ActiVis, an R Package for the Visualization of Functional Actigraphy Data (and Beyond)

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Outline

1. Introduction
2. ActiVis Feature 1: New Visualization Tools for Actigraphy Data
3. ActiVis Feature 2: Object–oriented Design
5. Conclusion & Future Work
6. Appendix
What is Actigraphy?

- **Actigraphy**: emerging technology for measuring a person’s activity level continuously over time

- **Actigraph**: watch-like device (attached to the wrist or leg) that uses an accelerometer to measure (human) movements (every minute or more often)
Actigraphy
Human Actigraphy

- Detecting sleep patterns, and insomnia
- Assessing restless leg syndrome
- Tracking recovery after heart attacks
- Assessing overall status of HIV patients
- Assessing depression
- Etc.
Current Visualizations of Actigraphy Data: Actogram & Histogram
Actigraphy Data

- 55 patients
- Two types of data
  - Actigraphy level data
  - Depression level data (PHQ–9 scale)
- Data collection rate: every 15 seconds or every minute, i.e., about 6,000 or 1,500 measurements per day (× 3–8 days per patient × 55 patients)
- Patient demographics
  - Gender: 17 males, and 38 females
  - Depression level: 15 patients with no depression (Level 0), 13 with mild depression (Level 1), 15 with moderate depression (Level 2), 8 with moderately severe depression (Level 3), and 4 with severe depression (Level 4)
Current Visualizations of Actigraphy Data: Scatterplot (Messy!)
Actigraphy data can be best described as functional data

Functional Data Analysis (FDA): “The basic philosophy of functional data analysis is to think of observed data functions as single entities, rather than merely as a sequence of individual observations.” (Ramsay & Silverman, 2006)
The ActiVis R Package

Feature 1: New Visualization Tools for Actigraphy Data

Feature 2: Integration of New and Current Visualization Tools Using Object–oriented Model Design

Feature 3: User–friendly Web Interface
Feature 1: New Visualization Tools for Actigraphy Data

- One Patient
- Multiple Patients
Enhanced Visualizations of Actigraphy Data: One Patient

- Smoothed time series
- Velocity (First derivative)
- Acceleration (Second derivative)
- Cumulative sum plots
- Sorted cumulative sums plots
Enhanced Visualizations of Actigraphy Data: One Patient

(a) Patient X Raw Data Plot

(b) Patient X Smoothed Data Plot

(c) Patient X Velocity (First Derivative) of Smoothed Daily Data

(d) Patient X Acceleration (Second Derivative) of Smoothed Daily Data

(e) Patient X Cumulative Sums Plot

(f) Patient X Sorted Cumulative Sums Plot
New Visualization Techniques for Actigraphy Data: Multiple Patients

- Density–based plots
- Data enveloping
- Data summing
- Multivariate time series plots
- Combination of plots (most effective)
## Density-based Plots: Multiple Patients

<table>
<thead>
<tr>
<th>Depression Level</th>
<th>Density-based Plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td><img src="image1.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level 1</td>
<td><img src="image2.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level 2</td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level 3</td>
<td><img src="image4.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level 4</td>
<td><img src="image5.png" alt="Graph" /></td>
</tr>
</tbody>
</table>
Data Enveloping: Multiple Patients

Envelope (Min−Max) Plot—Actigraphy Data
Aggregation = 1 mins

Envelope (40%−60%) Plot—Actigraphy Data
Aggregation = 1 mins
Data Summing: Multiple Patients

Envelop (Min−Max) Plot—Actigraphy Data
Aggregation = 20 mins

Envelope (40%−60%) Plot—Actigraphy Data
Aggregation = 20 mins
Multivariate Time Series Plots: Multiple Patients
# Density–based Plots of Cumulative Sums: Multiple Patients

<table>
<thead>
<tr>
<th>Depression Level</th>
<th>Density-based Plots For Actigraphy Cumulative Sums</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td><img src="image1.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level 1</td>
<td><img src="image2.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level 2</td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level 3</td>
<td><img src="image4.png" alt="Graph" /></td>
</tr>
<tr>
<td>Level 4</td>
<td><img src="image5.png" alt="Graph" /></td>
</tr>
</tbody>
</table>
# Envelope Plots of Cumulative Sums: Multiple Patients

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Data Envelopes for Actigraphy Data (Patient’s Gender Categories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25(^{th}) - 75(^{th})</td>
<td><img src="image" alt="Graph showing envelope plots for 25th to 75th percentiles for males and females." /></td>
</tr>
<tr>
<td>40(^{th}) - 60(^{th})</td>
<td><img src="image" alt="Graph showing envelope plots for 40th to 60th percentiles for males and females." /></td>
</tr>
</tbody>
</table>
What is Object–oriented Programming (OOP)?

- Objects: encapsulate state information and control behavior
- Classes: describe general properties for groups of objects
- Inheritance: new classes can be defined in terms of existing classes
- Polymorphism: a function/method has different behaviors depending on the class of one or more of its arguments
ActiVis Class Diagram
Object–oriented Programming in R

- **S3 System**
  - Easiest to use
  - Not fully object–oriented

- **S4 System**
  - Fully object–oriented
  - Less computationally efficient when compared to the S3 system

- **R.oo Package**
  - Extends the S3 system
  - Easy to use, and more user friendly
  - Makes use of reference variables

- **R5 System**
  - Reference Classes
  - Similar to R.oo, but it is part of R
  - We decided to use the R5 approach
library(ActiVis)
### initialize actigraphy object for this patient
patient <- ActData$new()
patient$fileName <- "Patient.AWC"
### read the data
patient$read()
### create a new raw data plot object for this patient
patient_raw <- RawDataPlot$new()
patient_raw$legendPosition <- "topright"
patient_raw$act_range <- c(0, 4000)
### setup the graph by calling the graphics device
patient_raw$setup()
### show the average of data for the days
patient_raw$average <- TRUE
### what days to plot?
patient_raw$plotdays <- c(2, 3)
### store this patient’s object in "patient" field in the graph object
patient_raw$patient <- patient
### show the data on the raw data plot
patient_raw$showData()}
Case Study: Raw Data Plot
Feature 3: User–friendly Web Interface

- Main users of the R package are doctors in the medical field
- Easy–to–use interfaces are needed (users unlikely to learn R)
- Approaches:
  - Windows interface
  - Web interface (everyone knows how to operate a web browser)
    - Rpad approach
    - Rook approach
    - rApache approach
ActiVis Web Interface

Visualization of Actigraphy Data

- File Upload
  - Upload Actigraphy Data Files
    - Browse
  - Upload Patients' Clinical Data File
    - Browse
- Graph Type
- Graph Parameters
Client–Server Architecture (1)
ActiVis Client–Server Architecture (2)
Summary

- Development of ActiVis R package (Prototype), including
  - New visualization tools for actigraphy data
  - OO–design
  - Web–based user interface
- Tested on single data set (55 patients) and on simulated data set
Future Work

- Finalize R package (and documentation) and submit to CRAN
- Test with additional data sets
- It’s OO: Extend to different types of actigraphy & functional data!
- Extend graphics, e.g., support dendograms in multivariate time series plots
- More interactivity in the web interface (zooming in/out, more plot parameters, etc.)
Further Reading

**Interface, 2010**

**Chance, 2011**

**JSM, 2012**
Web Interface: Main Page

Visualization of Actigraphy Data

- File Upload
  - Upload Actigraphy Data Files
  - Upload Patients’ Clinical Data File

- Graph Type
- Graph Parameters
Web Interface: Upload Files
Web Interface: Files Selected

Visualization of Actigraphy Data

- File Upload
  - Upload Actigraphy Data Files
  - Upload Patients' Clinical Data File
- Graph Type
- Graph Parameters
Web Interface: Choose Plot Type

Visualization of Actigraphy Data

- File Upload (1)
- Graph Type
  - Select Graph Type
    - Raw Data Plot
    - Smoothed Data Plot
    - Velocity Data Plot
    - Acceleration Data Plot
    - Cumulative Sums Data Plot
    - Sorted Cumulative Sums Data Plot
- Graph Parameters
Web Interface: Enter some Parameters

Visualization of Actigraphy Data

- File Upload (1)
- Graph Type (Cumulative Sums Data Plot)
- Graph Parameters

Enter Graph Parameters:
- Title
- Actigraphy Range
  - From
  - To
- Reset  Plot
Visualization of Actigraphy Data

- File Upload (1)
- Graph Type (Cumulative Sums Data Plot)
- Graph Parameters

Enter Graph Parameters:

Title: Cumulative Sums Plot

Actigraphy Range

From: 0
To: 500000

Reset | Plot
Web Interface: The Plot

Visualization of Actigraphy Data

- File Upload (1)
- Graph Type (Cumulative Sums Data Plot)
- Graph Parameters

Enter Graph Parameters:

Title
Cumulative Sums Plot

Actigraphy Range
From
0
To
500000

Reset | Plot

Cumulative Sums Plot

Jürgen Symanzik — August 22, 2013
Questions ?