web Viewing, Annotating, and Time Map Navigating for PhysioNet Databases

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Abstract

PhysmoNote is a new web-based viewer for the PhysioNet repository of complex biomedical signals. It incorporates significant features like the simplified navigation of databases and records, the ability to zoom into signals based on non-normal annotations, a resizable viewing window to increase detail in signals, and improvements to user-created annotations. By offering a simple interface and an easy way to locate and find non-normal signals, PhysmoNote provides an effective viewing option to PhysioNet's open databases.

1. Introduction

The Research Resource for Complex Physiologic Signals, commonly known as PhysioNet [1], offers a large collection of open data, including several collections of cardiac data, that is freely available and accessible via the internet. PhysioNet has its own web-based data browser, signal visualiser, and annotator client called LightWAVE [2], written in JavaScript, specifically for accessing its data on the web.

CosmoNote [3][1] is a web-based application that we designed and built for viewing, listening to, and annotating expressive (not deadpan) music information in the ERC project COSMOS (Computational Shaping and Modeling of Musical Structures)[2]. CosmoNote grew out of the tradition of audio annotation software for music [4] and speech [5]. As the research evolved to include relationships between music and synchronised physiological data, we added the capability to view concurrent physiological signals in CosmoNote. Having trialed the ability to view physiological signals in CosmoNote, a next step in its evolution was to test its ability to handle the breadth of physiological signals on PhysioNet. Using code from CosmoNote (itself built using the D3 [6] JavaScript library) we created a new PhysioNet web client called PhysmoNote[3] for human-centered inspection and analysis of PhysioNet data, as an adjunct to automated or semi-automated analysis of the data. Figure 1 shows a full-page screen capture.

In developing PhysmoNote, we had two goals: 1) to achieve feature parity with LightWAVE and 2) to improve the experience of browsing and visualizing PhysioNet data by adding entirely new features, particularly tailored for cardiac data. The next section describes how we achieved these goals. The examples are also in a YouTube playlist [4].

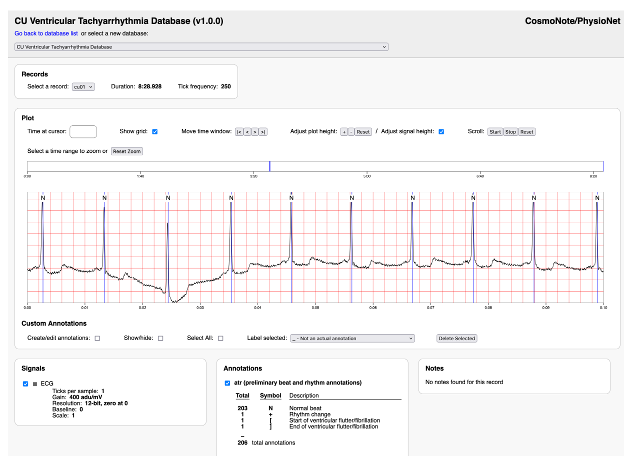

Figure 1. PhysmoNote showing the first record of PhysioNet's CU Ventricular Tachyarrhythmia Database [7].

2. PhysmoNote

A first development goal was for our PhysioNet client to, at a minimum, match the basic features currently available in LightWAVE: 1) allow for the navigation and selection of records (and subrecords if present) in PhysioNet databases; 2) display all signals in a selected record (or subrecord) along with a grid; 3) allow for the navigation

[1] https://cosmonote.isd.kcl.ac.uk
[2] https://cosmos.isd.kcl.ac.uk
[3] https://physmonote.isd.kcl.ac.uk
[4] https://bit.ly/PhysmoNote-features

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of signals by changing the time window (most signals are too long to display in their entirety); 4) display any annotations available for a selected record; 5) display any metadata for selected records including signal, annotation, and note metadata; and, 6) allow users to create their own annotations.

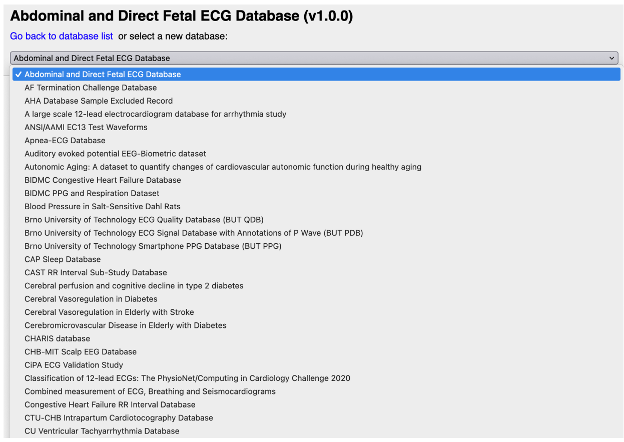

Figure 2. A selection of PhysioNet's open databases from the in situ list with the Abdominal and Direct Fetal ECG Database [8] already selected.

The second goal was to go beyond the basic features of LightWAVE. These improvements were identified as : 1) simplified navigation of PhysioNet databases, records, and subrecords; 2) improved display of record and subrecord metadata; 3) improved display of short-duration records; 4) the ability to zoom into user-specified time windows for a signal; 5) improved search and display of non-normal annotations, especially for cardiac data; 6) improved signal viewing via resizing; and, 7) improved creation and display of user annotations.

The PhysmoNote client has all the six basic features of LightWAVE, plus the improvements and new features in PhysmoNote as described in the following subsections.

2.1. Database and Record Navigation

A main objective was to make the database and record navigation as simple as possible to keep the focus on the analyzing of the data rather than on navigating the interface itself. To avoid having to navigate away to a separate page to choose another database from the PhysioNet list, navigation was improved by providing a drop-down list of PhysioNet databases in situ that users can easily choose from to navigate away and back at any time. The database list is shown in Figure 2.

In LightWAVE, to change the current record of a PhysioNet database, users need to click to a different tab and then to select a record from the select list there. To simplify navigating databases and records, we put all data navigation controls, including databases, records, and subrecords, on a single page, eliminating unnecessary clicks while allowing users to focus on viewing signals and annotations. Figure 3 shows the database and record selection lists, both of which are always displayed on the database/record/subrecord display page.

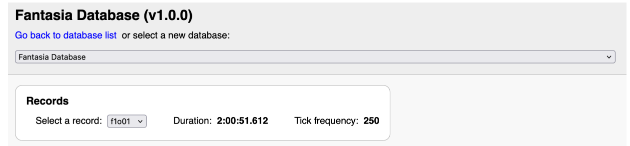

Figure 3. Database navigation (the Fantasia Database [9] is selected) and record selection and information.

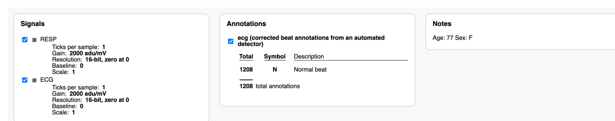

Figure 4. Info boxes for signals, annotations, and notes from the first record of the Fantasia Database.

2.2. Record Metadata

PhysioNet databases have metadata for records (including clinical notes), signals, and annotations. These can be accessed in LightWAVE by clicking to two tabs, one for the record and signal metadata and one for the annotation metadata. To simplify access to metadata in PhysmoNote, all three kinds of metadata are shown on the record display page along with the signals and annotations. Figure 4 shows metadata boxes for signals, annotations, and notes. Note that these boxes do not just contain metadata, there are also controls to toggle the display of signals and annotations on or off. Figure 1 shows the metadata boxes in the context of the entire page.

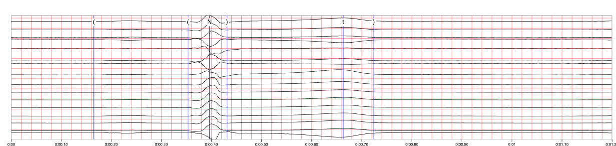

Figure 5. A record from the CiPA ECG Validation Study [10] database with a 1.2 second duration, less than the default time window of 10 seconds.

2.3. Short-duration Records

When most records are loaded in PhysmoNote, like in LightWAVE, only the first ten seconds of that record's signals and annotations are shown. While this works well for records longer than 10 seconds, records significantly shorter than 10 seconds are limited to a small segment of the plot. For PhysmoNote, records of less then ten seconds are re-sized to take the entire width of the signal plot as shown in Figure 5.

2.4. Zooming Signals

In both LightWAVE and PhysmoNote, the entire signal is not normally shown (with exceptions described in Section 2.3). To work around this, LightWAVE allows users to move the time windows in discrete steps of ten seconds forward or back or to the beginning or end of a record. PhysmoNote has the same time window feature. Both LightWAVE and PhysmoNote also feature scrolling in which the signals automatically move forward in time.

A new feature in PhysmoNote is the *time map*, an element inherited from CosmoNote. The time map is the smaller box above the main signal plot in Figure 1 that shows the time range for the entire record. By selecting a time range in the time map, the main viewing area zooms into the signals (and annotations) within the selected time range. Time ranges can be adjusted from the very small (less than a second) to the entire time span of the record. Figure 6 shows a time selected in the time map (the grey box) and the zoomed signal/annotation plot. The zooming feature, when combined with the non-normal annotations feature, allows users to zoom in to notable regions as described in Section 2.5.

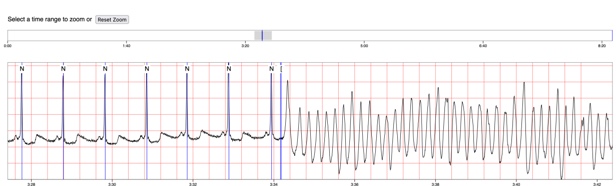

Figure 6. Zooming into a time range around an non-normal annotation in the first record of the CU Ventricular Tachyarrhythmia Database.

2.5. Non-normal Annotations

PhysmoNote improves data analysis, especially for cardiac data, with a novel exploration feature: in the zoom box described in Section 2.4, any non-normal annotations for a selected record are shown as blue lines. The blue lines serve as guides for selecting time ranges around that non-normal annotation, allowing an analysis of signal changes surrounding the annotation. For cardiac data, an annotation of type N is used to mark normal beats. To display non-normal annotations, we simply display any non-N annotation in the zoom box. Note that normal, type N beats are still shown in the main plot.

2.6. Resizable Viewing Area

The zooming feature described in Section 2.4 allows for the signal viewing area to be adjusted horizontally. The ability to adjust the viewing area vertically can also help with data analysis, especially for cases in which there are a large number of signals stacked in the viewing area, making the signals difficult to differentiate one from another. We added a feature in PhysmoNote to change the vertical size of the viewing area. This can be done while also increasing the size of the signals or while keeping signals the same size but increasing the space between them. Figure 7 shows a plot with several signals that are difficult to differentiate. Figure 8 shows the same signals but with an increased height, allowing the signals to be more visually separable.

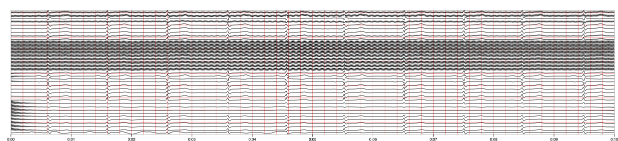

Figure 7. The Wilson Central Terminal ECG Database [11] has many signals, making it difficult to read.

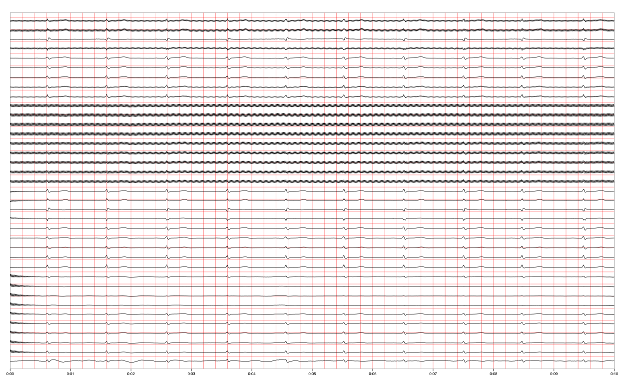

Figure 8. The Wilson Central Terminal ECG Database signal plot with better spacing after its height was increased.

2.7. User Annotations

LightWAVE allows users to create their own annotations for records, storing them in the client browser. PhysmoNote also allows users to create and edit their own annotations that are stored in their client browser. However, there are significant differences in how user annotations are implemented. In LightWAVE, users must navigate to a tab different from the signal viewing tab and work through separate controls to start annotating. Also, when a user creates annotations in LightWAVE, they are presently indistinguishable from any annotations that are stored with the records. There is also no way to restore any original annotations stored with a record or to turn of the display of user annotations.

In PhysmoNote, all user annotation controls are labelled and easily reachable beneath the main signal/annotation viewing area. Figure 1 shows the user annotations controls in context. Users can create, update, label, and delete their annotations. User-created annotations are also in a different color, green, to distinguish them from record annotations, blue. The display of user annotations or record annotations can be turned on and off. Figure 9 shows two normal beat user annotations for a database record that did not itself include annotations.

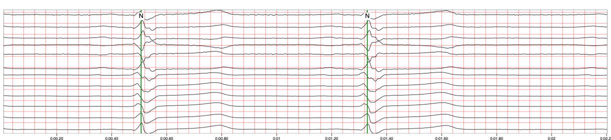

Figure 9. User annotations for the Norwegian Endurance Athlete ECG Database [12].

3. Discussion and Future Work

The LightWAVE PhysioNet client is the default client for viewing PhysioNet data on the web. PhysmoNote was designed from the start to have feature parity with LightWAVE and has achieved that goal. At the same time, PhysmoNote has features beyond those of LightWAVE that should make it useful for human-centered analysis of PhysioNet data, especially cardiac data.

For future work, the next major feature we will develop is the ability to share links that go directly to specific records in PhysioNet databases. This will allow easy sharing of data since anyone who receives the link will not have to navigate through a potentially large number of records in order to find the one of interest. In addition to sharing records via links, we will also enable the sharing of the visual parameters of the plot along with the link. For example, if the plot for the record of interest is zoomed into a particular time range (around a non-normal annotation), when someone receives the link to the record, the plot will also be zoomed into that time range. In this way, salient parts of signals can be shared.

Acknowledgments

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