MULTI-STATE CHURN ANALYSIS

WITH A SUBSCRIPTION PRODUCT

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DEVELOPING INTELLIGENCE POWERED BY DATA

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WHO IS THIS GUY?

MARCIN KOSIŃSKI

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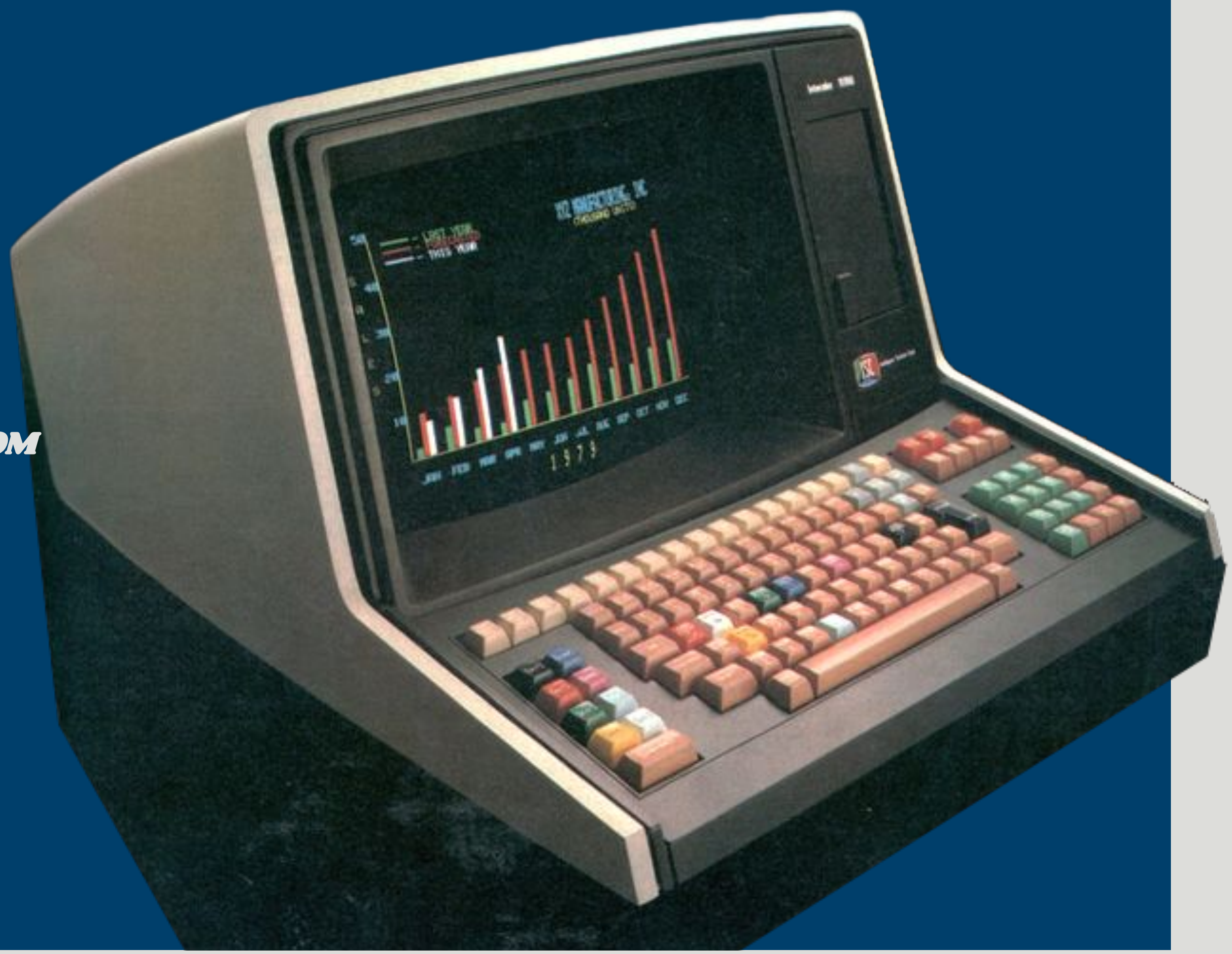

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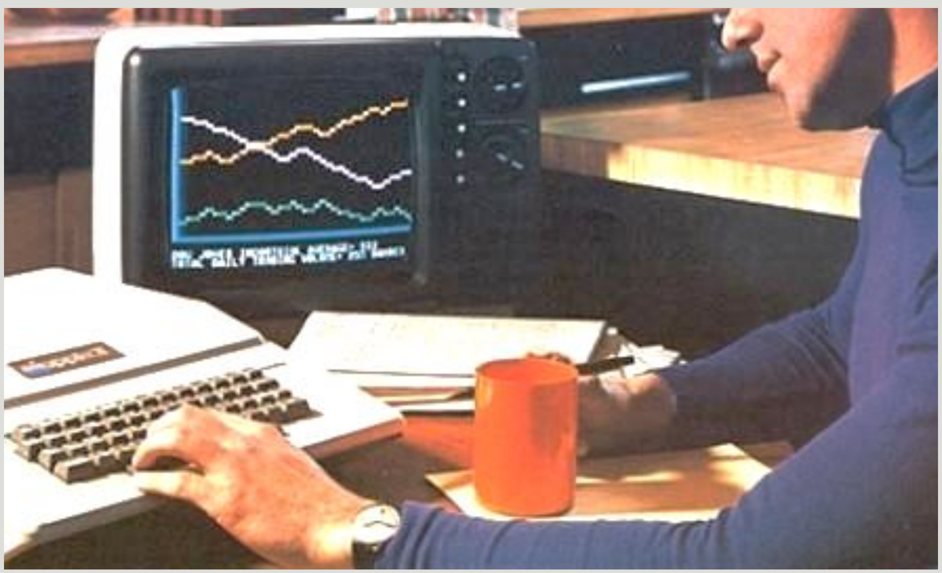
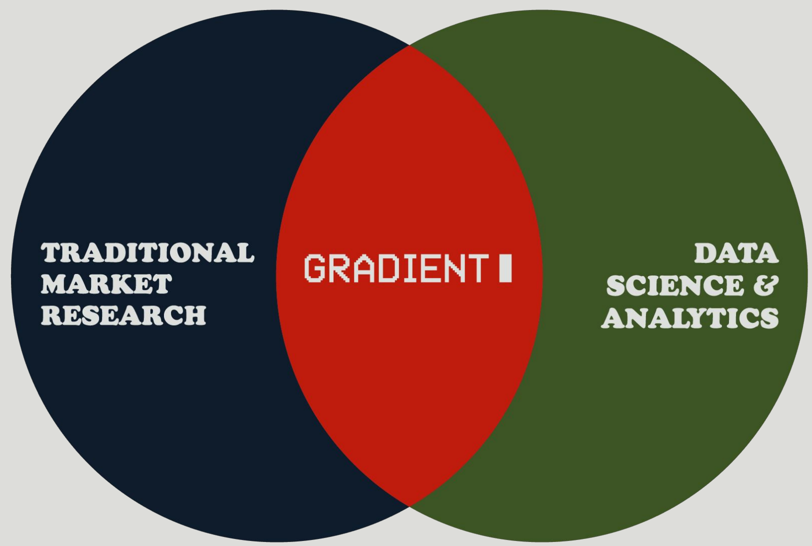
Nice to meet you!



WE'RE GRADIENT:

A crew of quantitative marketers and technologists that gather hard data and build robust statistical models to guide organizations through their most difficult decisions.

We're confirmed data geeks,
but word on the street is that we're easy to work with and pretty fun, too.



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SURVIVAL ANALYSIS

DEFINITION & EXAMPLES

LET'S START TALKING

A branch of statistics for analyzing the **expected duration of time until** one or more **events** happen.

Examples

1. A death of the patient.
2. A deactivation of the service.
3. An accident on the road.
4. The device failure.
5. An employee leaving the company.
6. A customer cancelling subscription.

SURVIVAL ANALYSIS

QUESTIONS IT (MIGHT) ANSWER

LET'S START ASKING

What’s the probability an event will (not) occur after a specific period of time?

Which characteristics indicate a reduced or increased risk of occurrence of an event?

What periods of time are most (or least) exposed to the risk of an event?

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SURVIVAL ANALYSIS

CHALLENGES IT FACES

DEPENDING ON THE SCENARIO

Data

1. Censoring.
2. Interval data.
3. Observations may not be independent.
4. Time varying features.

Events

1. Recurring events - one event might occur multiple times.
2. Competing risks - one of multiple events might occur.
3. A multi-state (cyclic/acyclic) nature of the process.

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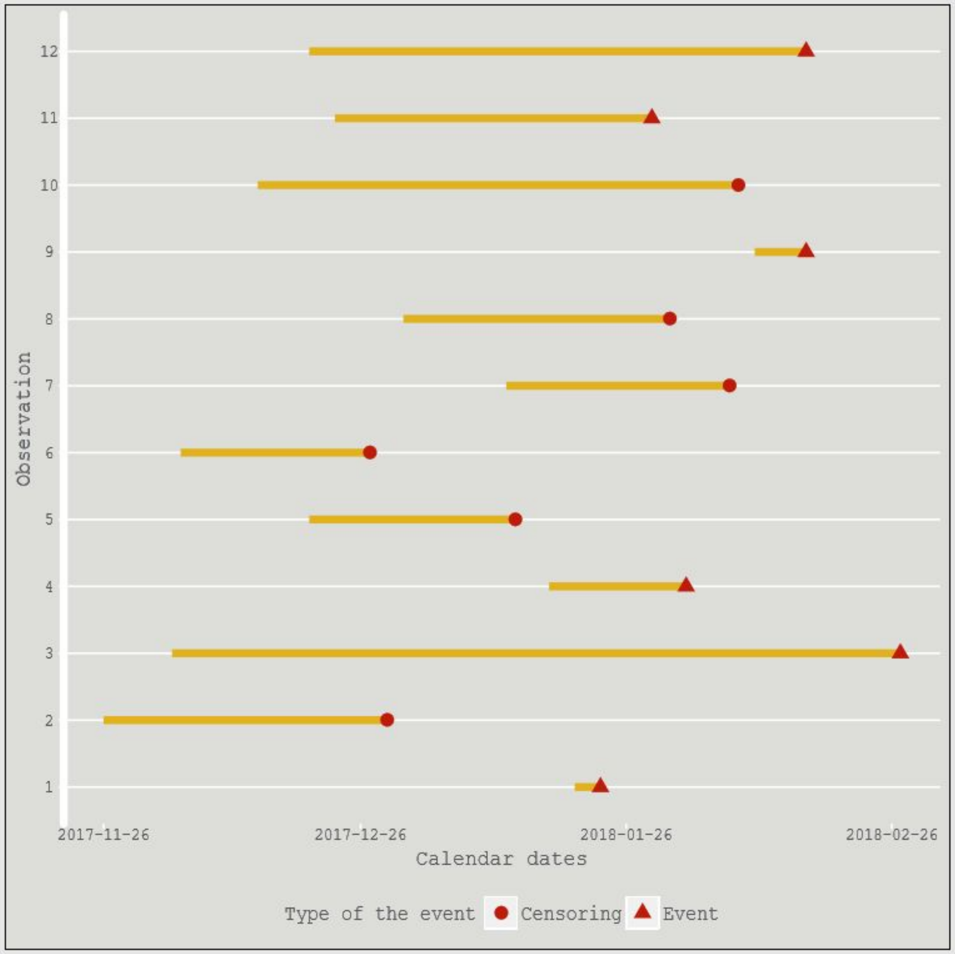
HOW YOU OBSERVE EVENTS

DATA STRUCTURE

SIMPLE CASE



HEAD OF THE DATA

ID	Start Date	End Date	Status
1	2018-01-28	2018-02-22	Censoring
2	2017-12-16	2018-01-08	Event
3	2017-12-09	2018-01-06	Censoring
4	2018-01-16	2018-02-23	Censoring
5	2017-12-16	2018-02-11	Event
6	2018-02-18	2018-03-01	Event

Data **do not** correspond to the plot.

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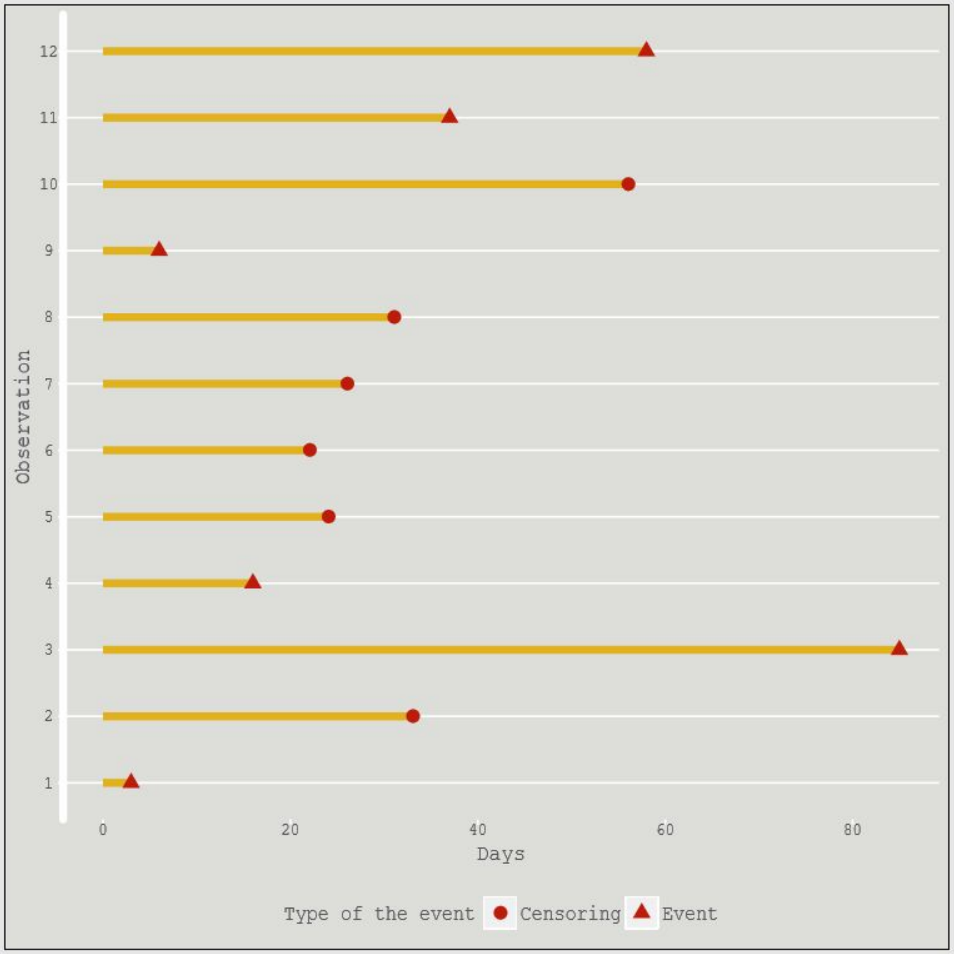
HOW YOU HANDLE THEM

DATA STRUCTURE

SIMPLE CASE



HEAD OF THE DATA

ID	Time	Status
1	3 days	Event
2	33 days	Censoring
3	85 days	Event
4	16 days	Event
5	24 days	Censoring
6	22 days	Censoring

Data **do** correspond to the plot.

KAPLAN-MEIER ESTIMATES

$$\hat{S}(t) = \prod_{t_i < t} \frac{n_i - d_i}{n_i}$$

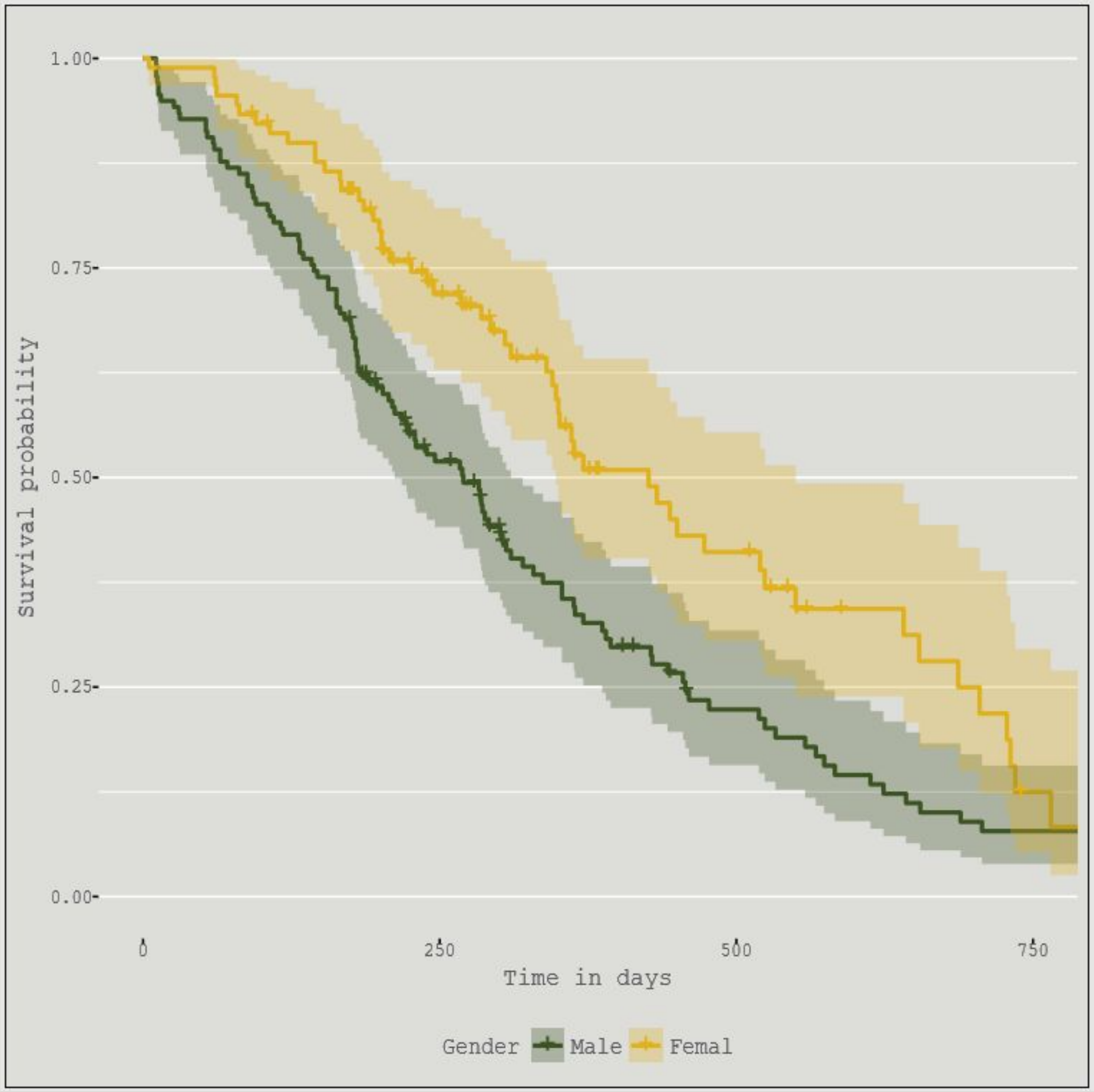
where

t_i **- time of i-th event**

n_i **- number of observations in a risk set at time** t_i

d_i **- number of events at** t_i

Log-rank test seeks for statistically significant differences between curves.

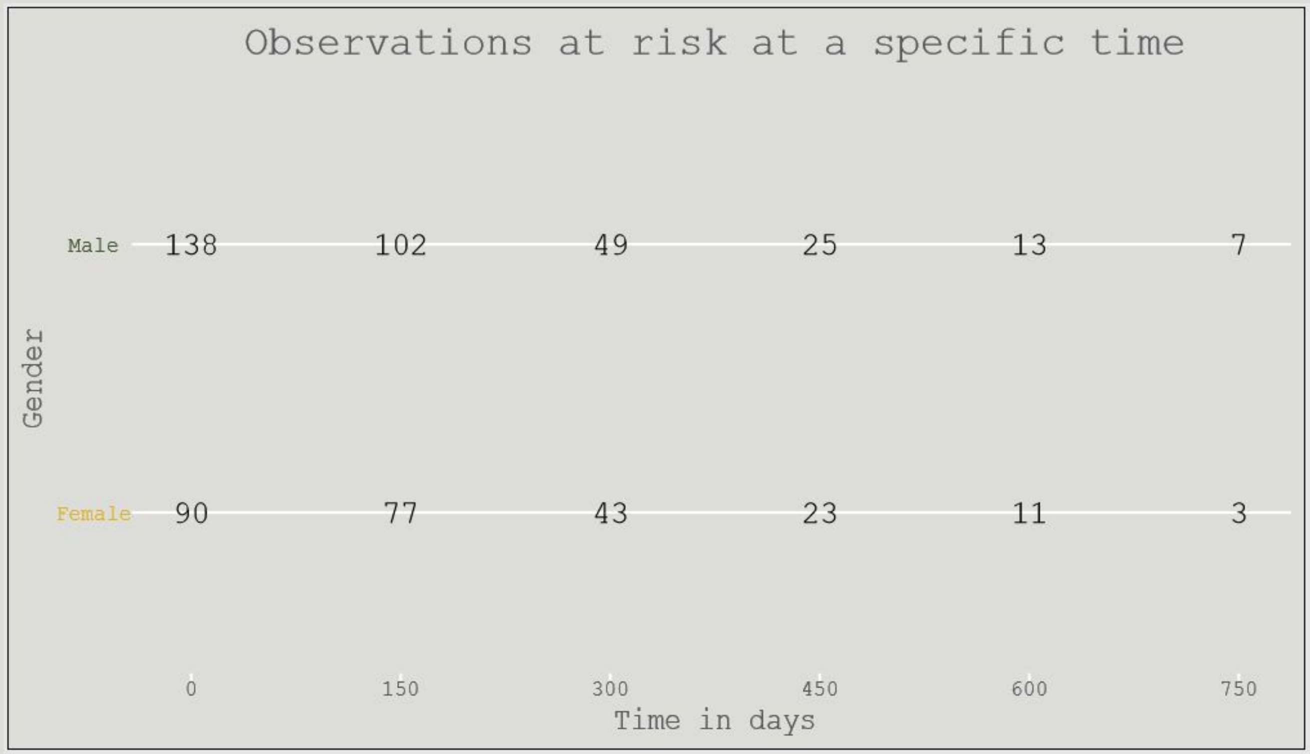


TOOLS

RISK SET (TABLE)

SURVIVORS AT A TIME

Useful when considering whether results at a specific time point are significant due to the sample size.



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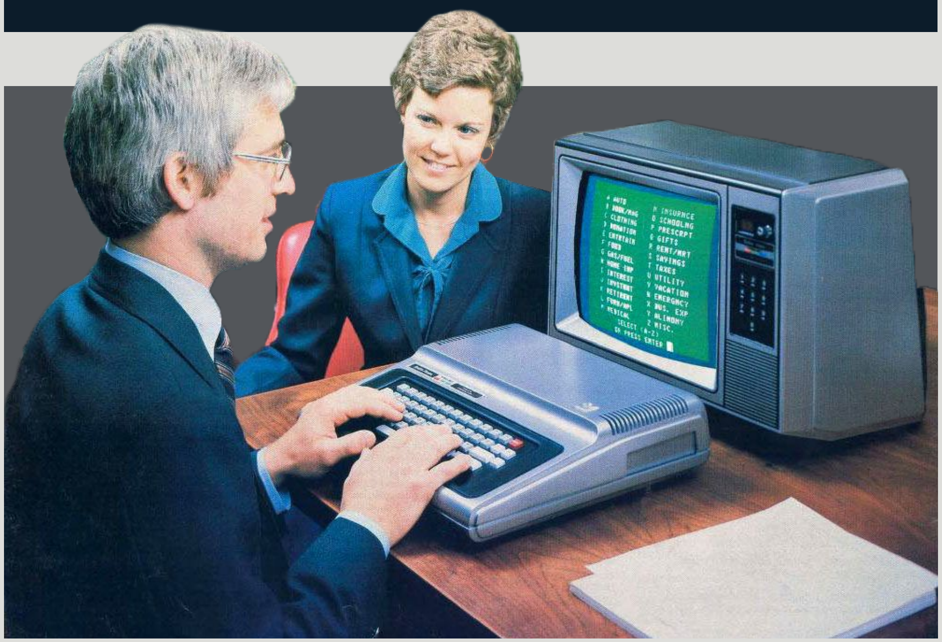
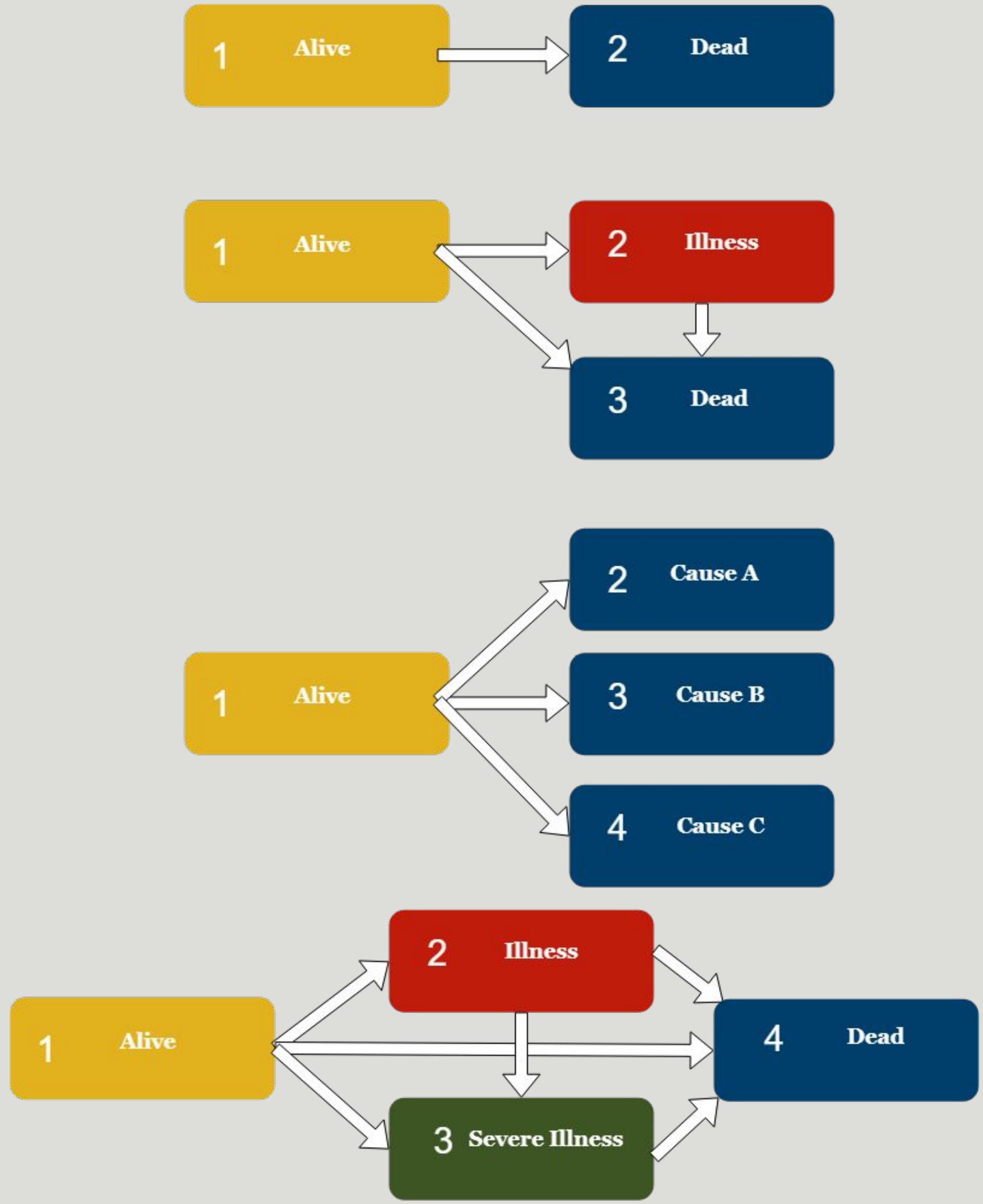
MULTI-STATE MODELS





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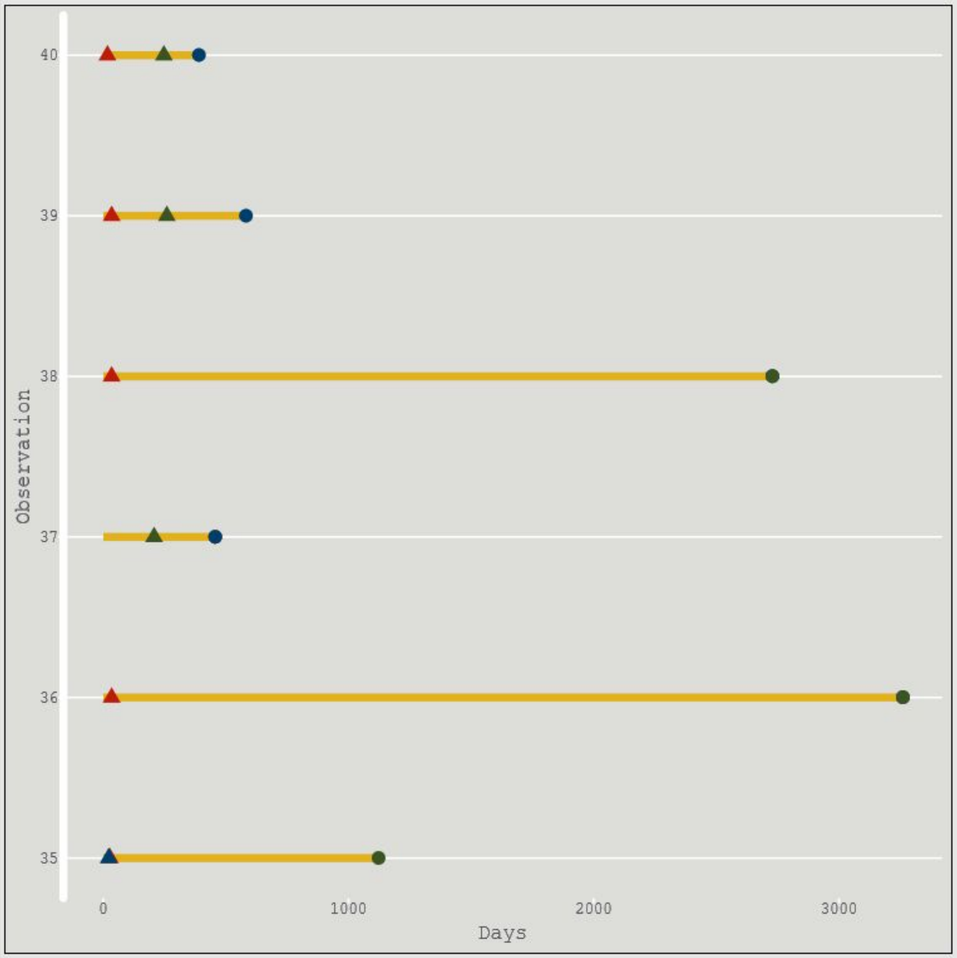
DATA STRUCTURE

MULTI-STATE CASE

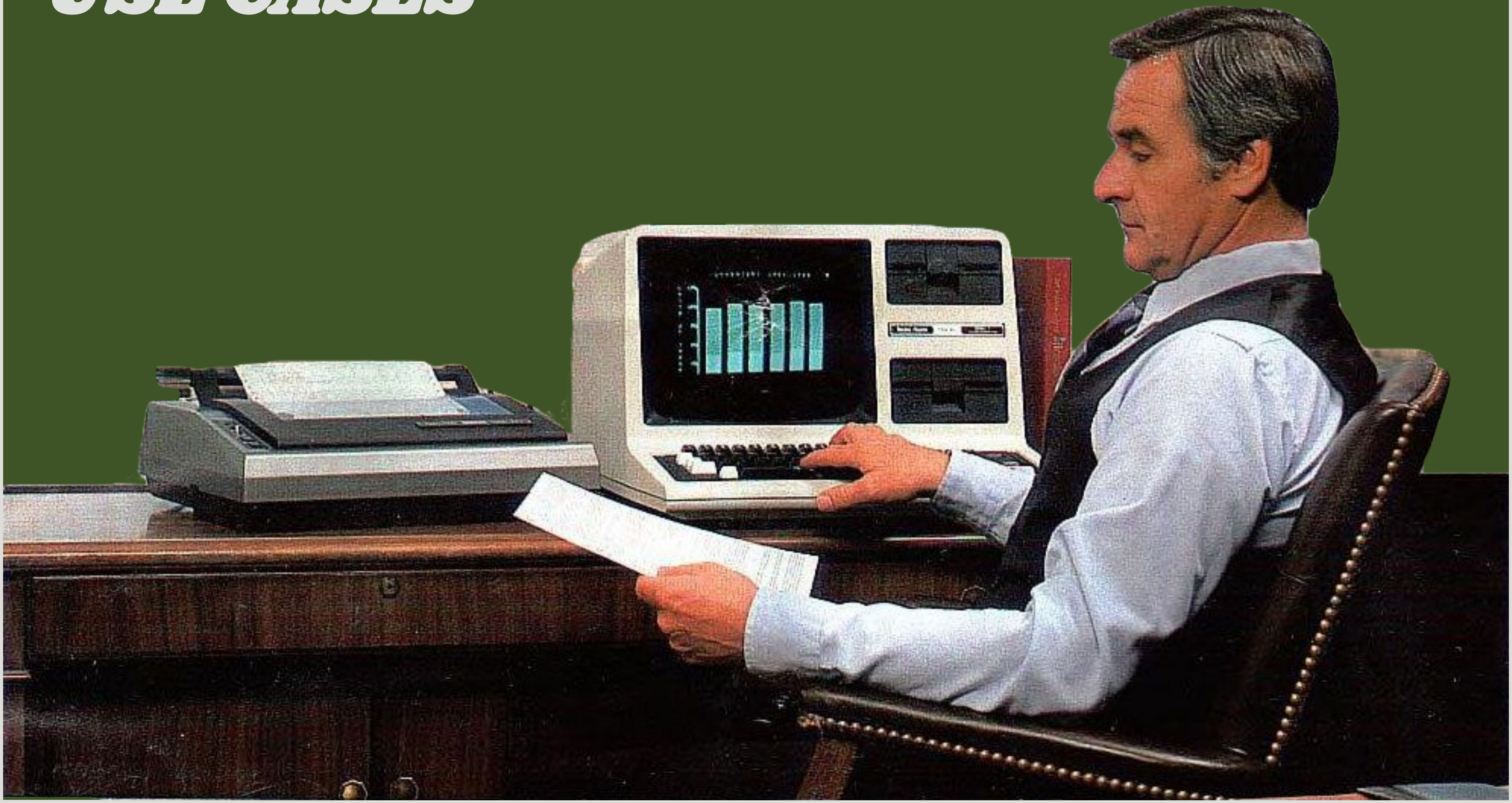


HEAD OF THE DATA

ID	Time 1	Event 1	Time 2	Event 2	Time 3	Event 3
1	22	1	995	0	995	0
2	29	1	12	1	422	1
3	1264	0	27	1	1264	0
4	50	1	42	1	84	1
5	22	1	1133	0	114	1
6	33	1	27	1	1427	0

Demonstrational data.

USE CASES



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1 EVENT / COX PROPORTIONAL HAZARDS

COX METHODOLOGY OVERVIEW

1. Proportional hazards assumptions.

2. Functional form of continuous variables.

3. Independent observations.

4. Independent censoring from the mechanism that rules of event's times.

5. Non informative censoring - does not give an information on parameters of the time distribution of events because it does not depend on them

NOTE

One can use accelerated failure time (AFT) models.

EXAMPLE COEFFICIENTS

variable	coef	exp(coef)
age	0.15	1.16
ecog.ps	0.10	1.11
rx	-0.81	0.44

```
coxph(Surv(futime, fustat) ~ age + ecog.ps + rx, data=ovarian)
```

DIAGNOSTIC PLOTS

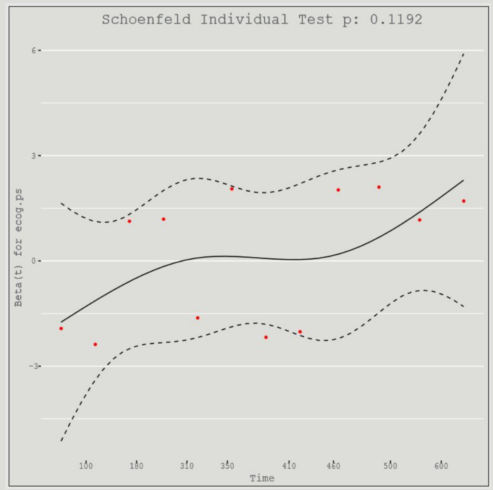
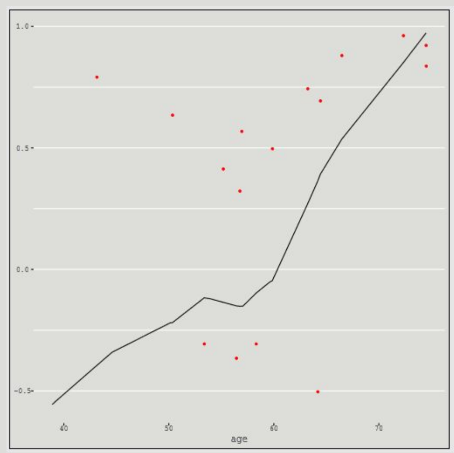


Fig. 1: Shoenfeld residuals.



OVARIAN DATA

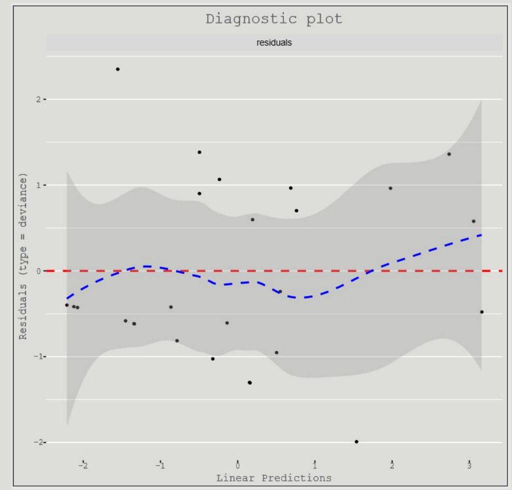


Fig. 2: Deviance residuals.

FUNCTIONS (survminer)

1. ggcoxzph
2. ggcoxdiagnostics
3. ggcoxfunctional

Fig. 3: Martingale residuals.

N EVENTS (ACYCLIC) MULTI-STATE MODEL

TRANSITION MATRIX

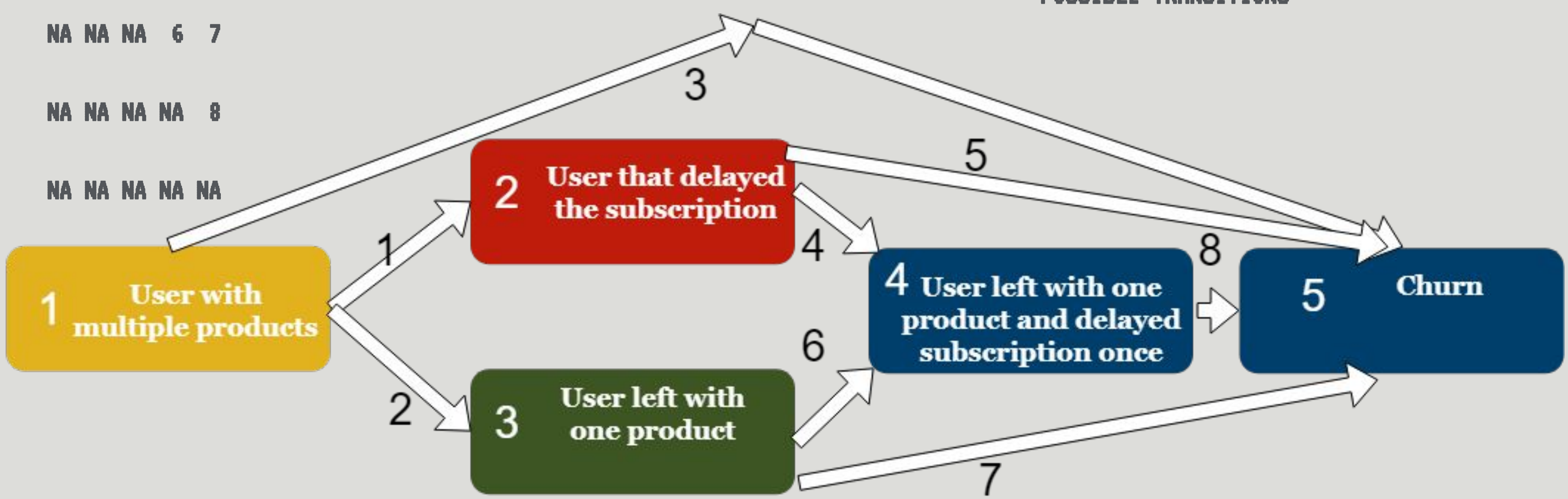
to / from	1	2	3	4	5
1	NA	1	2	NA	3
2	NA	NA	NA	4	5
3	NA	NA	NA	6	7
4	NA	NA	NA	NA	8
5	NA	NA	NA	NA	NA

NA = transition not possible

numbers in cells
=
***names* of transitions**

The most complicated part is the proper data coding for the model's input.

POSSIBLE TRANSITIONS



N EVENTS (ACYCLIC) MULTI-STATE MODEL

SOME COEFFICIENTS

transition	age=>40	age=20-40	discount=yes	gender=female	year=2008-2012	year=2013-2017
1	-1.15	-0.77	-0.26	-0.72	0.80	0.94
2	-1.34	-0.72	-0.15	-0.58	0.39	0.31
3	-0.43	-0.04	0.08	-0.53	0.02	-0.11
4	-0.86	-0.66	-0.09	-0.22	0.13	0.23
5	0.14	-0.64	0.14	-0.24	-0.54	-0.63
6	-1.65	-1.23	0.24	-0.35	0.88	1.33
7	-0.82	-0.57	0.39	-0.57	-0.35	0.09

Reference level for

- age - below 20
- year - 2002-2007

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N EVENTS (ACYCLIC) MULTI-STATE MODEL

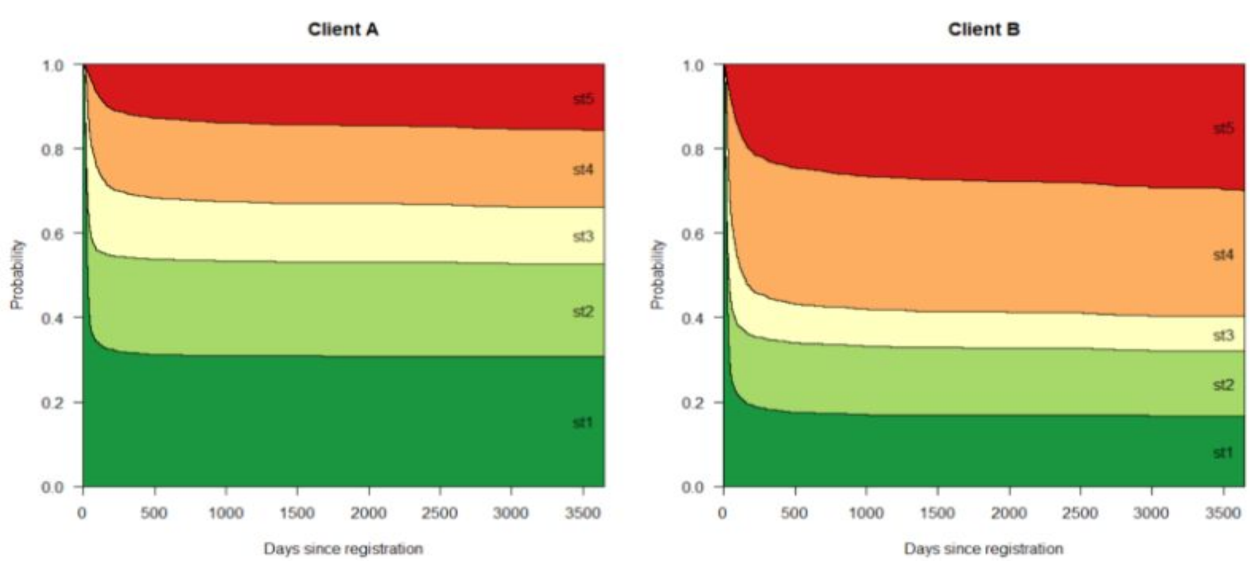
PREDICTIONS OF THE STATE

Depending on the customer features, the predictions of being in a state after particular time are different.

Credits for modeling:

cran.r-project.org/package=mstate

Customer A	Customer B
• Discount: Yes	• Discount: No
• Gender: Female	• Gender: Male
• Joined: 2013-2017	• Joined: 2002-2007
• Age: Younger than 20	• Age: 20-40



NOTES


INVENTORY
DESCRIPTION
WAREHOUSE QTY.
STORE QTY.
4K-LEVEL I
16K-LEVEL I
4K-LEVEL II
16K-LEVEL II
EXPANSION INT.
MINI-DISK I
MINI-DISK II
TRS-80 DESK
QUICK PRINTER
RS-232
TELEPHONE INTERFACE I
TRS-80

Model assumptions should be considered for every possible transition.

Time varying variables can be taken into the account when handling subscription based data.

Playing with cyclic models requires domain knowledge in (sub) Markov Chain field.

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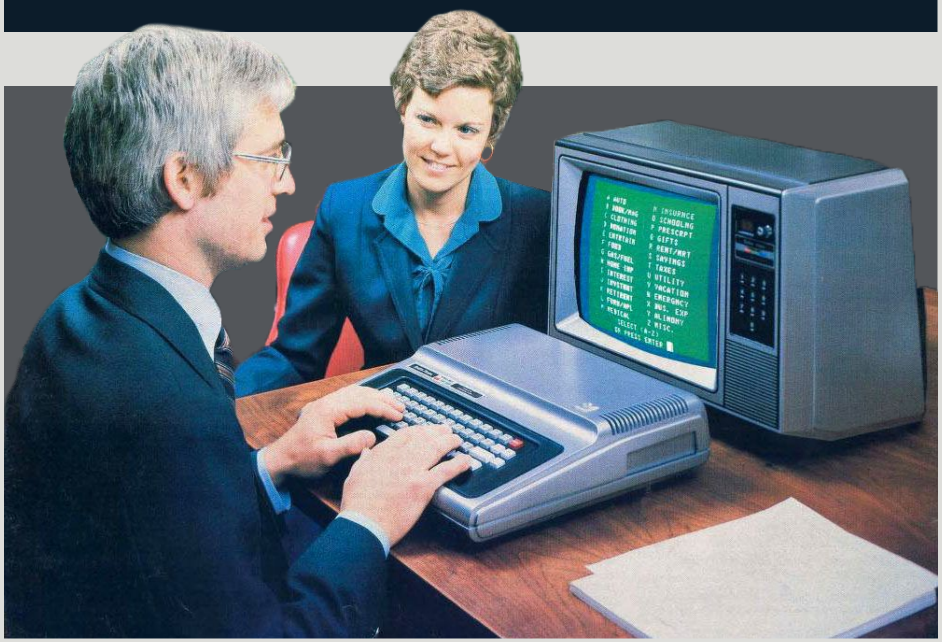
PLOTS BASED ON SURVMINER



Credits:
cran.r-project.org/package=survminer

github.com/kassambara/survminer

www.ggplot2-exts.org/gallery/

stdha.com/english/rpkgs/survminer

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youtube.com/WhyRFoundation

24-27 SEPTEMBER

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THANK YOU FOR THE ATTENTION

github.com/g6t/mchurn