Overview of R Package SMRD

Statistical Methods for Reliability Data in R

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Background

Statistical Methods for Reliability Data

- ***Statistical Methods for Reliability Data*** is a foundational text for analyzing failure time and survival data
- Along with the text, the authors developed an S-Plus software package to utilize the methods for industry data
- Today, R is the most popular statistical computing language in the world
- `SMRD` is a software pacakge to implement methods from Statistical Methods for Reliability Data in R
- This presentation introduces `SMRD` and details several features of the package

The R Project for Statistical Computing

- A statistical programming environment for data analysis and graphics
- Developed by Ross Ihaka and Robert Gentleman at the University of Auckland
- Open-source implementation of the 'S' language created by Becker et. al. at Bell Labs
- A pre-eminent tool for statistics and data science
- One of the fastest growing technical computing languages in the world
  - Used for data processing and visualization, computational statistics, and natural language processing etc.
  - Heavily used by Google, Facebook, Twitter, Microsoft, etc.

R Packages

- In R, the fundamental unit of shareable code is called a package
- Packages bundle together code, data, documentation, and tests to easily make analysis methods with others
- Currently 225 packages are available on the Comprehensive R Archive Network (CRAN)
- Many more available from the Bioconductor and GitHub repositories
- The huge variety of packages is a key reason why R is so successful
  - Chances are that someone has already solved a problem that you're working on
  - You can benefit from their work by downloading their package

SMRD - Development History

- Meeker developed a large collection of FORTRAN subroutines as part of contracted efforts at Bell Labs and Iowa State
- Meeker & Escobar wrapped the FORTRAN code into an S-Plus package called SPLIDA (S-Plus LIfe Data Analysis)
- *SPLIDA* serves as the companion software for Statistical Methods for Reliability Data 1st ed.
- Meeker attempted to translate *SPLIDA* into R under the name *RSplida*
  - Not user-friendly - couldn't be installed as a traditional R package
  - Couldn't be used with modern IDE's (i.e. RStudio, Visual Studio, Eclipse, etc.)
- Freels & Meeker sign MOU to share FORTRAN code for purpose of developing an R package
- Aim is to publish SMRD to the CRAN for use with the 2nd edition of Statistical Methods for Reliability Data

SMRD Package Features

Importing Data From Multiple Sources

- The SMRD package includes over 120 documented datasets
- For importing external data, SMRD leverages several other R packages
- Excel files
  - XLConnect
  - readxl
  - xlsx
- CSV/TSV files
  - base
  - utils
  - readr
- Info, Minitab, S, SAS, SPSS, Stata, Systat and Weka files
  - foreign
  - HMISC

Flexible Event Definitions - Utilize Data As It Exists

- Organizations can use different terms to describe similar events
  - 'Failure' = 'Failed' = 'Fail' = 'dead' = 'died'
  - 'right' = 'rcensored' = 'suspended' = 'alive'
  - 'left' = 'doa' = 'lcensored'
  - 'interval' = 'int' = 'icensored' = 'grouped'
- SMRD minimizes data pre-processing by accepting many event definitions
- Event definitions can also be mixed
- For users familiar with the R package `survival`
  - SMRD includes functions to map event definitions to the correct numeric values
  - Produce `Surv`-class objects directly

SMRD Default Event Definitions

Failed	Left-censored	Right-censored	Interval-censored
event	l	a	b
exact	l-censored	alive	bin
d	left-censored	c	i
dead	left	censor	interval
died	leftcensored	censored	i-censored
f	start	end	intervalcensored
fail	mstart	mend	interval-censored
failed	2	noreport	3
failure		r	
report		r-censored	
repair		right-censored	
repaired		removed	
replaced		right	
replacement		rightcensored	
1		s	
		survived	
		survive	
		suspend	
		suspended	
		0	

Data Analysis & Reliability Estimation

- *SMRD* can estimate reliability measures for many types of failure data
  - Multiple failure modes
  - Censored observations (right, left, and interval censoring)
  - Truncated observations (right, left, and interval truncation)
  - Failure times with explanatory variables (normal, Weibull, and logistic regression)
  - Repeated measures degradation data
  - Repairable system failures (recurring events)
  - Physical degradation measures
  - Failure times with prior information (Bayesian reliability)
  - Reliability growth test data
  - Reliability test simulations

Exporting & Visualizing Results

- With SPLIDA, the code was intended to remain underneath a GUI
- Results of SPLIDA analyses were presented all together
  - Plots
  - Tables
  - Single numeric values
  - Text summaries
- For GUI-based tools, presenting multiple results simultaneously is **GOOD**
- For tools emphasizing reproducible research and literate programming, presenting multiple results simultaneously is **BAD**
- A great deal of effort has gone into ensuring that specific results can be produced and called where desired

Example

The Shockabsorber Dataset

- This example demonstrates a few of the SMRD function to analyze the shockabsorber dataset used throughout the text

```
  miles      mode    event
1  6700     Mode1  Failure
2  6950 Censored Censored
3  7820 Censored Censored
4  8790 Censored Censored
```

```
   miles      mode    event
35 27410 Censored Censored
36 27490     Mode1  Failure
37 27890 Censored Censored
38 28100 Censored Censored
```

Creating `life.data` Objects

- The methods in the package require we create a `life.data`-class object

```
shock.ld <- frame.to.ld(frame = shockabsorber,
                        response.column = 1,
                        failure.mode.column = 2,
                        censor.column = 3,
                        time.units = 'Miles')
```

- Since SPLIDA was written for a GUI, functions to produce results already existed
- Thus, once the `life.data` object has been created, many different plots and numeric results can be produced with a single line of code

Producing Results From `life.data` Objects

Plots

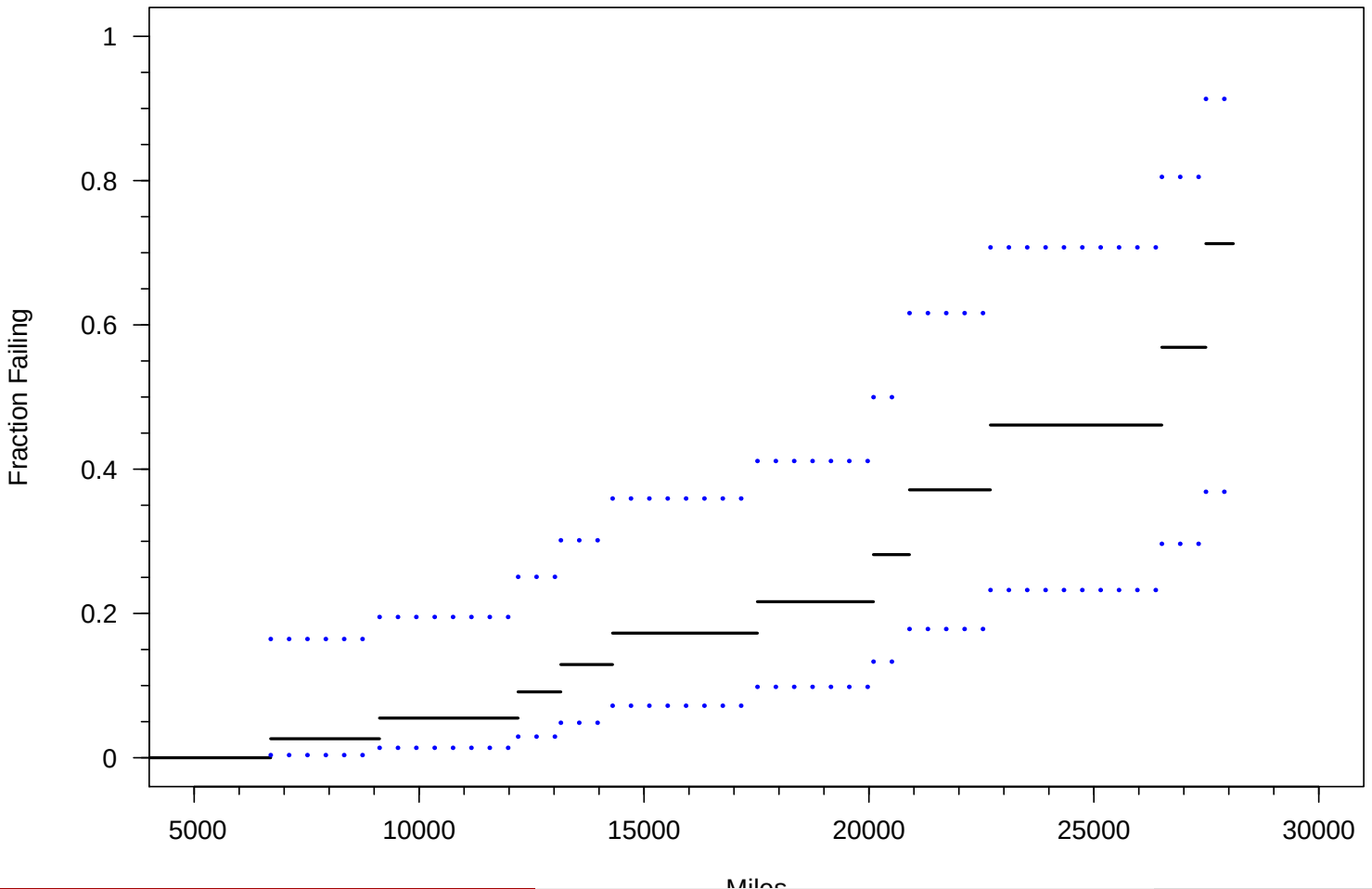
- Nonparametric CDF plots
- Parametric CDF plots
- ML CDF and hazard plots
- Explanatory variable plots
- Multi-failure mode plots
- Likelihood surfaces
- Relative likelihood curves

Numeric Results

- $F(t)$ at specified values of t
- $h(t)$ at specified values of t
- $t^{-1}(p)$ at specified values of p
- ML parameter estimates and standard errors
- Logit and log transformed confidence intervals (pointwise and simultaneous)

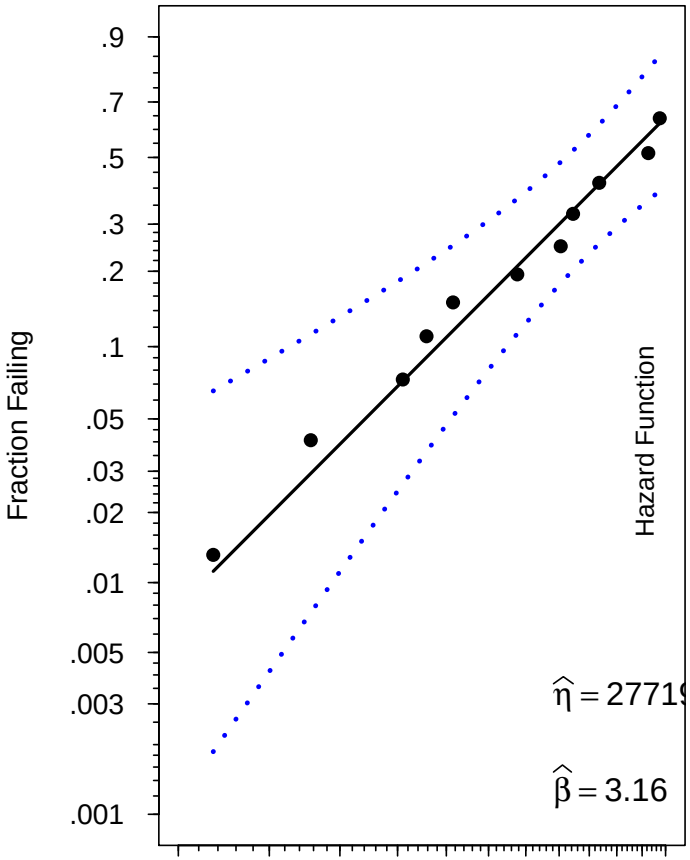
Nonparametric CDF plots

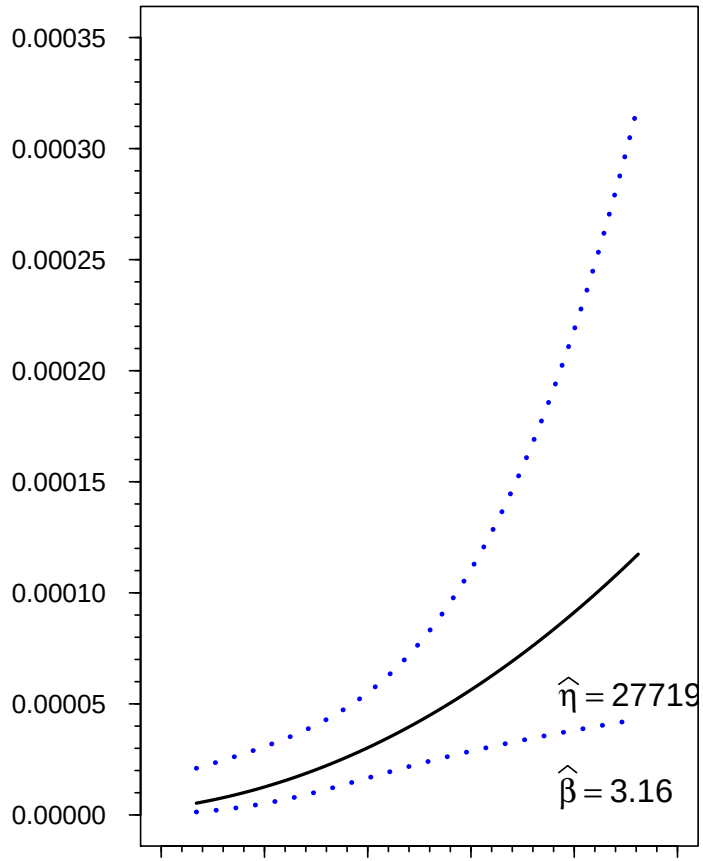
```
plot(shock.ld)
```



ML Plots ($F(t)$ & $h(t)$)

```
mleprobplot(shock.ld, distribution = 'weibull')
mlehazplot(shock.ld, distribution = 'weibull')
```





Integration with Rmarkdown & Shiny

- By taking advantage of the existing SPLIDA code, SMRD is ideal for use with the shiny and rmarkdown packages
  - Allows for a seamless reliability workflow to create papers & presentations incredibly fast
  - The package can be used to create high-quality plots with a single line of code
  - Turn results into LaTeX tables instantly
  - Create interactive content

Remaining Work & Spin-off Projects

Remaining Work

- Several tasks must be completed before the package can be published the CRAN
- The following tasks are listed in order of time required to complete
  - Convert underlying FORTRAN code to C++
  - Document functions
  - Separate results for middle chapters
  - Update plots
  - Integrate shiny gadgets and rmarkdown templates make the analysis workflow super-fast

Spin-Off Projects

- Teaching with the SMRD package throughout the development has spawned several projects
- SMRD.apps - R package of interactive visualizations and examples from the text
- A companion text to help SMRD readers learn R programming skills and along with the course content
- SMRD.resources R package for instructors to automatically create problem sets, homework solutions and in-class examples from the text
- teachingApps R package containing 150 apps to help students and instructors visualize statistical concepts and R programming

Summary

Summary

- SMRD is an upcoming R implementing the methods presented in the Statistical Methods for Reliability Data in stuff goes here
- Plan is to release in conjunction with the second edition on the book
- Always looking for help testing the package

Questions

QUESTIONS?