Building Economic Models of Human-Computer Interaction Part IV

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BUILDING A MODEL

Building a Model

- **1. Get a precise definition of the problem, and all relevant data about it**
  - Identify the factors and variable that may affect the system
    - Uncontrollable factors – these are environmental and not under direct control
    - Controllable factors – these can be controlled by the system and/or user
  - What factors are stochastic i.e. probabilistic?

Murty (2003)

Building a Model

- Assume there is some agent, who makes **choices** to advance their objectives.
  – They make choices under constraints.
- So, who are these **agents/people**, and
  – what are they trying to achieve (maximize/minimize)?
- What **constraints** are they under?
  – Time, money, knowledge, skills?
- What **interactions** are available?
  – And how can they interact with the system?

Adapted from Varian (1994)

Building a Model

- What **benefit** do they receive from the **choices/interactions** they make?
- What **costs** do they incur from the **choices/interaction** they make?
- **Draw/sketch** out what the **process** is that the **person/agent** undertakes.
- Consider how the variables/actions relate together.

Adapted from Varian (1994)

Building a Model

- **2. Construct a mathematical model of the problem**
  - i.e. define the objective function that needs to be minimized or maximized
  - Usually real world problems are very complicated – so make a simplified version by
    - Making assumptions
    - Using heuristics
    - And taking approximations.

Murty (2003)

Building a Model

- **3. Solve the model**
  - This could be done:
    - analytically i.e. mathematically
    - graphically i.e. plotting out the functions
    - via simulation especially if there are stochastic variables
- **4. Implement the model**
  - Put it into practice
  - Draw hypotheses from the model

Murty (2003)

COMPUTATIONAL EXAMPLE

Computational Approach

- Fix a number of parameters, and then varying one parameter over a range of values
- Plot how the search behavior (outputs) changes in response to the changes in the parameter.
- If some variables are stochastic, then a simulation can be performed, where the computations repeated for different roles of the dice.

Patches Example II

- Under IFT, the forager wants to maximize the amount of gain per unit of time.
  - i.e.

$$\max \frac{\Delta g}{\Delta t}$$

- Let's assume that we know:
  - The time a forager spends per query (say $\boldsymbol{t_q}$)
  - The time a forager spends time per document (say $\boldsymbol{t_d}$)

Patches Example II

- We know that the total time spent after examining ***i*** documents is:
  - the query time (***t_q***) plus the number of documents examined (***i***) multiplied by the document time (***t_d***)

$$t_i = t_q + i.t_d$$

Patches Example II

- Next we need to work out the gain received from each document assessed.
- Each document examined yields a certain amount of gain
  - Hmm… how much?

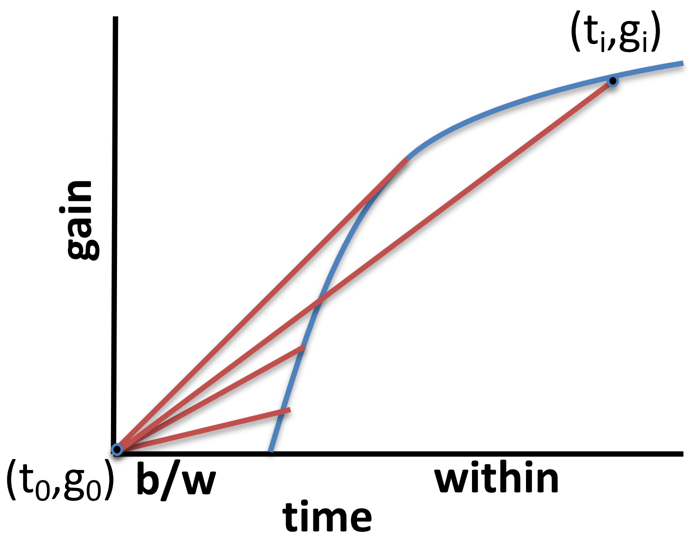
Patches Example II

- No idea, so lets play and make something up!
  - Lets say that the 1st document gives 4 pieces of information, the 2nd document gives 3 pieces, then 2, 3, 1, 1, 0, 0 for the subsequent documents.
  - So the gain of document k is:

k	1	2	3	4	5	6	7	8
$g(d_k)$	4	3	2	3	1	1	0	0

  - Note that we could of ran a query and got the gain values, or used a function to model the gain.

Patch Example II



$$\frac{\Delta g}{\Delta t} = \frac{g_i - g_0}{t_i - t_0} = \frac{g_i}{t_i}$$

- The slope of the line can be calculated using the formula above
- When the slope of the line is the greatest, then the gain per unit of time is maximized.

Patch Example II

- The time at ***i*** is the query time (t_q) plus the number of documents examined (***i***) times the average time to examine a document (t_d)

$$t_i = t_q + i.t_d$$

- The total gain at ***i*** is the sum of the gain of all the docs:

$$g_i = \sum_{k=1}^{i} g(d_k)$$

Patch Example II

- Let t_q = 3 and t_d=1

k	1	2	3	4	5	6	7	8
$g(d_k)$	4	3	2	3	1	1	0	0
g@i	4	7	9	12	13	15	15	15
t@i	4	5	6	7	8	9	10	11
g/t	1	1.4	1.5	1.7	1.6	1.5	1.4	1.3

- The optimal stopping point is at ***i***=4
  - Recall that this assumes that all the patches have a similar distribution of gain.

ANALYTICAL EXAMPLE

An Example Gain Function

$$g = k.(t - c)^{\beta}$$

$$t > c$$

$$0 \leq \beta \leq 1$$

- *t* – time spent looking at results.
- *g* – gain received from the results.
- *c* – cost of the query, cost per document is 1.
- *beta* and *k*– free parameters controlling the how much and how fast gain is encountered.
- The graphs in the previous slides used k=1,c=2,b=0.5

Patch Example III

- To compute the stopping point, we need to construct a tangent line from the origin to the gain curve.
  - Take the first derivative of g(t) to get the slope of the line, and let that equal g over t.

$$\frac{dg}{dt} = k.\beta.(t-c)^{(b-1)} = \frac{g}{t}$$

  - Recall that the slope of a line is $m = (y_1 - y_0)/(x_1 - x_0)$, where m is the gradient, $y_0=0$ and $x_0=0$

Patch Example III

- This results in the following criteria:
  - The optimal time per patch is:

$$t = \frac{-c}{\beta - 1}$$

  - And the gain received is:

$$g = k.(\frac{-\beta.c}{\beta - 1})^{\beta}$$

Static Comparatives

- Fix all variables but one, and see how the outcome is affected.
- What happens to the time in patch:
  - if the cost ***c*** of querying goes up/down?
  - If the performance beta goes up/down?

$$t = \frac{-c}{\beta - 1}$$

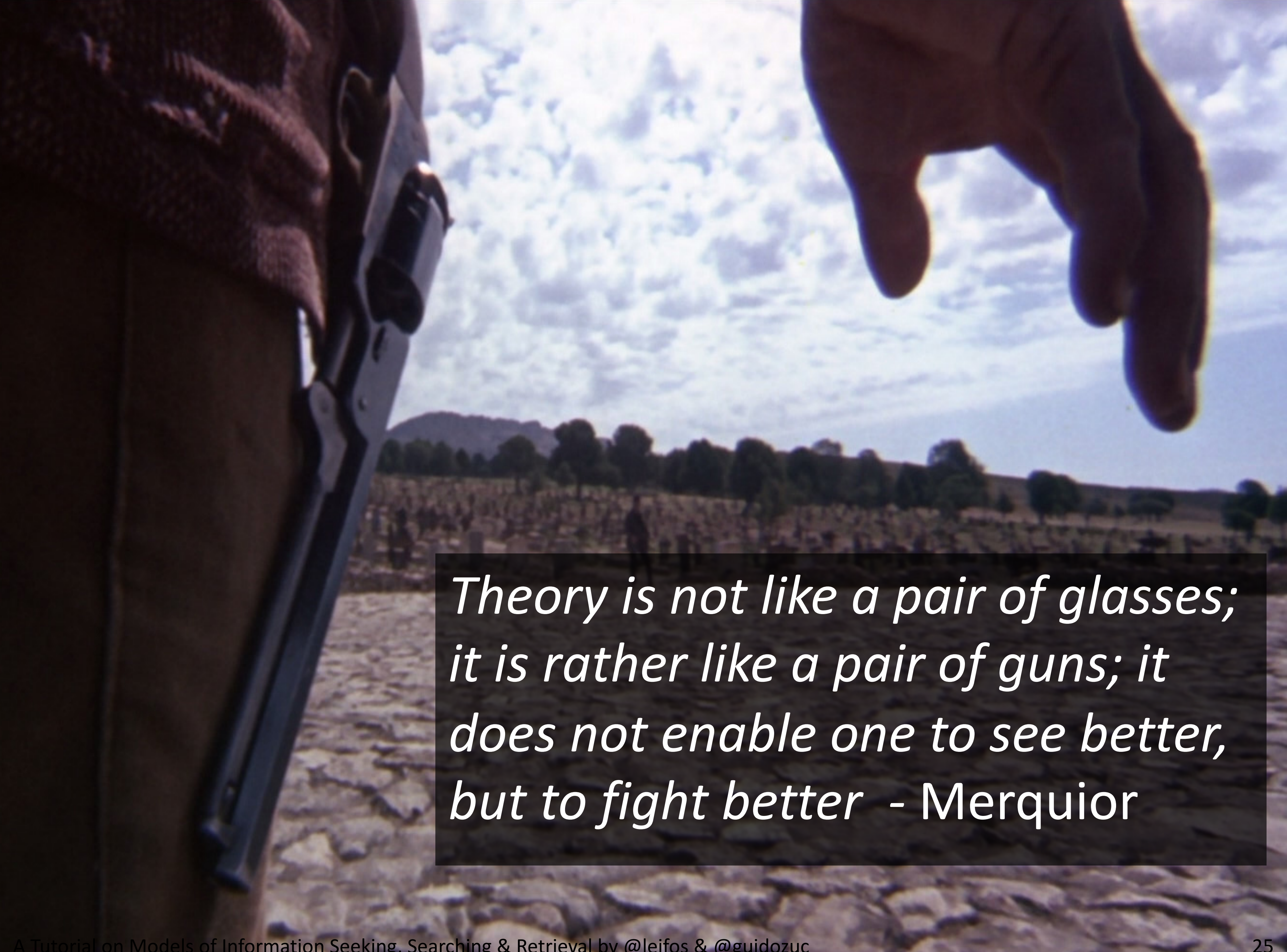
Insights from IFT's Patch Model

- If the query cost ***c*** increases, then users will spend more time in the patch (i.e. examine more documents).
- If the rate of gain ***beta*** increases, then users will spend less time in the patch (i.e. examine less documents).
- If the magnitude of gain ***k*** increases, then user behavior does not change, but they receive more gain.

Summary

- What benefit do they receive from the choices/interactions they make?
- What costs do they incur from the choices the choices/interaction they make?
- Now, work through a simple (the simplest) example possible, so you can see what is going on.
  - i.e. One user, one query…
  - How does it generalize to one user, n queries.
- Always remember to make it as simple as possible (KISS)

Adapted from Varian (1994)


Theory is not like a pair of glasses; it is rather like a pair of guns; it does not enable one to see better, but to fight better - Merquior

SCENARIOS

Result Page Exercise

- How many result snippets should we show the user per page?
  - Assume the user wants to examine ***m*** snippets, where ***m*** is likely to be a number greater than 10
  - i.e. we want to set the number of results per page such that the user's costs are minimized.
- Hints:
  - **Draw** up a screen to represent the problem
  - What are the **variables** of **interest**/**importance**?
- More Hints:
  - What are the **constraints**? What are the main **interactions** and **interaction costs**?
  - What if we only showed 1 results per page? Compare that to 2 results per page? Which one is better?

App Search

- On a mobile phone, what is better: to search for the app or to browse through the apps?
- **Goal**: Find app x on a phone in the minimum amount of time.
- What is the optimal number of apps to show per screen?
  - Consider what interactions are associated with searching and browsing.
  - Consider how the time to locate an app on a screen changes with the number and size of app icons.

Extensions to App Search

- Let’s say we swap to a tablet, where the screen size is larger.
  – What is the optimal number of apps to show per screen, now?
- Let’s say that that we wanted to evaluate a hierarchy based menu approach for app search?
  – Would this be more efficient?

Collaborative Search

- A student and a supervisor are working on a particular research topic and they need to find around 30-40 references.
  - How should they divide their effort?
- Assume that the student's time is cheap, and the supervisor's time is expensive.
- However, the supervisor's search prowess is better than the student's.
- Who should spend more time searching
  - And under what conditions?

Mobile Search

- You need to search for some information while walking around the mean streets of Melbourne.
  - Should you type your query?
  - Or use voice and tell your mobile what you want?
  - Consider how long it takes to type/talk, and how easily one can type/talk, and whether the input is correct or not.