Adaptive Test Development
Using Concerto Platform

Dr Luning Sun
Psychometrics Module, Lecture 3
Social Sciences Research Methods Centre | SSRMC
Outline

- Introduction to CAT
- CAT in R
- CAT in Concerto
Some materials and examples come from previous workshops run by:
  Michal Kosinski (Stanford University)
  David Stillwell (University of Cambridge)
  Chris Gibbons (Harvard University)
Computerised Adaptive Testing

- Standard test is likely to contain questions that are too easy or too difficult
  - Classical Test Theory
  - Item Response Theory

- Adaptively adjusting the level of the test to individual participant:
  - Increases the accuracy
  - Saves time / money
  - Prevents boredom / frustration
Elements of CAT

- Item bank and calibration (IRT model)
- Starting point
- Item selection algorithm (CAT algorithm)
- Scoring on-the-fly method
- Termination rules
And
- Item bank protection / overexposure
- Content Balancing
Example of CAT

Start the test:
1. Ask first question, e.g. of medium difficulty
2. Correct!
3. Score it
4. Select next item with a difficulty around the most likely score (or with the max information)
5. And so on…. Until the stopping rule is reached
Standard test to assess Kumamon

= A question from our test

Maths ability

2+2

1134 x 16
Standard test to assess Kumamon

= A question from our test

Maths ability

Kumamon’s ability
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability

8 x 4
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability

182 + 427
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability

🌟🌟
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability

1134 x 16
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability

1712 + 3218
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability

⭐️⭐️⭐️⭐️⭐️
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability

204 x 16
Computer adaptive test to assess Kumamon

= A question from our test

Maths ability
Maths ability

Kumamon

Computer adaptive test to assess Kumamon

=A question from our test

Kumamon’s ability
Classic approaches to item selection

- Maximum Fisher information (MFI)
  - Obtain a current ability estimate
  - Select next item that maximises information around the current ability estimate

- Urry’s method (bOpt; in 1PL equals MFI)
  - Obtain a current ability estimate
  - Select next item with a difficulty closest to the current one

- Other methods:
  - Minimum expected posterior variance (MEPV)
  - Maximum likelihood weighted information (MLWI)
  - Maximum posterior weighted information (MPWI)
  - Maximum expected information (MEI)
Examples of item overexposure prevention

- Randomesque approach (Kingsbury & Zara, 1989)
  - Select >1 next best item
  - Randomly choose from this set
- Embargo on overexposed items
- Location / Name / IP address rules
- Large item bank
- Regularly updated item bank

Ascertain that all subgroups of items are used equally

Example:
- Arithmetic, Algebra and Geometry in a math test
- Different domains in an intelligence test
- Emotion recognition test

Multidimensional CAT
Stopping rules

- Test length *(e.g., 20 items, 15 items)*
- Test time *(5 minutes)*
- Reliability of theta estimate *(standard error)*
- Other, clever stuff
Reliability and **Standard Error**

\[ \text{reliability} = 1 - SE^2 \]
Reliability and **Standard Error**

- $\text{Alpha}(0.90) = \text{SE}(0.32)$
- $\text{Alpha}(0.80) = \text{SE}(0.45)$
- $\text{Alpha}(0.70) = \text{SE}(0.55)$
1. The pool of available items is searched for the optimal item, based on the current estimate of the examinee's ability
2. The chosen item is presented to the examinee, who then answers it correctly or incorrectly
3. The ability estimate is updated, based upon all prior answers
4. Steps 1–3 are repeated until a termination criterion is met
CAT Qualities

- **Efficiency** – how many items do I need to ask before I get to a certain level of precision

- **Precision** – How precise can my measurement be
CAT Summary

• What do we need for CAT –

Item information (questions, scoring keys)
Item parameters
Item selection method
Scoring algorithm
Stopping rule
Others ......
CAT in R

catR package
Women’s Mobility
- Item 1: Go to any part of the village/town/city.
- Item 2: Go outside the village/town/city.
- Item 3: Talk to a man you do not know.
- Item 4: Go to a cinema/cultural show.
- Item 5: Go shopping.
- Item 6: Go to a cooperative/mothers' club/other club.
- Item 7: Attend a political meeting.
- Item 8: Go to a health centre/hospital.
library(ltm)
my2pl <- ltm(Mobility ~ z1)
plot(my2pl, type = "IIC")
Item Information Curves

Ability

Information
require(catR)
c <- coef(my2pl)
itemBank <- cbind(c[,2], c[,1], 0, 1)
Choose the item to start with:

- **max info around average?**
  
  ```r
  plot(my2pl, type = "IIC")
  plot(my2pl, type = "IIC", items=4)
  ```

- **Random one?**
```r
items_administered <- c(4)
responses <- c(1)

it <- itemBank[items_administered, 1:4, drop=F]
theta <- thetaEst(it, responses)
sem <- semTheta(theta, it)

q <- nextItem(itemBank, theta=theta, out=items_administered)
qu$item
```
CAT in Concerto
HTML User interface (data collection)

- Introduction
- Items
- Feedback

- Bank
- Parameters
- Responses

- SQL Server (spreadsheet)
- R Statistics (calculations)

- Logic
- Theta

- SEM
Concerto hosting website
  ◦ https://hosting.concertoplatform.com/user/registration

Sign up and log in
Create your own server
Start your Concerto experience
Name
URL
Node:
  ◦ info
  ◦ questionnaire
  ◦ CAT
  ◦ form (save_data)
  ◦ feedback
Basic questionnaire

CES–D scale (The Center for Epidemiologic Studies Depression Scale; Radloff, 1977)
- 20 items
- 4 response options
- Score above 16 indicates depression

https://concertotest.com/luning/SSRMC/test/cesd

CAT – dichotomous

Women’s Mobility
- 8 items in the item bank
- Item selection: MFI
- Scoring: BM
- Stopping: 3 items
- Randomesque: 1
- Content balancing: no
- Feedback:
  - \( \text{score}\leftarrow \text{round}(\text{score}\theta*15+100,0) \)
faceiq.icar-project.com
- Adaptive face detection test
- Adaptive emotion recognition test
- Adaptive abstract reasoning test
- And more …..
Thank you!

- Any questions?