Building Models from Task Analysis

Psyc2965 -- wk09

Outline

- **Introduction**
  - **Task analysis**
  - **Network Representations**
- **From Task Analysis to Network Representations**
  - **Constructing a Network Representation**

Issues

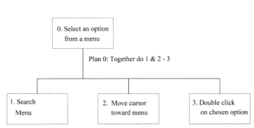
- **Task analysis are frequently carried out, but mathematical and computer models of task are less frequent**
- **Why? -- Perceived difficulty in constructing such models**
- **But, task analysis contains most of the information needed to construct a working model**

Task Analysis

- **Task analysis is a detailed description of all aspects of the task, based on observation, interviews, and inference**
- **Article focuses on how to use this description to construct a model that will identify those task components most critical for determining the completion time of the task**

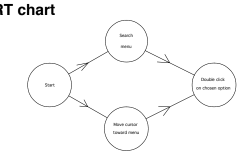
Hierarchical Task Analysis

- **Example of selecting an option from a pop up menu**
- **Achieve this goal by carrying out *operations* according to *plans***
- ***Fig 1***



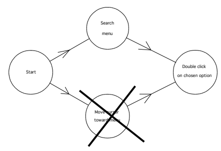
Network Rep-- Activity Networks (fig2)

- **HTA operations = activities**
- **Dependencies built-in**
- **Concurrency implied**
- **Task duration = longest path through network (I.e., the *critical path*)**
- **Aka critical path network or PERT chart**



Network Reps -- Order-of-Processing Diagrams

- **For activity network if cursor was already over the right menu item (say by chance) then network would have just three nodes**



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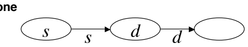
OP Diagrams

- **Each node represents a state; I.e., the set of processes currently active**
- **3 states**
  - **user searching menu (s)**
  - **user double clicking an option (d)**
  - **done**



- **Line drawn between two states ("a directed arc") if the current set of processes in the successor state is consistent with the completion of exactly one of the processes in the current set of predecessor states**
- **The arc is labeled with the process that completed (s or d in the above example)**

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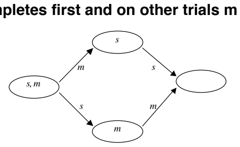
OP Diagrams

- **Now with 3 processes**
  - **searching menu -- s**
  - **moving cursor towards menu -- m**
  - **double clicking an option -- d**
- **s & m begin in parallel -- one completes first**
- **Assume times for s & m are random variables -- so that on some trials s completes first and on other trials m completes first**



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From Task Analysis to Network Rep

- Task analysis emphasizes analysis
  - Detailed description of the task components and their relationships
- Network modelig emphasizes synthesis
  - Calculations of how the components fit together to determine quantities such as task completion time
- There are three steps in moving from a task analysis to a model.
  - First, the task analysis is used to construct a network representation for the task.
  - Second, estimates of the durations of the activities are found in the literature, or, if they are unavailable, obtained through Multidimensional Scaling.
  - Third, the network model is implemented with equations, or a computer program is written for simulations.

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Constructing a Network Representation

- **Two network reps discussed in this paper**
  - **Activity Networks & Order-of-Processing Diagrams**
  - **Critical path network is special case of an activity network**
- **HTA is considered here as the most general representation of a task analysis**
  - **Used to discuss the 6 types of plans**
  - **Provides springboard for discussion of how to construct a network rep**

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Plans in Task Analysis

- **Six basic types of plans**
  - **fixed sequence**
  - **concurrent operations**
  - **optional completion**
  - **cycles**
  - **choices**
  - **contingent sequences**
- **How are these handled by Activity Networks and/or Order-of-Processing Diagrams?**

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Plans in Activity Networks

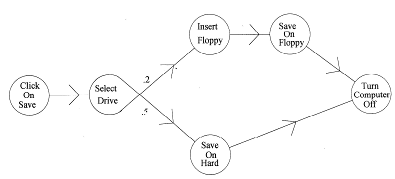
- 1. Fixed sequence -- (obvious) a node is drawn to represent each operation in the HTA as an activity, and an arrow is drawn from each activity to its immediate successor
- 2. Concurrent operations -- (obvious)
- 3. Optional completion -- case in which order for executing operations is optional -- only constraint is that they all be completed
  - May simplify training by teaching one order of completion (treat an optional completion plan as if it were a fixed sequence)
  - Completion time usually independent of order, but if not can represent each order of completion as a separate node in the activity network (with its own completion time)

Plans in Activity Networks (cont.)

- 4. Cycles -- plans that require an operation or set of operations to be repeated until a certain condition is met
  - Easy to estimate time per cycle, harder to estimate number of cycles

Plans in Activity Networks (cont.)

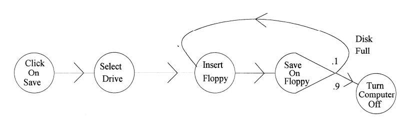
- **5. Choice --** When there is a *choice* of operations, one operation in a set of operations is selected. For example, one may choose to save a file on a hard disk or save it on a floppy disk



- The probability of each option is indicated on the arrow pointing to it

Plans in Activity Networks (cont.)

- 5. Choice
  - A critical path network cannot represent a choice, because all the options are not used, only one of them
  - Awkward for ANs
  - For task completion times per option -- need to draw separate AN for each option
  - For mean task completion times -- use OP diagram



Plans in Activity Networks (cont.)

- 6. Contingent Sequence -- a plan in which an operation is cued by something (e.g., an alarm) other than the finishing of the preceding operations
  - Awkward for AN
  - For task completion times per option -- need to draw separate AN for each option
  - For mean task completion times -- use OP diagram

AN --> OP Diagrams

- Critical path networks (a type of AN) can easily be used to represent
  - fixed sequence, concurrent ops
- With some loss of detail CPN can be used for
  - optional completion, and cycles
- Given a CPN of these 4 plan types and OPD can be “automatically” constructed
- Cannot construct CPN for choices or contingent sequences -- CAN construct OPDs of these

Plans in OPD

- **Choice**
  - **A choice in HTA is represented as a state in OPD**
  - **Options from which the "choice" is made are listed as "activities" currently underway**
  - **Different options take different amounts of time to evaluate -- these times affect probability of chosing that option**
  - **The option selected is considered to be the activity completed to exit the state -- all other options are dropped at that point**

Plans in OPD

- **Contingent sequence**
  - **In HTA some activity is started by something other than completion of the preceding activity (e.g., an alarm sounds & . . .)**
  - **Consider an alarm that can go off at any time -- this activity "Alarm Goes Off" is added to each state of the OPD**
  - **For each state -- one of the ways of exiting the state is for the alarm to go off -- for the potential alarm activity to be "completed"**

Plans -- Summary

- **Fixed sequence -- exact counterparts in AN**
- **Concurrent operations -- exact counterparts in AN**
- **Optional completion -- can be represented in AN, but not an exact counterpart**
- **Cycles -- can be represented in AN, but not an exact counterpart**
- **Choice -- either AN or OPD**
- **Contingent sequence -- either AN or OPD**

Discussion of CPM-GOMS

- **GOMS**
  - **Analyzes organization of the task (basic task analysis) &**
  - **Specifies times for the basic operations**
- **CPM-GOMS**
  - **A method for modeling *concurrent activities***

Task Analysis to Model -- Steps 2 & 3

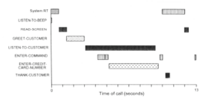
- Second, estimates of the durations of the activities are found in the literature, or, if they are unavailable, obtained through Multidimensional Scaling
  - Means + SDs
  - Means but no SDs
  - No means, no SDs
- Third, the network model is implemented with equations, or a computer program is written for simulations
- We first discuss these steps for AN (pp18-36) then for OPD (pp36-44)

Activity Network: Step 2 -- duration of activities

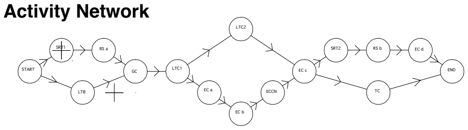
- **Step 1 -- Activity Network constructed**
- **Step 2 -- Obtain means and standard deviations of activity durations**
- **Will use as a test case the example of a telephone call from GJA93**

Bar Chart & Activity Network

- **Bar Chart**



- **Activity Network**



- **8 ways through this network**

GJA93 -- Durations?

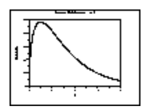
- **Activity durations from videotapes (benchmark) and literature (normative)**
- "If two activities in the activity network are not joined by a directed path, neither is required to be finished before the other can start. They may be carried out literally simultaneously, although simultaneity is not necessary. The activity network does not indicate simultaneity, because activity durations are random, and when the task is carried out repeatedly, two activities not joined by a directed path might sometimes be simultaneous and sometimes not be simultaneous" p. 20.

GJA93 -- Variability?

- **To use Telephone call example to produce a model we will need the probability distributions of the activity durations**
  - **For example, each mouse click is not always, exactly, precisely 200 msec (from KLM); each keystroke is not always, exactly, precisely 280 msec, & each activity from GJA93 is not always, exactly, precisely its benchmark duration or its normative duration**

Estimating Probability Distributions (i.e., standard deviations)

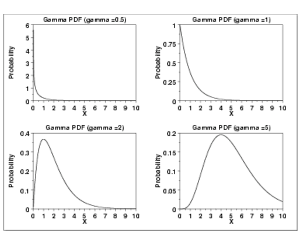
- **Use gamma distribution as the distribution function for reaction times and elementary activities**



- **Skewed to the right, as are human response times**

Gamma Distribution

- **Extreme forms of gamma type the form of the exponential distribution or normal distribution**



Coefficient of Variation

- **CV = stdev/mean**
- **For human response time, standard deviations tend to range from 1/10 of the mean (rarely smaller) to about equal the mean (rarely larger)**
- **I.e., CVs range from 0.1 to 1.0**
- **Randomly assign a CV from set (0.1 0.2 . . . 1.0) to each activity from GJA analysis**

Table 1

- Then use the CV to derive beta and alpha -- two parameters needed for the Gamma Distribution

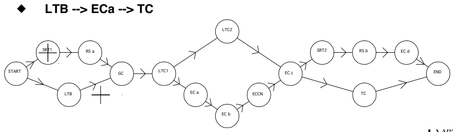
Activity Name & Abbreviation	Mean	CV	V = $(CVxMean)^2$	beta = V/Mean	alpha = Mean/beta
Listen-to-Beep (LTB)	100	0.1	100	1.0	100.00
Enter-Command (EC)	320	0.5	25600	80.0	4.00
Read-Screen (RS)	340	0.9	93636	275.4	1.23
Thank-Customer (TC)	360	0.2	5184	14.4	25.00
System-RT1 (SRT1)	730	0.4	85264	116.8	6.25
Listen-to-Customer1 (LTC1)	1000	0.8	640000	640.0	1.56
Greet-Customer (GC)	1570	1.0	2464900	1570.0	1.00
System-RT2 (SRT2)	2000	0.7	1960000	980.0	2.04
Enter-Credit-Card-No. (ECCN)	4470	0.6	7193124	1609.2	2.78
Listen-to-Customer2 (LTC2)	5280	0.3	2509056	475.2	11.11

Activity Network: Step 3 -- Implementing a Network Model

- By equations
- By simulation
  - For fixed sequence and concurrent operations, in the search menu example, Search Menu Simulation.xls
  - For a choice, in the save file example, Save File Simulation.xls
  - For a cycle and contingency, in the save file with disk full example, Save File Disk Full Simulation.xls
  - Project Ernestine

PE -- 8 paths through network

- 8 paths, but how many of these are *critical* paths?
  - SRT1 --> LTC2 --> SRT2
  - SRT1 --> LTC2 --> TC
  - SRT1 --> ECa --> SRT2
  - SRT1 --> ECa --> TC
  - LTB --> LTC2 --> SRT2
  - LTB --> LTC2 --> TC
  - LTB --> ECa --> SRT2
  - LTB --> ECa --> TC



Paths

- Mean duration of a path is sum of the mean duration of the activities on it
- Mean duration of path with the longest mean duration is 11.88 (in my simulation over 10,000 trials)
- This duration is less than the mean time to complete the task: 12.982
- Also note that the mean duration of this path *when it is the critical path* is 12.394
- How can it be that ??
  - The duration of the longest path is less than the mean duration of a trial
  - Less than itself when it is the critical path?

PE -- 8 critical paths

	SRT1, LTC, SRT2	SRT1, LTC, TC	SRT1, ECa, SRT2	SRT1, ECa, TC	LTB, LTC, SRT2	LTB, LTC, TC	LTB, ECa, SRT2	LTB, ECa, TC
Frequency on CP	5744	5	4242	8	1	0	0	0
mean duration of CP trials	12.394	9.787	13.788	10.779	8.291			
mean duration over all trials	11.880	9.595	11.664	9.378	10.912	8.626	15.967	13.681

Mean duration over all trials is 12.982

PE -- Paths

- Mean duration of longest path through network is less than the mean duration of the task?
- Longest path through network is not always the same path
  - That is, the path with the longest mean duration is NOT the critical path on every trial
  - When a path is the critical path for a trial, it is longer than the other seven paths
  - Mean duration of a path underestimates the contribution of that path to the average completion time of the task

PE -- Paths

- **Implications of the underestimation**
  - **Any particular activity, X, is on the longest path through the network on some trials, but not on others**
  - **Hence, the *criticality* of an activity is the key quantity**
  - **The probability that the activity is on the critical path**

	SRT1	LTB	RS a	GC	LTC1	LTC2	EC a	EC b	ECCN	EC c	SRT2	TC	RS b	EC d
Total Critical Trials	9999	1	9999	10000	10000	5750	4250	4250	4250	10000	9987	13	9987	9987
Mean (criticality)	1.0	0.0	1.0	1.0	1.0	0.6	0.4	0.4	0.4	1.0	1.0	0.0	1.0	1.0
Criticality* Duration	729.9	0.0	340.0	1570.0	1000.0	3036.0	136.0	136.0	1899.8	320.0	1997.4	0.5	339.6	319.6

Criticality of an Activity

- **Activities of high criticality are important**
  - **but an activity with high criticality may be of short duration, moderating its overall importance**
- **Another measure of the importance of an activity is its criticality times its mean duration**

Repeated Criticality (across simulations)

Name	Criticality (SFP)	Criticality (Gray)
Listen-to-beep	.001	.000
Thank-Customer	.001	.001
Enter-Commanda	.424	.425
Enter-Commandb	.424	.425
Enter-Credit-Card-No	.424	.425
Listen-to-Customer-2	.576	.575
Enter-Commandd	.999	.999
Read-Screenb	.999	.999
System-RT2	.999	.999
System-RT1	1.000	1.000

Criticality versus Critical Path

- **Activity with the highest criticality in both simulations (SFP & Gray's) is Listen-to-Customer2**
- **But, the "most critical" activity is only on the critical path 0.575 of the time**

set1srt1 --> RSa --> GC --> LTC1 --> LTC2 --> ECc --> SRT2 --> RSb --> Ecd --->End
set2srt1 --> RSa --> GC --> LTC1 --> LTC2 --> ECc --> TC --->End
set3srt1 --> RSa --> GC --> LTC1 --> ECa --> ECb --> ECCN --> ECc --> SRT2 --> RSb --> Ecd --->End
set4srt1 --> RSa --> GC --> LTC1 --> ECa --> ECb --> ECCN --> ECc --> TC --->End
set5LTB --> GC --> LTC1 --> LTC2 --> ECc --> SRT2 --> RSb --> Ecd --->End
set6LTB --> GC --> LTC1 --> LTC2 --> ECc --> TC --->End
set7LTB --> GC --> LTC1 --> ECa --> ECb --> ECCN --> ECc --> SRT2 --> RSb --> Ecd --->End
set8LTB --> GC --> LTC1 --> ECa --> ECb --> ECCN --> ECc --> TC --->End

OP Diagram: Steps 2 & 3

- **Step 1 -- OP Diagram constructed by one means or another**