SaECG: a new FHIR Data format revision to enable continuous ECG storage and monitoring

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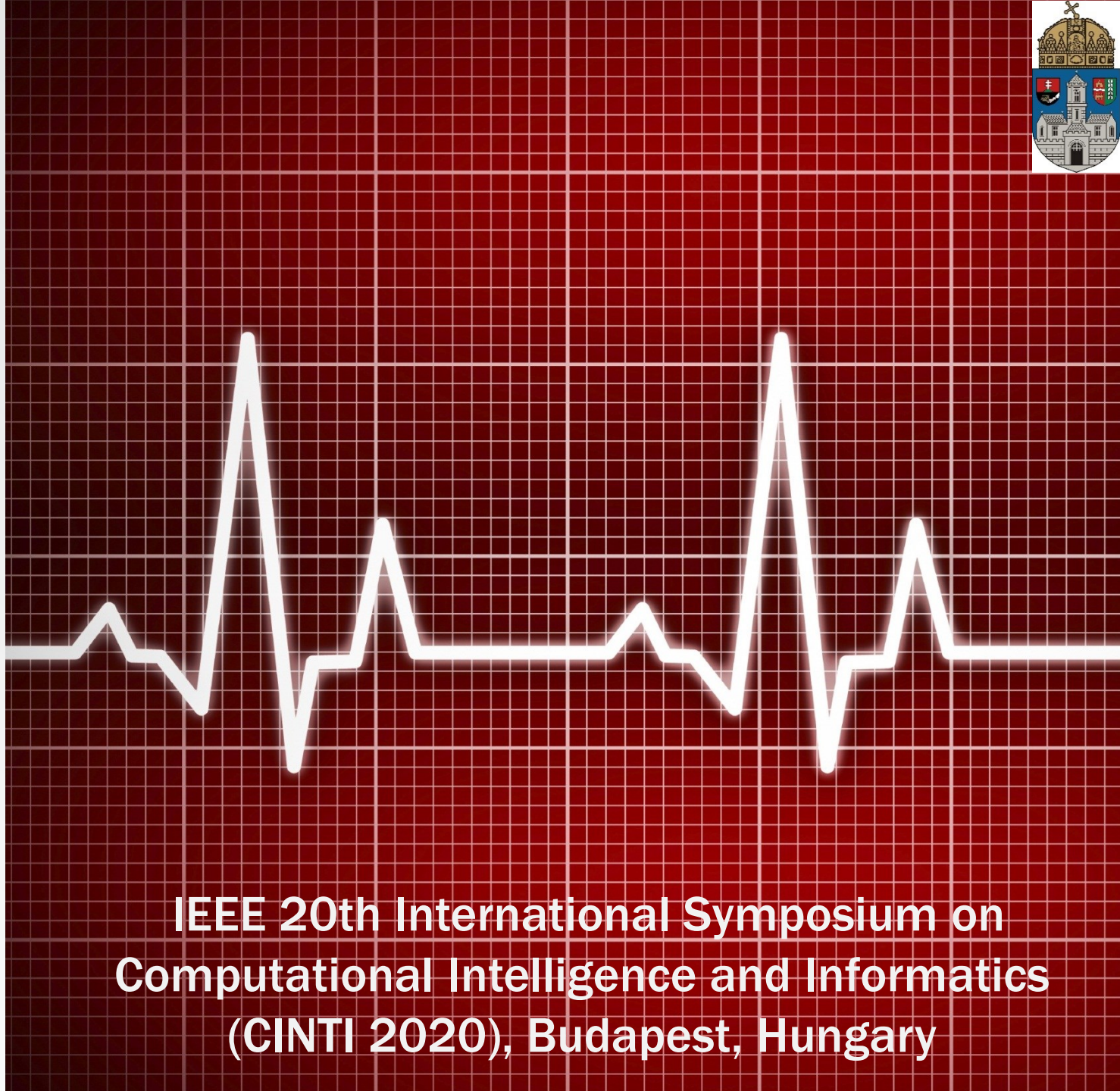

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INTRODUCTION

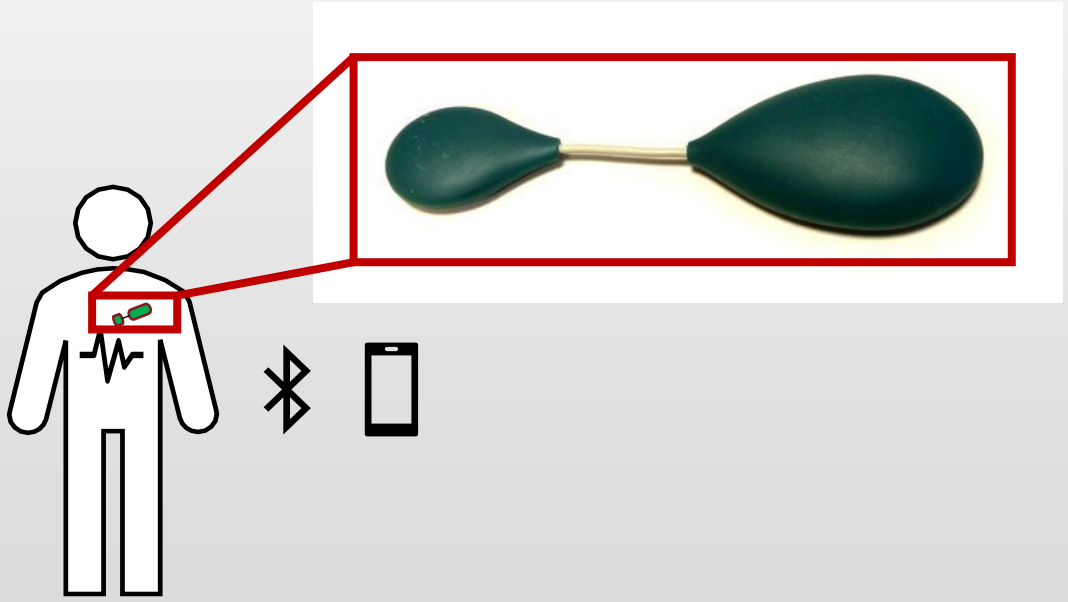
- Many different standards & file formats for medical data digitalization and storage,
- Interoperability problems between different formats !
- Stream-like ECG monitoring for long-term,
- HL7-aECG is a good starting point to make an extension for stream-like ECG data storage,
- Stream-enabled annotated ECG (SaECG) enabling long-term ECG data storage.

MOTIVATION

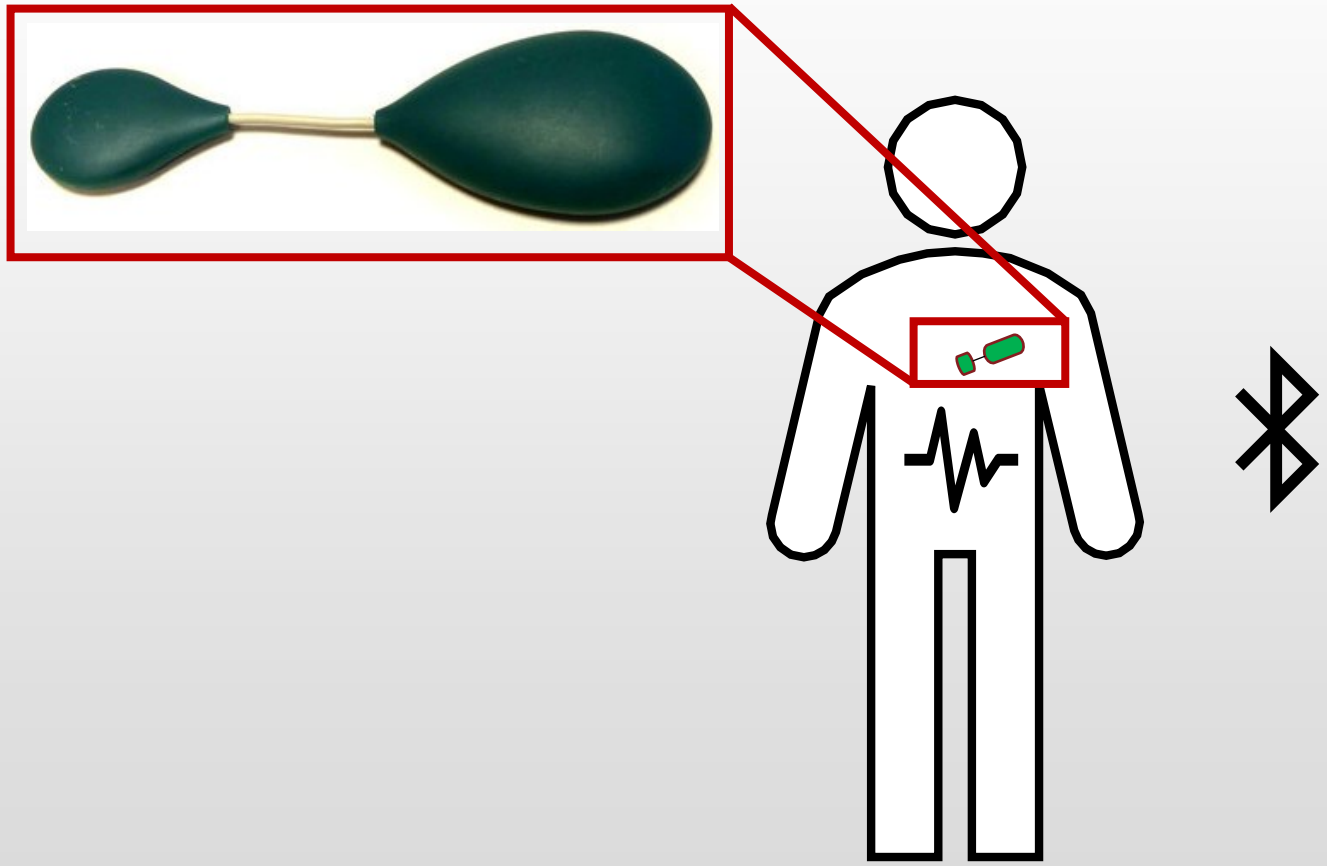
- No support for streaming ECG data storage.
- No possibility for daily ECG monitoring during different daily activities.

➢Single channel Savvy ECG data enabled.

➢Working for many hours / days.



Savvy for real-time ECG monitoring (Part of our proposed solution)



DrHealth App

Plugin

- Device connection.
- Data collection service.
- Data buffering.

UI

- Data acquisition & storage (local / remote)
- Data visualization
- Data monitoring & Analysis (local / remote)

Old HL7-aECG Format Example

- **(a)** is the bigger XML node that contains the information regarding the whole observation process.
- **(b)** presents the set of nodes that defines basic information regarding the observation such as the "id", which defines an aECG record for HL7. The observation status, the subject patient, the performer of the given observation, and Some extra information about the used device.
- **(c)** is the node that defines a one lead component from the ECG record.
- **(d)** defines how to store an ECG observation record with multiple leads.
- **(e)** presents a set of nodes used to define the currently presented lead from the ECG record. It contains some parameters such as the period in milliseconds between each ECG value, the minimum and the maximum voltage within the recorded data.
- **(f)** is the most important XML node which is used to store the sensed ECG data for the current observation's lead. The values are stored in an XML node' attribute called "value" inside the node "<data>" and are separated with a single white character (space character).

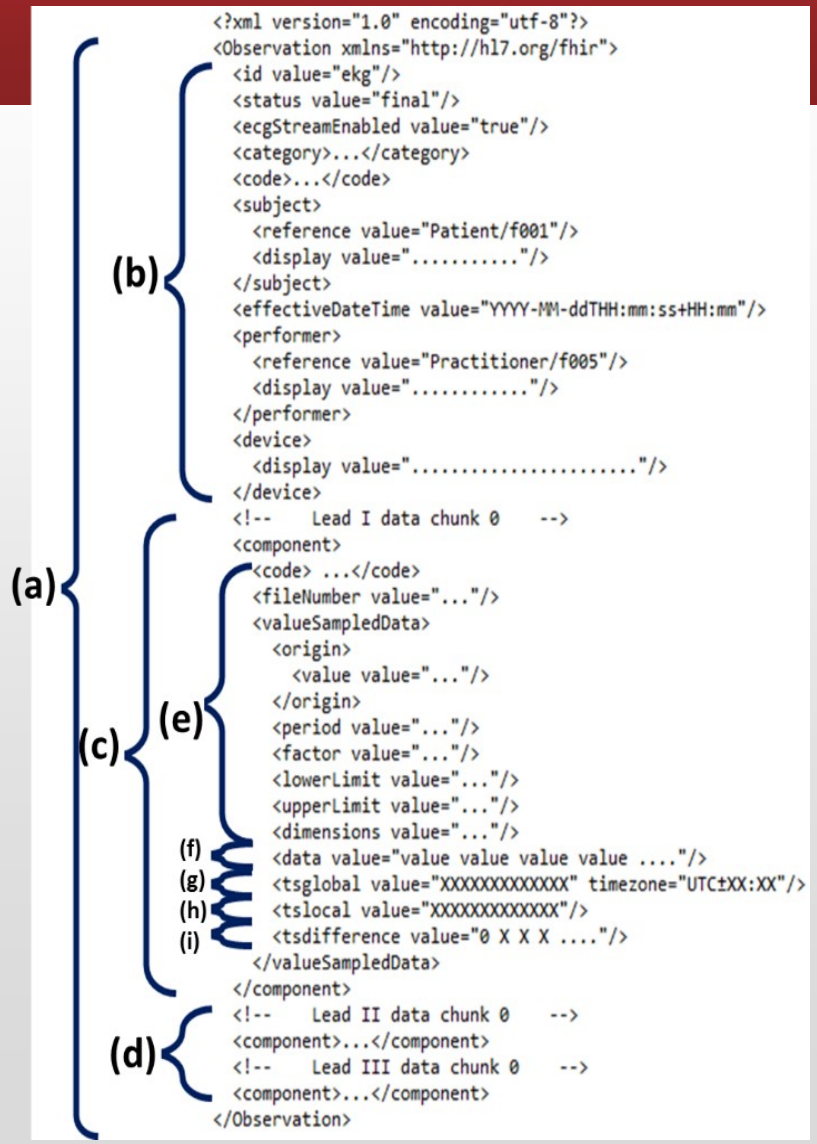
```
<?xml version="1.0" encoding="UTF-8"?>
<Observation xmlns="http://hl7.org/fhir">
  <id value="ekg"/>
  <status value="final"/>
  <category>...</category>
  <code>...</code>
  <subject>
    <reference value="Patient/f001"/>
    <display value="..........."/>
  </subject>
  <effectiveDateTime value="YYYY-MM-ddTHH:mm:ss+HH:mm"/>
  <performer>
    <reference value="Practitioner/f005"/>
    <display value="..........."/>
  </performer>
  <device>
    <display value="......................."/>
  </device>
  <!--    Lead I data chunk 0    -->
  <component>
    <code> ...</code>
    <valueSampledData>
      <!--    Zero potential    -->
      <origin>
        <value value="..."/>
      </origin>
      <!--    period in ms = 1000/frequency    -->
      <period value="..."/>
      <!--     factor.value    -->
      <factor value="....."/>
      <!--     voltage-min    -->
      <lowerLimit value="-3300"/>
      <!--     voltage-max    -->
      <upperLimit value="3300"/>
      <dimensions value="1"/>
      <data value="2041 2043 2037 2047 2060 2062 ...."/>
    </valueSampledData>
  </component>
  <!--    Lead II data chunk 0    -->
  <component>...</component>
  <!--    Lead III data chunk 0    -->
  <component>...</component>
</Observation>
```

(a) (b) (c) (d) (e) (f)

SaECG Format Example

Same as the old format + the following

- **(g)** is the "<tsglobal>" node that defines the starting Unix timestamp of the given observation. This should be stored from a trusted device other than the sensor itself. It could be used to compare with the Unix timestamp of the sensor, and to recover the correct timestamp of the beginning of the observation session if the sensor fails to give a correct time. The timestamp is included in the "value" attribute, and the current time zone is saved in the "timezone" attribute.
- **(h)** is the "<tslocal>" node that defines the starting Unix timestamp of the given observation. This should be stored from the used sensor itself.
- **(i)** is a sequence of integer values that defines the timestamp difference in milliseconds between two sequential values.



What is new?

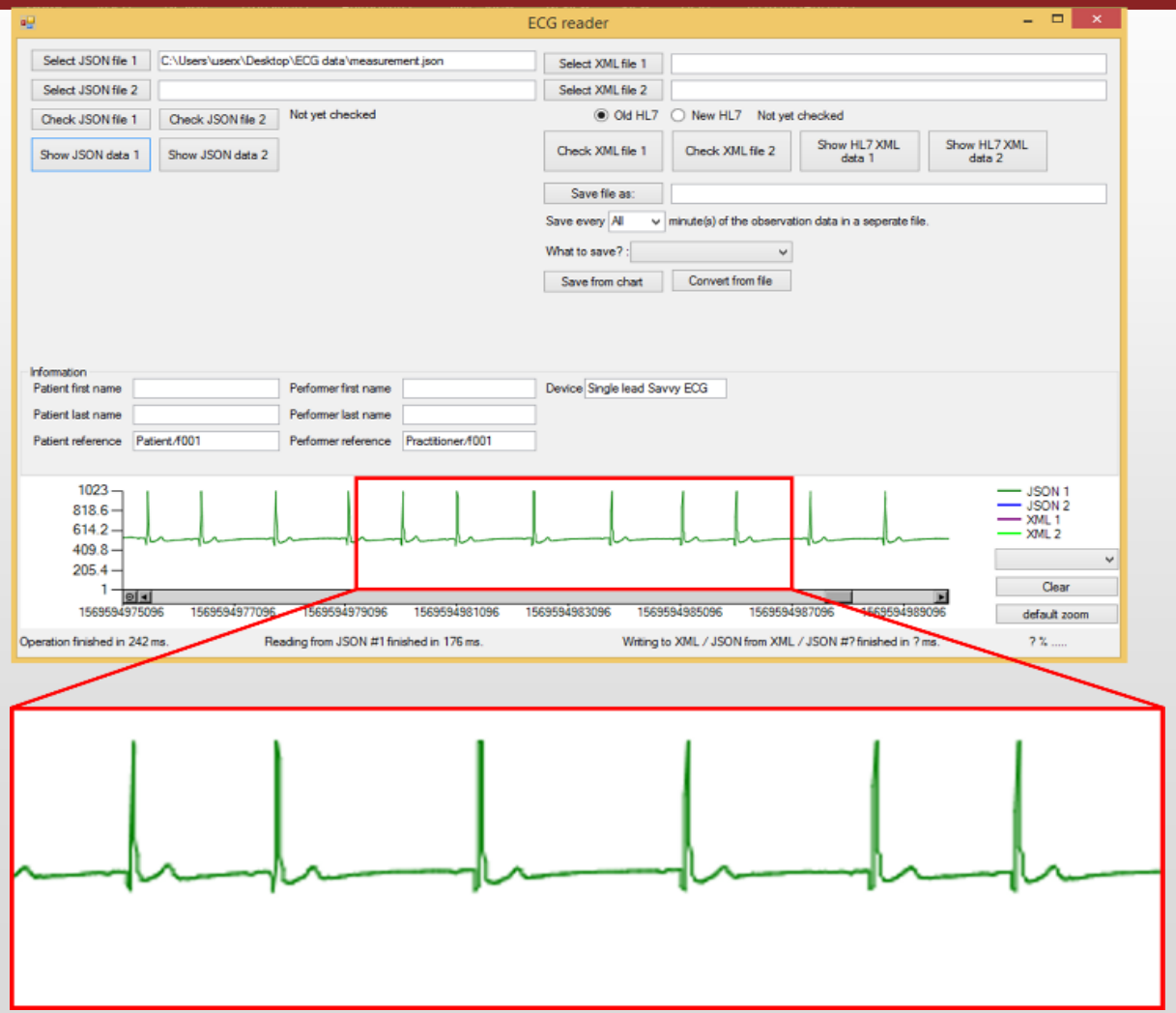
- A new node “<ecgStreamEnabled>” with value “true” is included in the point (b) of figure 3. This gives the information that the present file is saved from a streaming ECG device.
- Depending on the used device and its data acquisition frequency, a data size limit should be used per each file in order to keep balance with the processing performance.
- A new file is created in case of reaching this limit which contains the number of the sequential file number. The last part of the file name defines the number of the file in the same observation, E.g. “observation1.part1.xml”. The file number is also saved in the value attribute of the new node “<fileNumber>” in the point (e) of figure 3.
- A new file is created in case of expected or unexpected stop of the measurement process due to any reason. Either a sensor / device failure, or a connection or storage failure. The new timestamp values of the new measurement session are stored in the next file.
- Every parameter which is dependent with non-streaming observation’ lead, such as “<period>” and “<factor>”, should have a value of an empty string. This means that the given values are stored in the parameters of the streaming ECG presented previously in points (g), (h), and (i).

Results & Test cases

A .NET (C#) tool was made on top of the new format in order to :

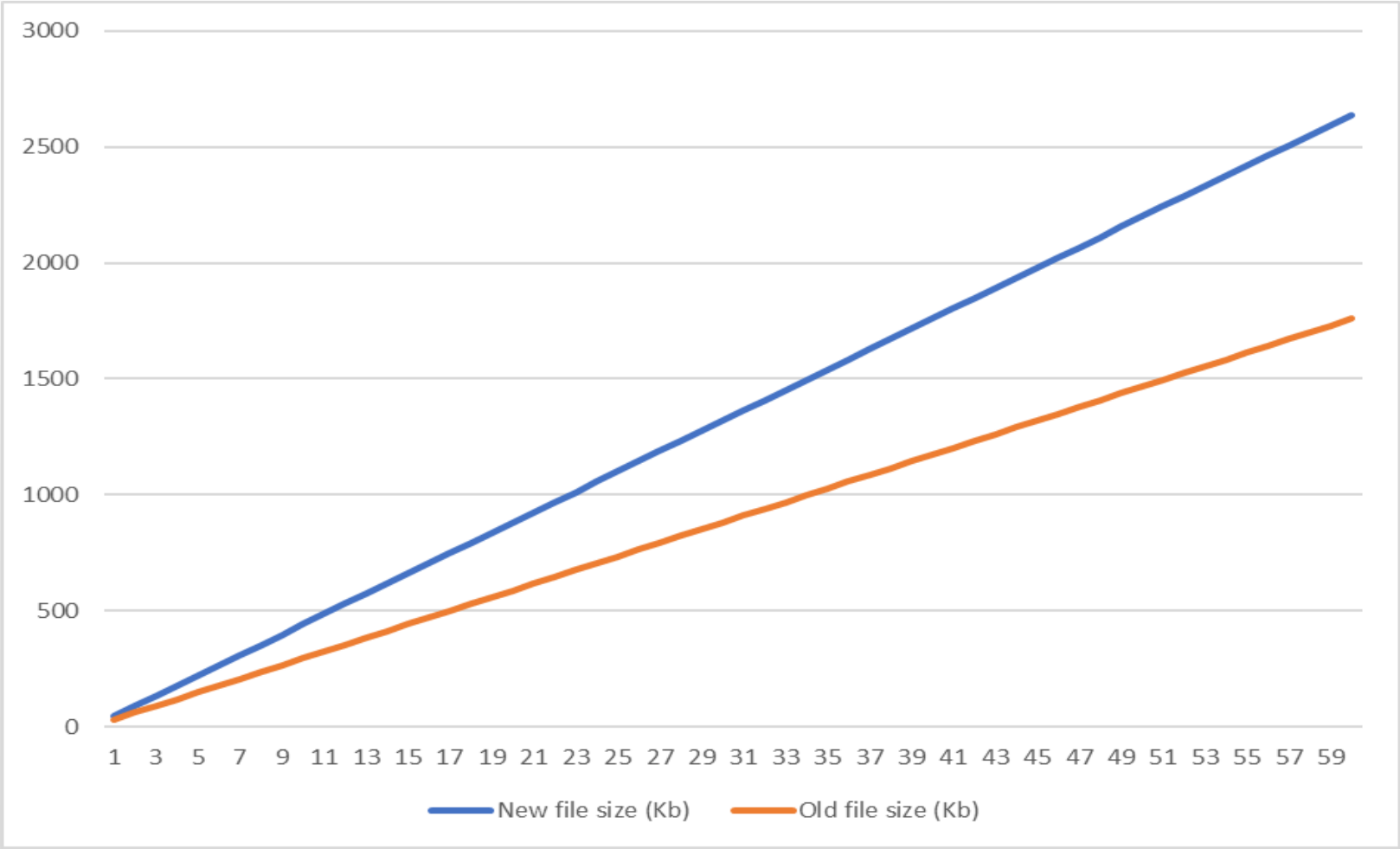
- Read from,
- Visualize, and
- Save to

The new proposed format and the old format.



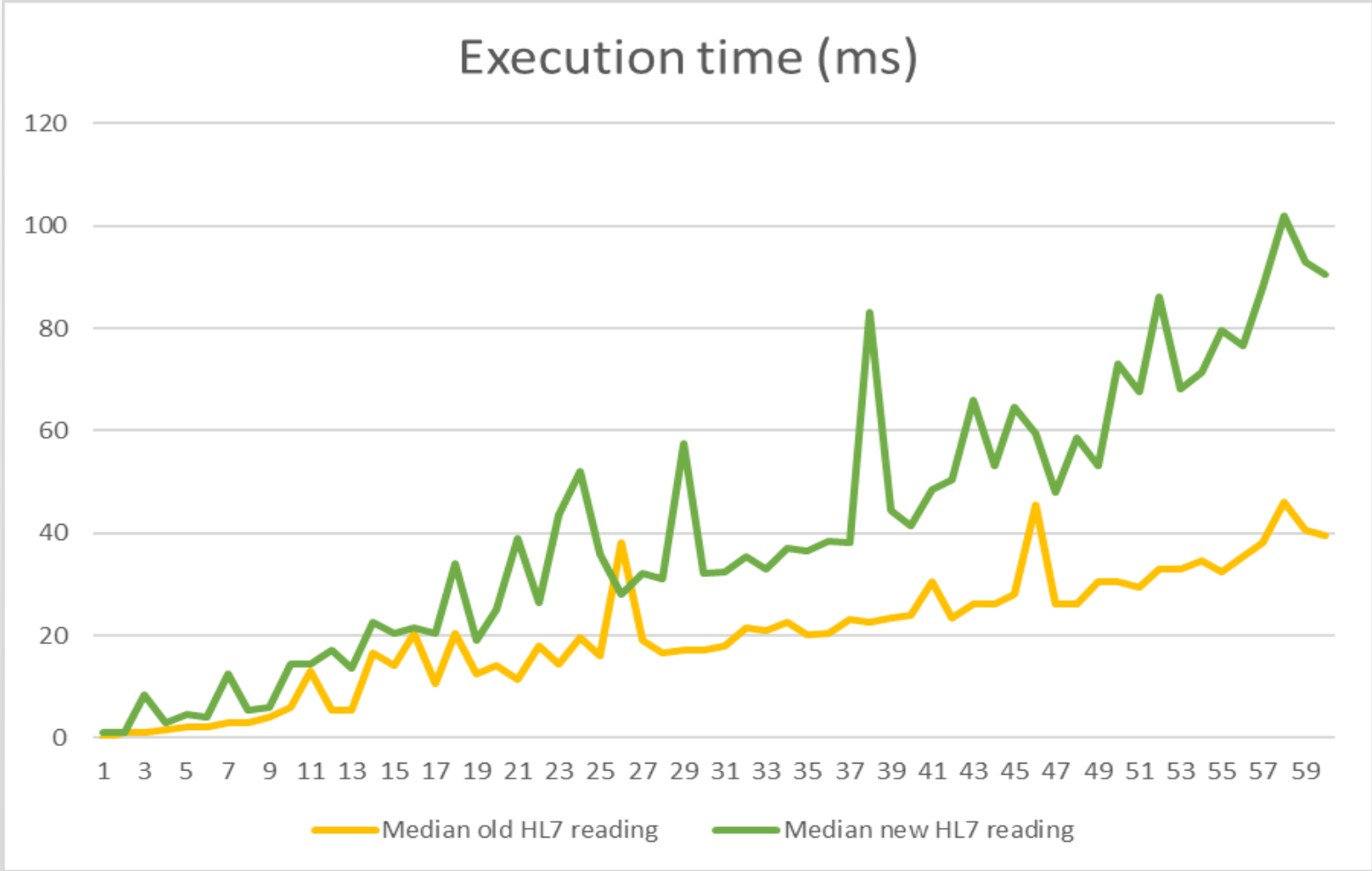
Results & Test cases

aECG observation file size comparison between the usual aECG and the new proposed format versus observation time in minutes



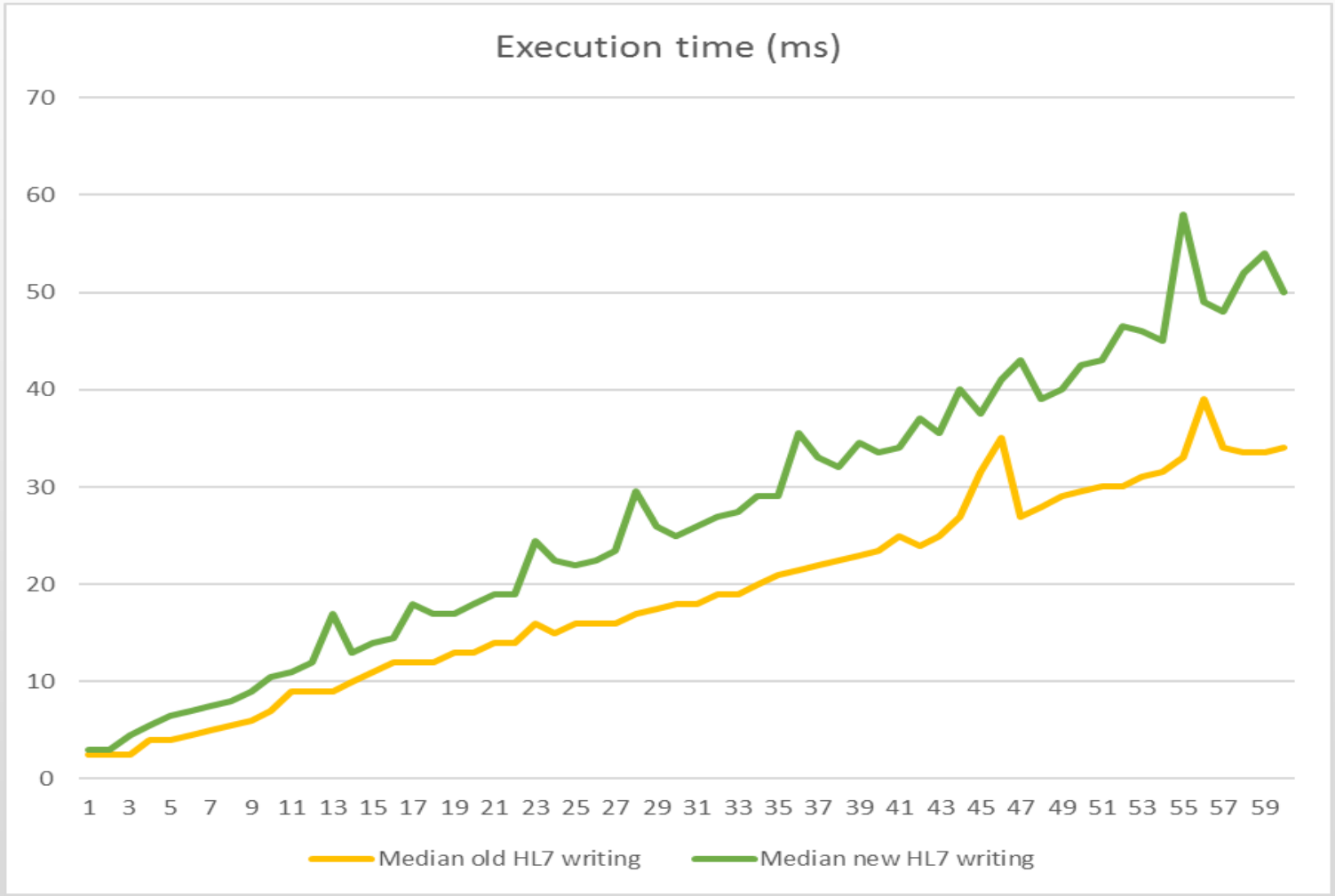
Results & Test cases

Execution time for reading process of old and new proposed HL7 aECG



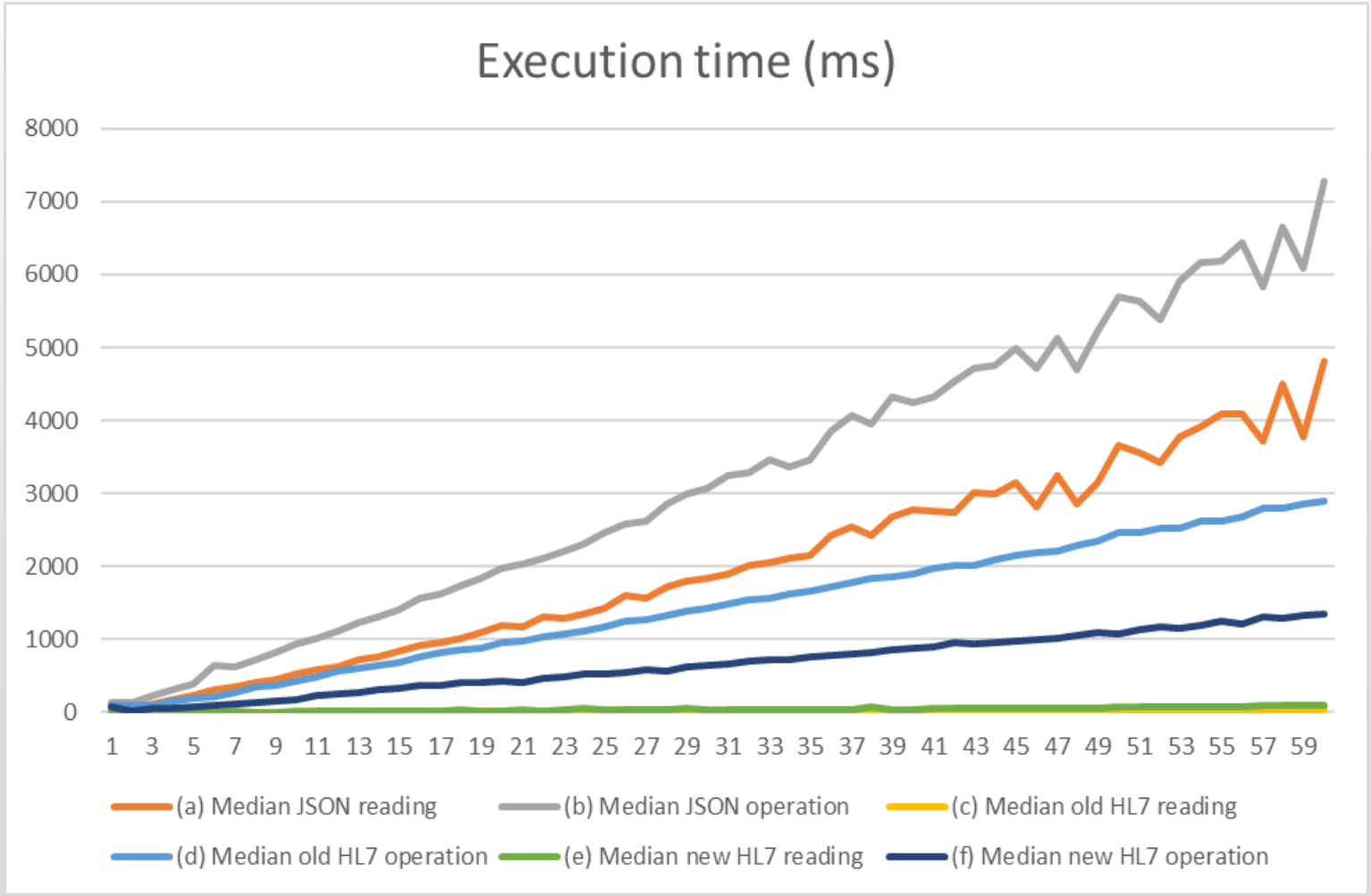
Results & Test cases

Execution time for writing process of old and new proposed HL7 aECG



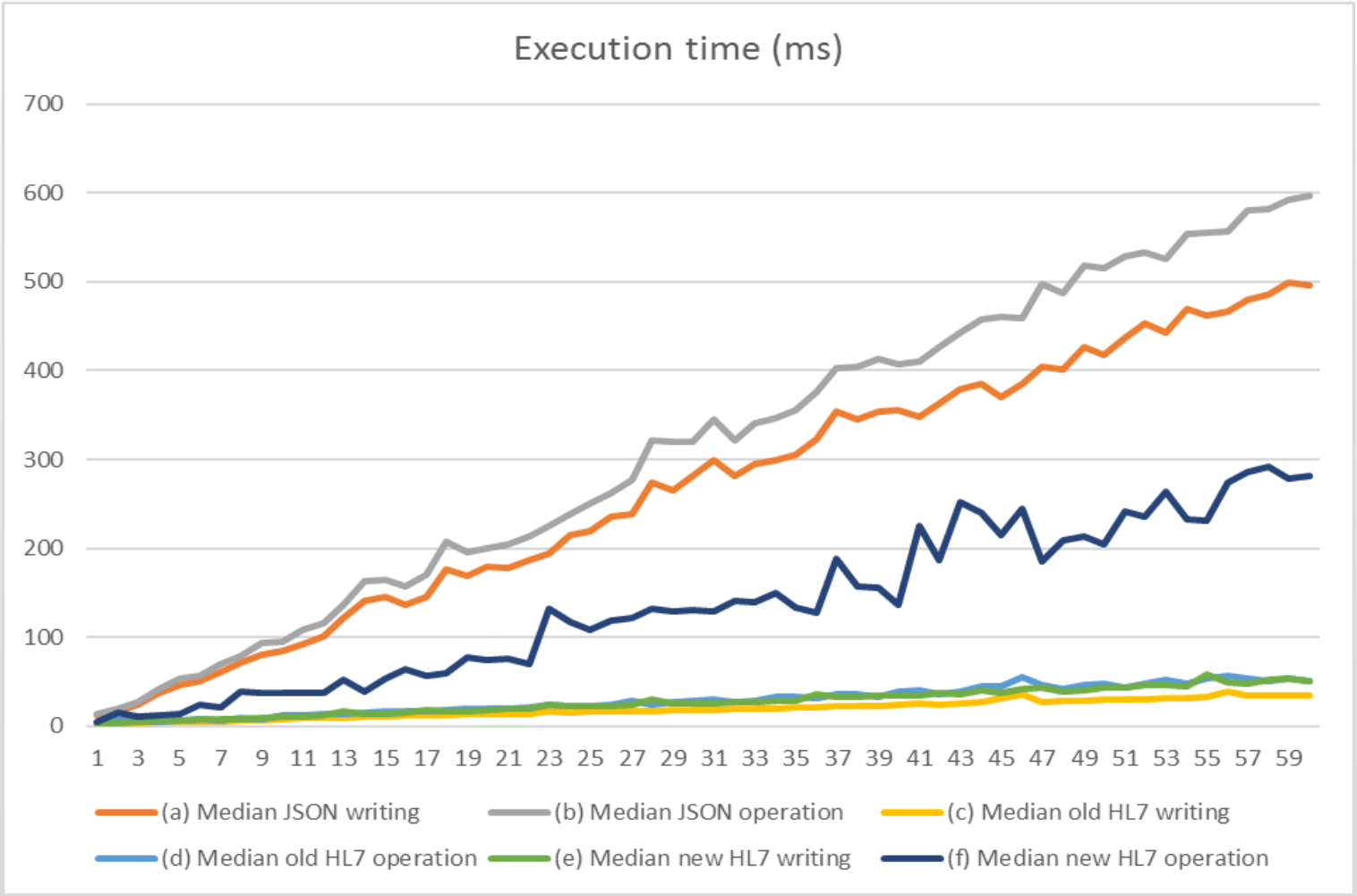
Results & Test cases

Execution time for reading, treatment, and display process of old and new proposed HL7 aECG and the used intermediate JSON format



Results & Test cases

Execution time for preparing and writing process of old and new proposed HL7 aECG and the used intermediate JSON format



SUMMARY

- The new proposed format (SaECG) showed good results in comparison with the HL7 aECG format.
- Each tested format contains both the reading time from the associated file and the whole execution time for a reading operation including the treatment and display time.
- The Stream-enabled annotated ECG (SaECG)is compatible with different ECG streaming sensors and is capable to use many and independent channels.
- The new format is tested in our living lab and showed very good results compared to the old version.
- **Further work:**
  - These results provide a good starting point for further research on ECG data monitoring in order to enable further procedures (eg.: analysis, monitoring, or even prediction).
  - Ensure interoperability between preexisting formats or standards.

Acknowledgement

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“Developing and testing a framework to support

sustainable implementation of

telemedicine-based care forms”

- Doctoral School of Óbuda University.

Thank you for your Attention