187.A27 VU **Design Studies**

11. Ingenieurwiss. u. kognitiver Ansatz

Descriptive Design Research

- empirische Untersuchung – Designexperiment
- Untersuchungsergebnisse

- Analysing (video-recorded) designing
- Protocol Analysis
- FBS ontology
  - UE: FBS – coding
  - LINKODER
  - Maße

187.A27 VU **Design Studies**

11. Descriptive Design Research

Analysing (video-recorded) designing

Protocol Analysis

- FBS ontology
  - FBS coding UE
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http://www.linkoder.com/

Data input for LINKODER
coded segments, links (excel spreadsheet)

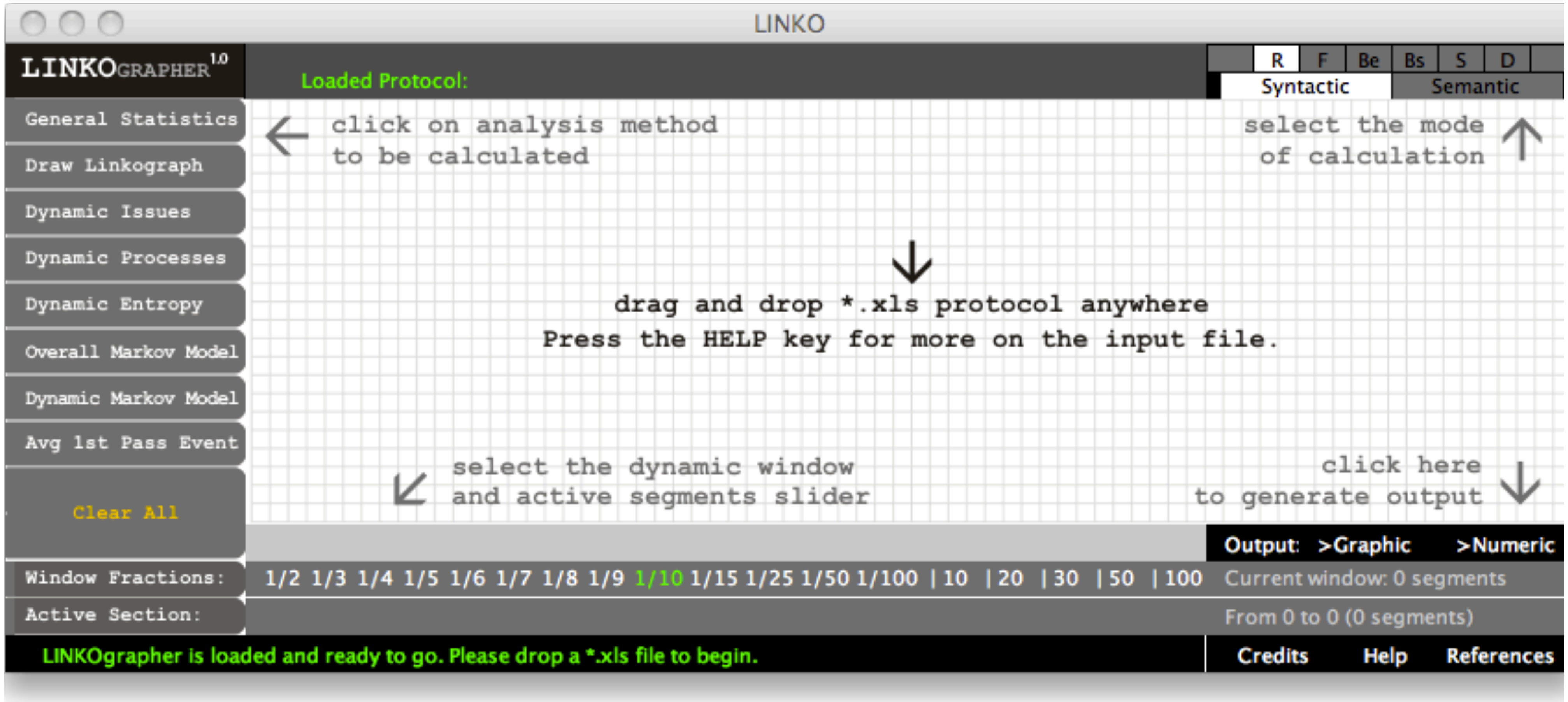
1	NUMBER	UTTERANCE	CODE	LINKS					
2	1	J: I ended up with the (.) hold on (2.2) sledge	S						
3	2	A: the sledge excellent so what did that generate then? ((write: sledge))	D	1					
4	3	J: well the sledge manages to keep level by having quite a wide base	Bs	1					
5	4	A: ((write: wide base))	D	3					
6	5	J: and then a main force in the middle so	Bs	3	1				
7	6	J: unlike the set of skis	S	3	1				
8	7	J: where quite narrow and	S	6	3	1			
9	8	J:you go up on an edge- when you're turning	Bs	7	6	5	3	1	
10	9	J: the sledge is er quite broad	S	7	6	3	1		
11	10	J: and then you have the weight right in the middle	Bs	9	6	5	3	1	
12	11	J: so they manage to keep both runners on the snow-	Bs	10	9	8	5	3	1
13	12	A: ((write: force in middle))	D	10	5				
14	13	J: more often than say a sledge or a snowboar- a skis or snowboard	Be	10	9	1			
15	14	A: some some guiders almost down the side of this	S	13	1				
16	15	J: well I guess the easiest way to keep the pen at a right angle would be	Be						
17	16	J: to have a set of stabilisers on it based on the idea of a sledge	S	15	9	3	1		
18	17	A: yeah no problem (.) stabilisers (6) like a bicycle yeah that's a good	S	16					
19	18	A: ((write: stabilizer))	D	16					

Extract: engineering design meeting1

reliability

Coding1 vs Arbitrated (%)	Coding2 vs Arbitrated (%)
85.1	89.3

http://www.linkoder.com/



Descriptive statistics

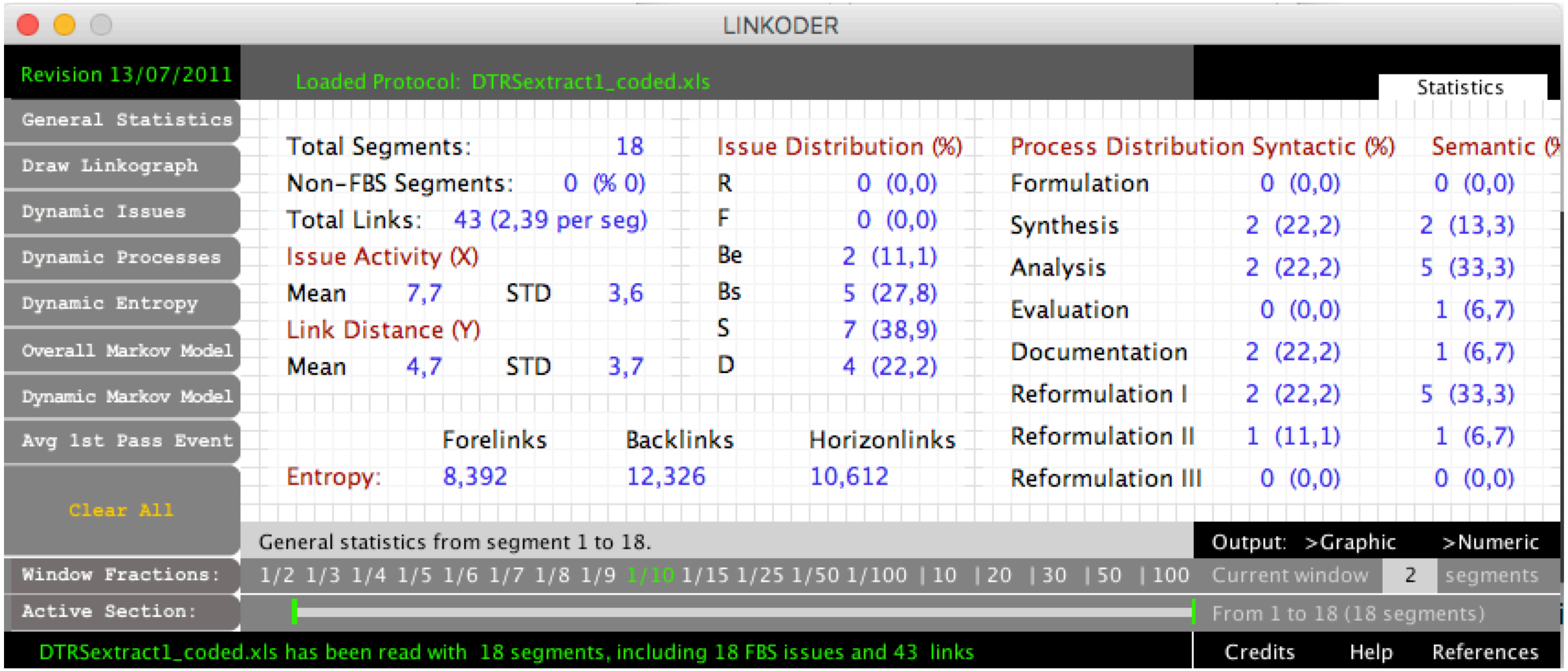
- Segment and link counts
- Design issue distribution
- Issue Activity (X)
- Link Distance (Y)

  means for distribution of link nodes in both vertical and horizontal axes

  how far the linked segments are apart
- Design process distribution
- Backlink / Forelink counts
- Backlinks-, Forelinks-, Horizonlinks - entropy

LINKODER - measurement tool analysis methods

- standard statistical analyses
  - issues distribution
  - dynamic issues distribution
  - process distribution
  - dynamic process distribution
- Markov model generation
- dynamic Markov model generation
- entropy model generation
- dynamic entropy model generation
- dynamic entropy model generation
- drawi**n**g of linkograph



Extract: engineering design meeting1

Issue distribution, distribution of codes

engineering design meeting1

Code	Segment	
R	7	1.6%
F	17	3.8%
Bs	126	28.1%
Be	69	15.4%
S	180	40.2%
D	49	10.9%
Total	445	100%

semantic process distribution

FBS processes derived from the links of the coded segments, engineering design meeting1

Processes		Occurrence	Percentage
Formulation	R>F,F>Be	14	1.4
Synthesis	Be>S	68	6.9
Analysis	S>Bs	120	12.2
Documentation	S>D	52	5.3
Evaluation	Be<>Bs	48(Be>Bs),49(Bs>Be)97	9.9
Reformulation I	S>S	262	26.7
Reformulation II	S>Be	32	3.3
Reformulation II	S>F	1	0.1
	Total	646	65.9

problem-/solution focused designing styles

single-value measurement to summarize the designing style of an entire design session.
The **problem-solution (P-S) index** is … the ratio of the total occurrences of the design issues concerned with the problem space to the sum of those related to the solution space:

$$\text{P-S index} = \frac{\Sigma\,(\text{Problem-related issues})}{\Sigma\,(\text{Solution-related issues})} = \frac{\Sigma\,(R,F,Be)}{\Sigma\,(Bs,\,S)}$$

We define a design session with

P-S index > 1 as one with a problem-focused designing style,

P-S index value ≤ 1 as one with a solution-focused style. (4)

Problem/solution space	Design issue
Problem space = Problem-focused design issues	Requirement (R) Function (F) Expected Behavior (Be)
Solution space = Solution-focused design issues	Behavior from Structure (Bs) Structure (S)

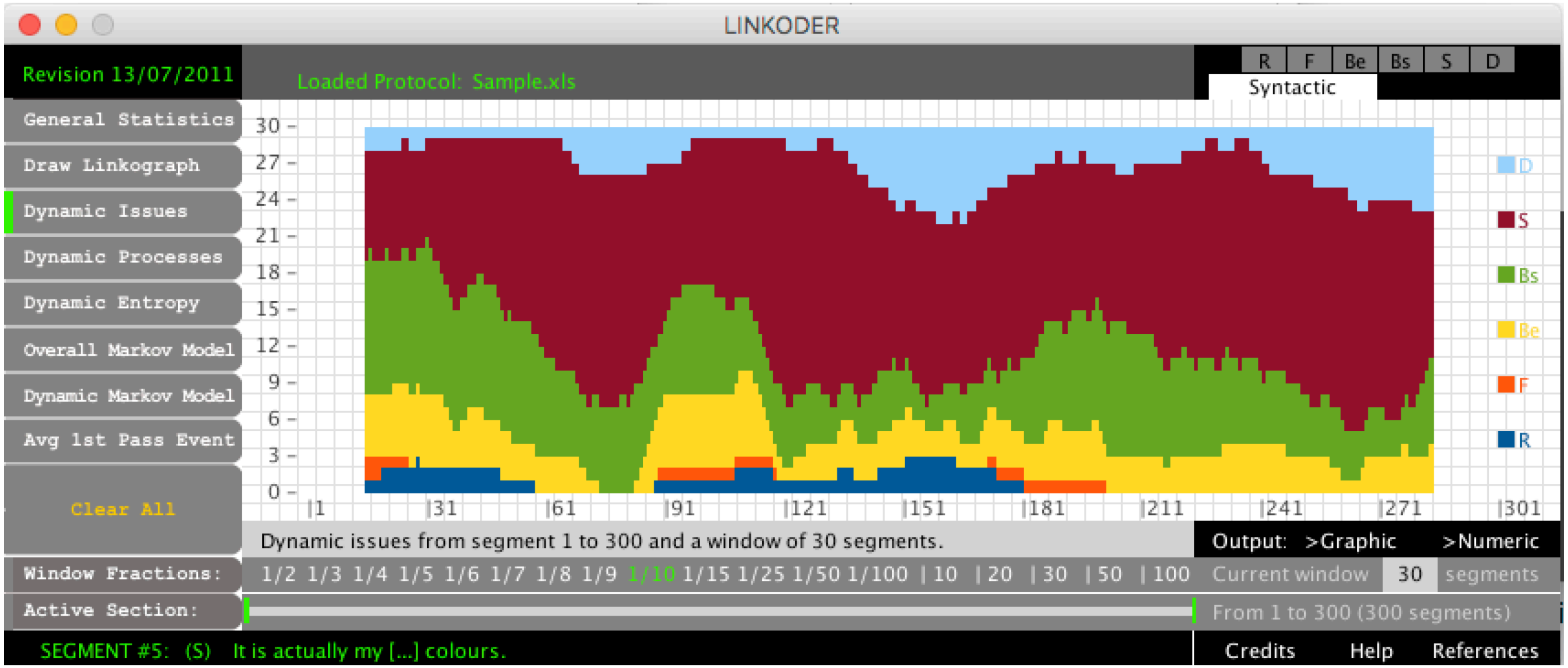
problem-/solution focused designing styles

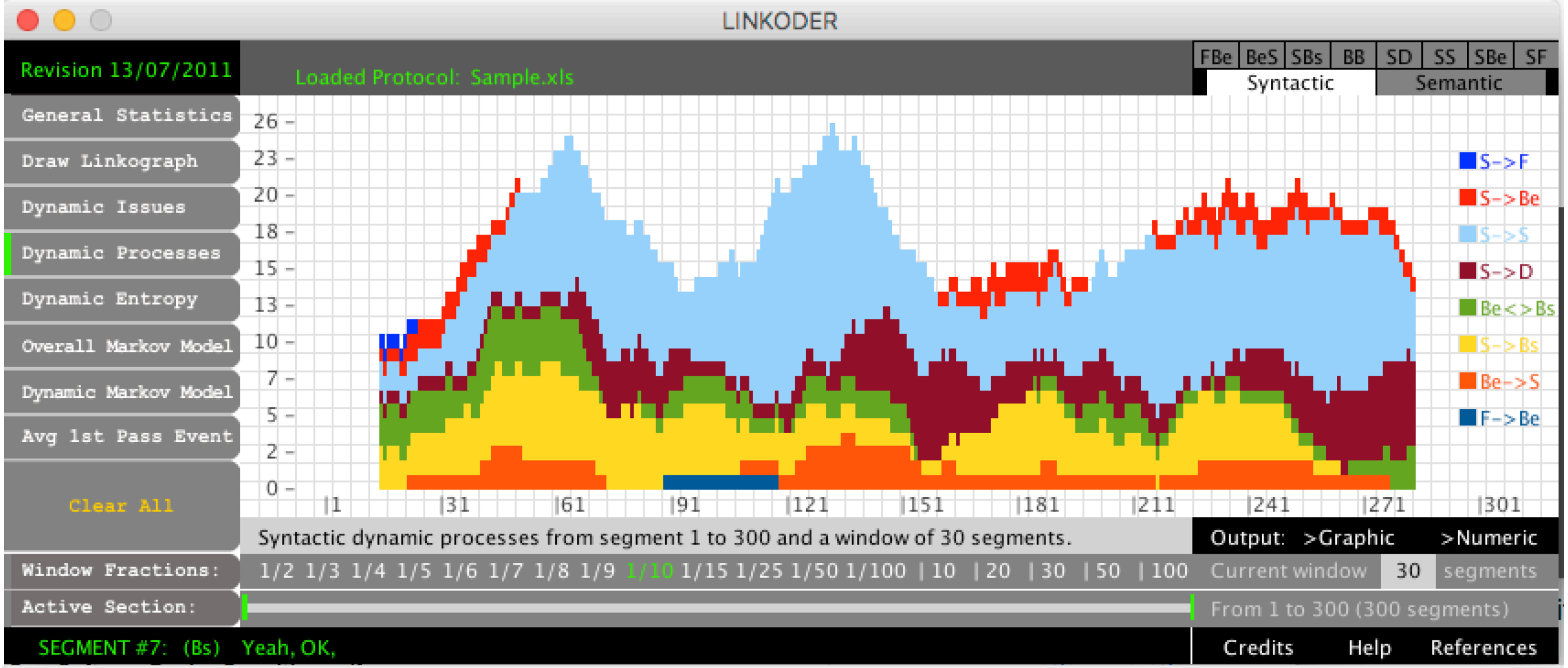
Sequential Problem-Solution index across design session

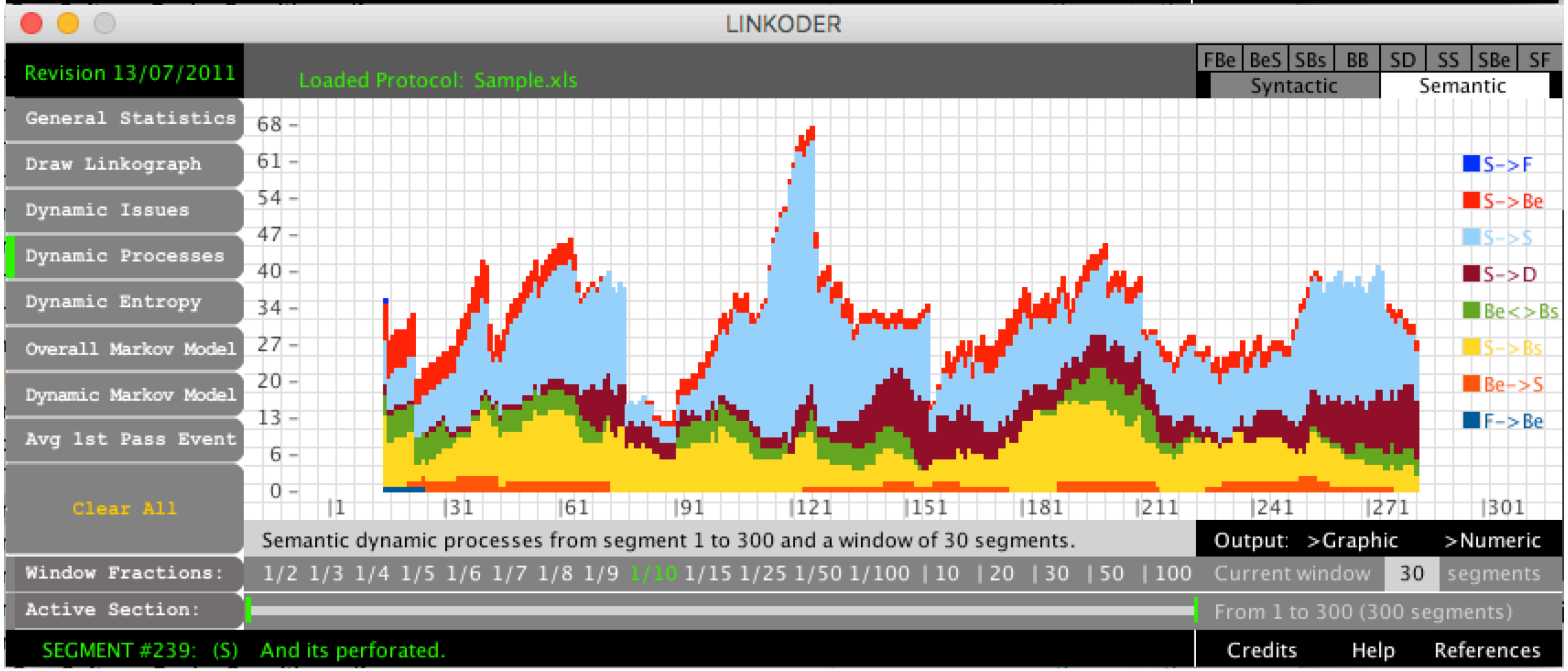
the entire design session is divided - **fractioned into 10** consecutive non-overlapping **sections** each with an equal number of design issues. The P-S index for each section is calculated. A **sequence of temporally ordered P-S indexes** is read as a "signature" of dynamic designing **style**.

$$\text{P-S index} = \frac{\Sigma\,(\text{Problem-related issues})}{\Sigma\,(\text{Solution-related issues})} = \frac{\Sigma\,(R, F, Be)}{\Sigma\,(Bs, S)}$$

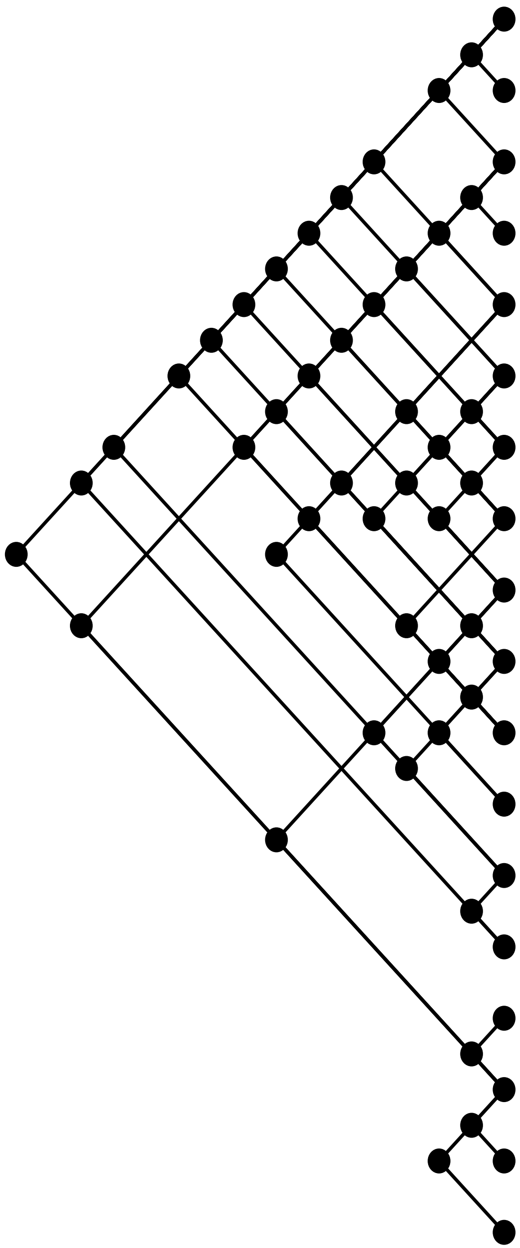
Jiang Gero & Yen: Exploring Designing Styles Using a Problem-Solution Division. DCC'12.
Gero, et al. 2013: Design cognition differences when using unstructured, partially structured, and structured concept generation creativity techniques." Int. J .Design Creativity & Innovation


LINKODER
Revision 13/07/2011
Loaded Protocol: Sample.xls
R F Be Bs S D
Syntactic
General Statistics
Draw Linkograph
Dynamic Issues
Dynamic Processes
Dynamic Entropy
Overall Markov Model
Dynamic Markov Model
Avg 1st Pass Event
Clear All
30 27 24 21 18 15 12 9 6 3 0
|1 |31 |61 |91 |121 |151 |181 |211 |241 |271 |301
D S Bs Be F R
Dynamic issues from segment 1 to 300 and a window of 30 segments.
Output: >Graphic >Numeric
Window Fractions:
1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/15 1/25 1/50 1/100 | 10 | 20 | 30 | 50 | 100
Current window 30 segments
Active Section:
From 1 to 300 (300 segments)
SEGMENT #5: (S) It is actually my [...] colours.
Credits Help References


LINKODER
Revision 13/07/2011
Loaded Protocol: Sample.xls
FBe BeS SBs BB SD SS SBe SF
Syntactic
Semantic
General Statistics
Draw Linkograph
Dynamic Issues
Dynamic Processes
Dynamic Entropy
Overall Markov Model
Dynamic Markov Model
Avg 1st Pass Event
Clear All
26
23
20
18
15
13
10
7
5
2
0
|1 |31 |61 |91 |121 |151 |181 |211 |241 |271 |301
S->F
S->Be
S->S
S->D
Be<>Bs
S->Bs
Be->S
F->Be
Syntactic dynamic processes from segment 1 to 300 and a window of 30 segments.
Output: >Graphic >Numeric
Window Fractions:
1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/15 1/25 1/50 1/100 | 10 | 20 | 30 | 50 | 100
Current window 30 segments
Active Section:
From 1 to 300 (300 segments)
SEGMENT #7: (Bs) Yeah, OK,
Credits Help References


LINKODER
Revision 13/07/2011
Loaded Protocol: Sample.xls
FBe BeS SBs BB SD SS SBe SF
Syntactic
Semantic
General Statistics
Draw Linkograph
Dynamic Issues
Dynamic Processes
Dynamic Entropy
Overall Markov Model
Dynamic Markov Model
Avg 1st Pass Event
Clear All
68
61
54
47
40
34
27
20
13
6
0
|1 |31 |61 |91 |121 |151 |181 |211 |241 |271 |301
S->F
S->Be
S->S
S->D
Be<>Bs
S->Bs
Be->S
F->Be
Semantic dynamic processes from segment 1 to 300 and a window of 30 segments.
Output: >Graphic >Numeric
Window Fractions:
1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/15 1/25 1/50 1/100 | 10 | 20 | 30 | 50 | 100
Current window 30 segments
Active Section:
From 1 to 300 (300 segments)
SEGMENT #239: (S) And its perforated.
Credits Help References

Linkograph



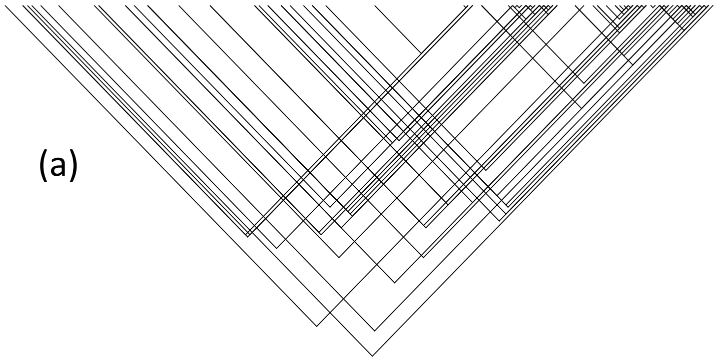
1	S	J: I ended up with the (.) hold on (2.2) sledge
2	D	A: the sledge excellent so what did that generate then? ((write: sledge))
3	Bs	J: well the sledge manages to keep level by having quite a wide base
4	D	A: ((write: wide base))
5	Bs	J: and then a main force in the middle so
6	S	J: unlike the set of skis
7	S	J: where quite narrow and
8	Bs	J:you go up on an edge– when you're turning
9	S	J: the sledge is er quite broad
10	Bs	J: and then you have the weight right in the middle
11	Bs	J: so they manage to keep both runners on the snow–
12	D	A: ((write: force in middle))
13	Be	J: more often than say a sledge or a snowboar– a skis or snowboard
14	S	A: some some guiders almost down the side of this
15	Be	J: well I guess the easiest way to keep the pen at a right angle would be
16	S	J: to have a set of stabilisers on it based on the idea of a sledge
17	S	A: yeah no problem (.) stabilisers (6) like a bicycle yeah that's a good
18	D	A: ((write: stabilizer))

Extract: engineering design meeting1

shape of a Linkograph

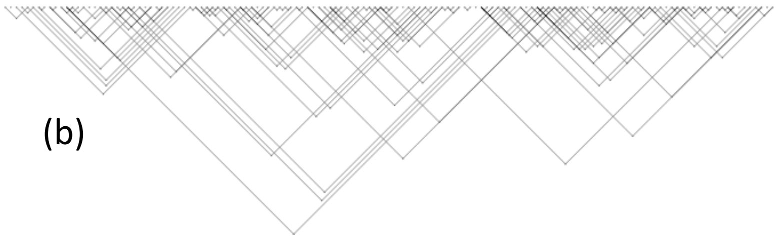
The design process … (as) patterns of moves associations.
With the linkograph, we can trace the structure of reasoning.

(a)



(a) reflects a relatively **holistic design process** (the linkograph is well integrated)

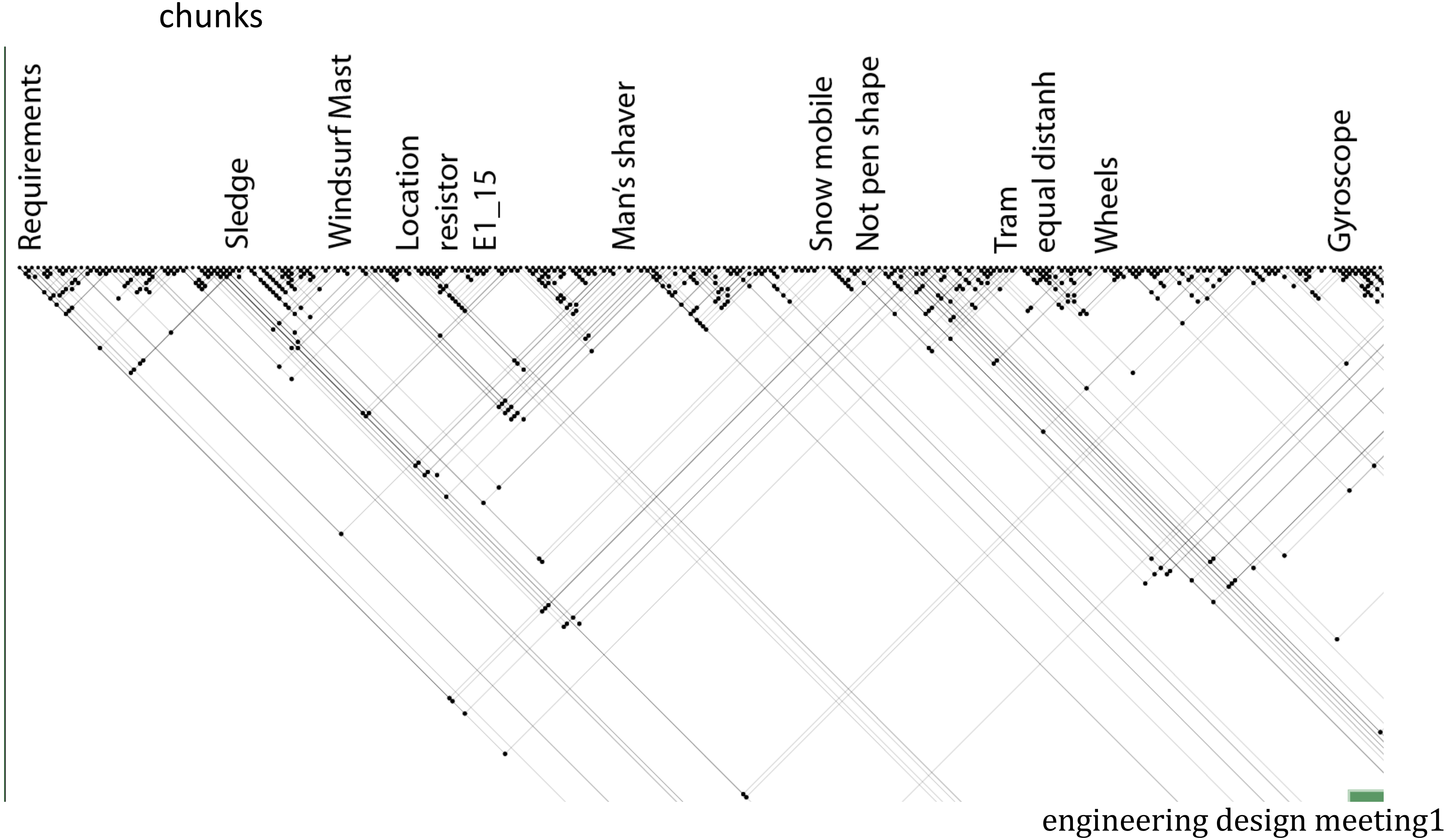
(b)



(b) represents a process of **trying out different options** (there are obvious clusters in the linkograph)

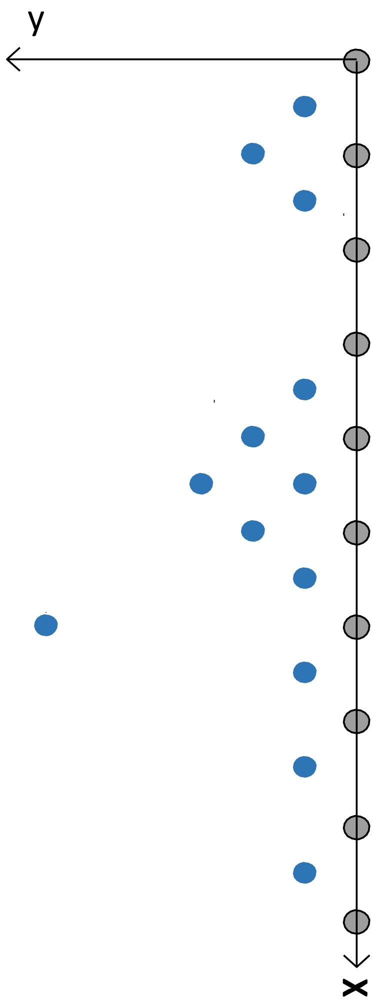
Kan, Bilda & Gero: Comparing Entropy Measure Of Idea Links In Design Protocols. DCC06.
Kan & Gero 2009: Using the FBS Ontology to Capture Semantic Design Info in Design Protocol St.

Part of the linkograph of the segmented protocol



Kan & Gero 2009: Using the FBS Ontology to Capture Semantic Design Information in Design Protocol Studies

Statistical Description of Linkograph



consider the nodes (but not the moves /segments) in a two dimension space.

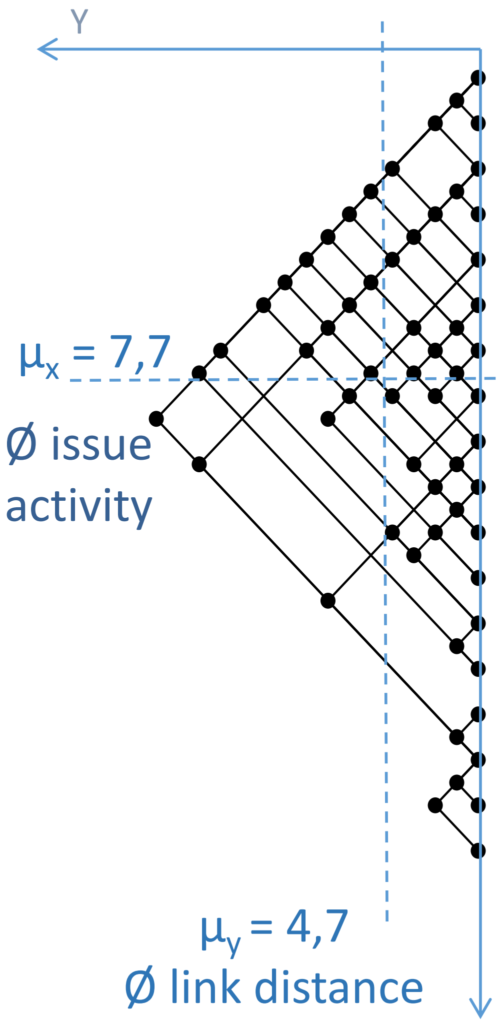
Treating each node as a point in the X-Y plane we can statistically describe a linkograph in terms of the

- **total number of nodes** (Links count)
- **mean values of X** and **Y** – average position (centroid) of all nodes (issue activity; link distance)
- **deviations** in the X and Y axes.

A higher/lower mean value of X implies that more nodes appear at the end/beginning of a session.

A higher mean value of Y indicates longer linking lengths.

LINKODER – basic descriptive statistics
issue activity (X); link distance (Y)



1	S	I ended up with the+ hold on+ sledge
2	D	the sledge excellent so what did that generate then? ((write: sledge))
3	Bs	well the sledge manages to keep level by having quite a wide base
4	D	((write: wide base))
5	Bs	and then a main force in the middle so
6	S	unlike the set of skis
7	S	where quite narrow and
8	Bs	you go up on an edge– when you're turning
9	S	the sledge is er quite broad
10	Bs	and then you have the weight right in the middle
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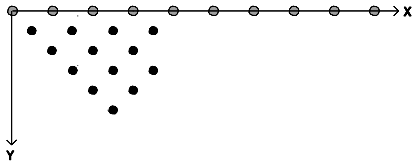
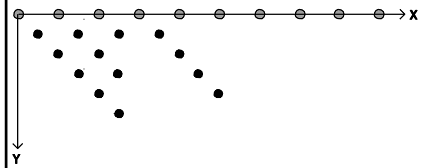
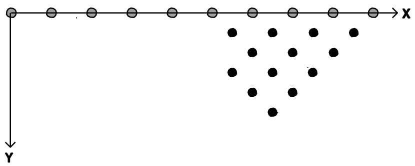
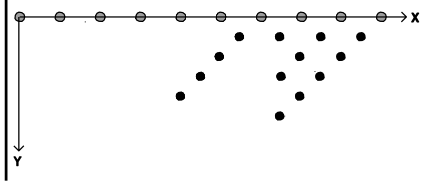
12	D	((write: force in middle))
13	Be	more often than say a sledge or a snowboar– a skis or snowboard
14	S	some some guiders almost down the side of this
15	Be	well I guess the easiest way to keep the pen at a right angle would be
16	S	to have a set of stabilisers on it based on the idea of a sledge
17	S	yeah no problem++ stabilisers +++like a bicycle yeah that's a good
18	D	A: ((write: stabilizer))

shape of a Linkograph

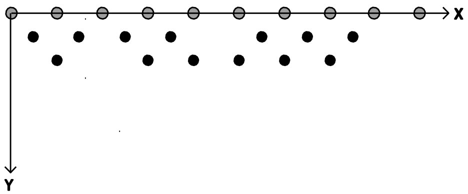
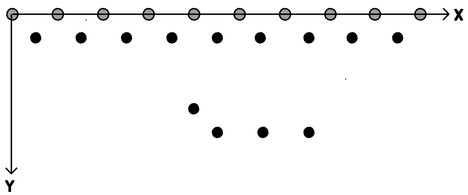
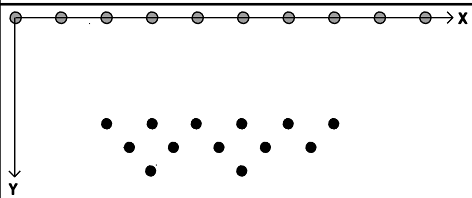
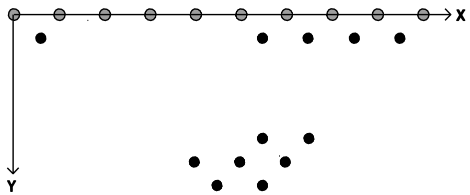
issue activity (X); link distance (Y)

with the same number of nodes, in relation to mean and standard deviation of **X**.
A higher value of X-mean signifies - more **activities at** the end of the session.

X Axis	Small standard deviation	Large standard deviation
Small mean		
Large mean		

Standard deviations: how concentrated the nodes are clustered around the means. The lower the value the closer those nodes are toward the mean

same number of nodes, in relation to mean and standard deviation of **Y**.
A lower value of Y-mean indicates shorter **linking distance**.

Y Axis	Small standard deviation	Large standard deviation
Small mean		
Large mean		

Kan & Gero 2006: Acquiring Information from Linkography

Link index, critical moves - **design productivity**

General statistics from segment 1 to 18

Total Segments:	18
Non-FBS Segments:	0 (% 0)
Total Links:	43 (2,39 per seg)

$$\textbf{Link index} = \frac{\text{number of links}}{\text{number of segments/moves}} = \text{links per seg.}$$

"Link Index is a measure of **how connected** the **design ideas are** in a design session."

A higher value of Link index and critical moves indicates more **productive design process.**

(leading to "successful products" (Goldschmidt: Criteria…))

Critical Moves (CM)

CM = design moves /segments that are rich in links

CM = moves that generate a **higher number of links** (backward or forward).

“CM identifies design concepts that are deemed ‘successful’ in the sense that the designer values them enough to devote time trying to develop the concepts …”. Goldschmidt (2003) established a

‘critical move’ threshold criterion:

a move/segment that varies between 5 and 8 links;

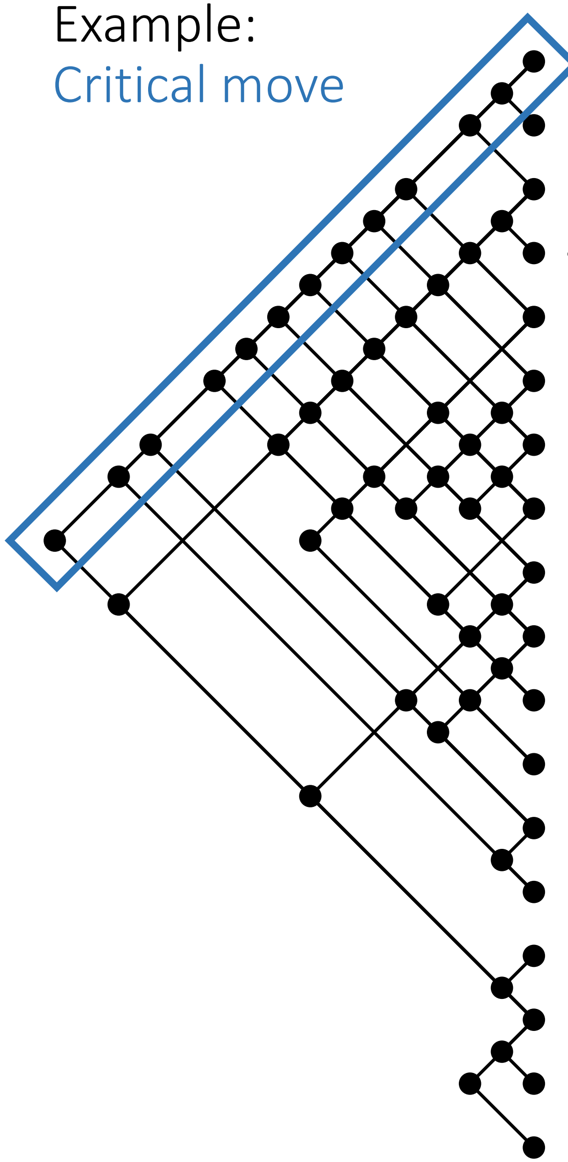
number of CM < 10% of number of moves

CM^i = a critical move carrying ‘i’ number of links.

Goldschmidt, G. 2003. Cognitive economy in design reasoning

Linkograph

Example:
Critical move



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entropy

$$H = p1*h(p1) + p2*h(p2) + \ldots + pN*h(pN) \qquad (1)$$

p1, … pN are probabilities corresponding to N states and h(p) is the information-generating function devised by Shannon which he derived to be -logb(p).

Therefore

$$H = -\sum_{i=1}^{n} p_i \log_b(p_i) \quad \text{with} \quad \sum_{i=1}^{n} p_i = 1 \qquad (2)$$

Entropy is calculated according to the probability of ON/OFF of each link. Following Shannon's theory, formula (2), H becomes:

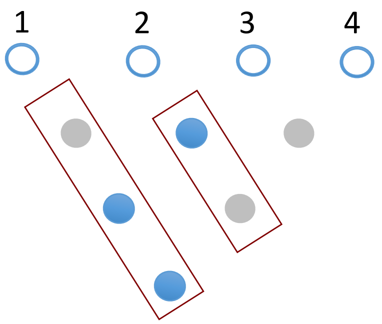
$$-p(ON)\log(p(ON)) - p(OFF)\log(p(OFF)) \qquad (3)$$

Kan, Zafer Bilda & John S Gero: Comparing Entropy Measure Of Idea Links In Design Protocols. DCC06.

Assuming that moves / segments in a linkograph are the manifestation of ideas and

entropy indicates the idea development potential

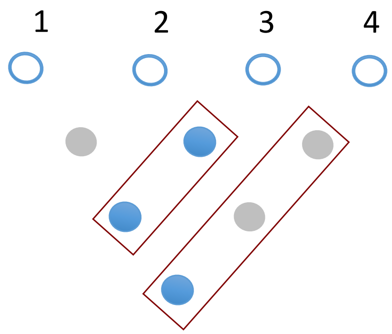
Types of links



forelinks

links of **moves that connect subsequent moves**;
1 is forelinked to 3 and 4; forelinks bear evidence to its contribution to the production of further moves.

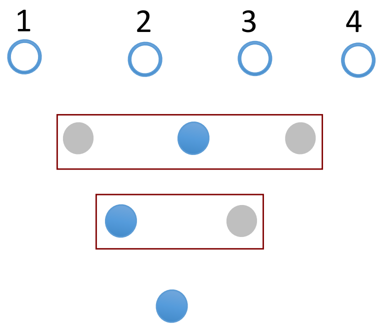
forelink entropy measures idea generation opportunities in terms of new creations or initiations



backlinks

links of **moves that connect to previous moves**; move 4 and 3 are backlinked to 1;
- record the path that led to a move's generation.

backlink entropy measures the opportunities according to responses; opportunity in building upon previous design moves



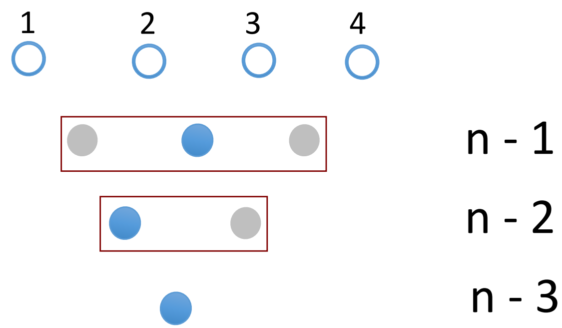
horizonlinks

Link distance - measure of move-time (separation) between links

Horizonlink entropy measures opportunities relating to cohesiveness and incubation of ideas

Kan, Bilda & John S Gero: Comparing Entropy Measure Of Idea Links In Design Protocols. DCC06.

horizonlinks



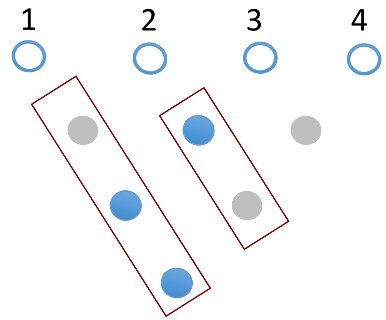
Horizonlink is not a link itself but it bears the notion of length of the links which is a measure of move-time (separation) between links. We can view it as a measure of the distances of the links.

In Figure we can observe there can be n - 1 rows in an n moves linkograph.

Let n - i denotes the row number, the links in rows with a small i indicate that the distance between moves is small, we label them as short links. These moves will likely reside in working memory and we refer this to the cohesiveness of ideas. However, if the ideas are too cohesive, it might imply fixation and lack of innovation. The links in the rows with a large i connect moves that are far apart; we call them long links. These moves may not be in the working memory, we consider those as incubated moves. Long links are comparatively rare and may signify reflection in action. Our assumption of a good design process contains unsaturated short links plus a number of long links.

Kan, Bilda & John S Gero: Comparing Entropy Measure Of Idea Links In Design Protocols. DCC06.

calculating the forelink entropy of an individual segment



forelinks

In segment 1 there are three nodes for links inside the rectangle;
Segments 1 and 2 are unlinked;
segment 1 is linked to segments 3 and 4.
The percentage of linked nodes is 66.6%, and the percentage of unlinked nodes is 33.3%.
If we consider linked nodes as ON and unlinked nodes as OFF, the respective probabilities will be p(ON) = 0,666 and p(OFF) = 0,333.

forelink entropy for segment 1:

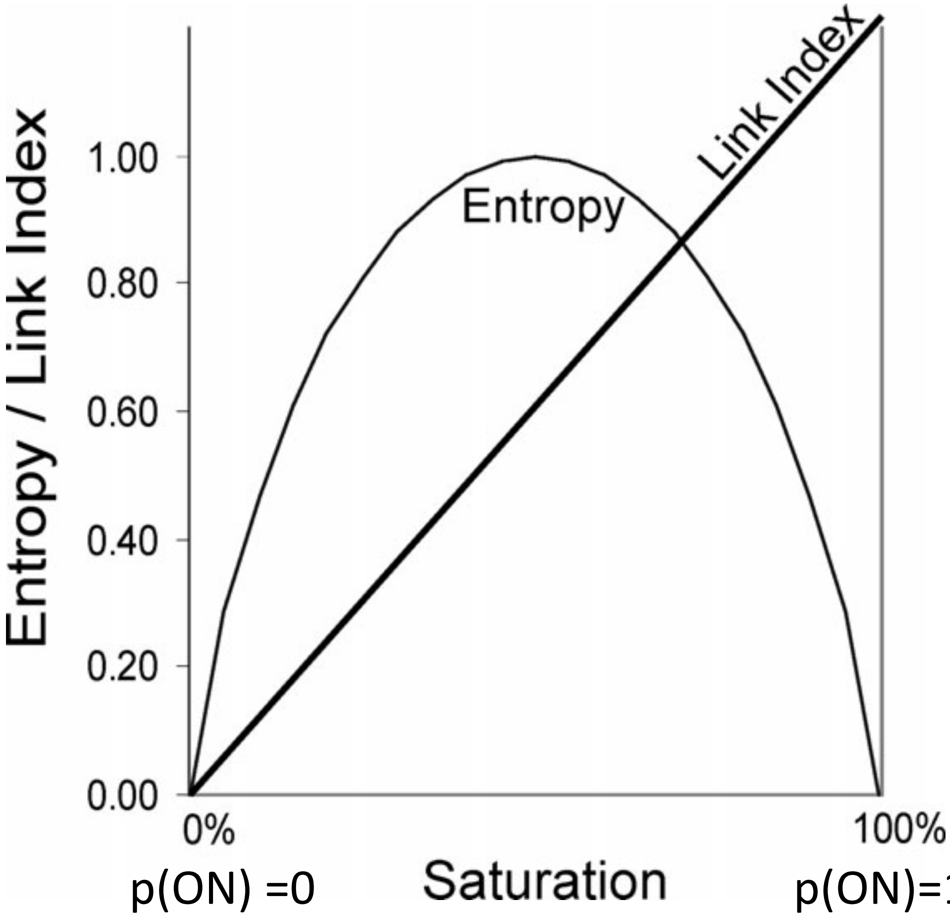
$$H = 0{,}666 \log_2(0{,}666) - 0{,}333 \log_2(0{,}33) = 0{,}918$$

Similarly, for segment 2 the forelink

$$H = 0{,}5 \log_2(0{,}5) - 0{,}5 \log_2(0{,}5) = 1$$

Kan, Bilda & Gero: Comparing Entropy Measure Of Idea Links In Design Protocols. AI EDAM 21(4): 367-377.

comparison of the link index and entropy measurement



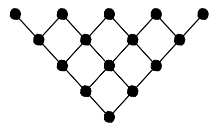
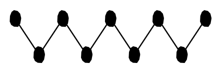
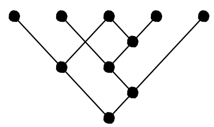
p(ON) =0
p(OFF)=1

p(ON)=1
p(OFF)=0

Maximum entropy when
p(ON)=p(OFF)=0.5

Kann, Bilda, Gero: Comparing entropy measures of idea links in design protocols. 2007

Some possible linkographs of 5 design moves and their interpretations

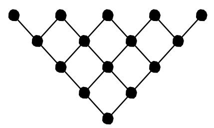
			Link Index	Cumulative entropy
Case 1		Five moves are totally unrelated, indicating no converging ideas, very low opportunity for idea development.	0	0
Case 2		All moves are interconnected; this shows that this is a totally integrated process with no diversification, hinting that a premature crystallization or fixation of one idea may have occurred, therefore there is a very low opportunity for novel idea.	2	0
Case 3		Moves are related only to directly preceding moves. This indicates the process is progressing but not developing; indicating some opportunities for idea development.	0,8	5,46
Case 4		Moves are inter-related but not totally connected, indicating that there are lots of opportunities for good ideas with development.	1	8,56

Kan & Gero 2006: Acquiring Information from Linkography

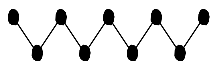
Some possible linkographs of 5 design moves and their interpretations

Case 1

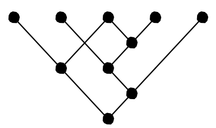
Case 2



Case 3



Case 4



	Forelink Entropy				
	Move 1	Move 2	Move 3	Move 4	**Total**
Case 1	0	0	0	0	**0**
Case 2	0	0	0	0	**0**
Case 3	0.811	0.918	1.000	0	**2.730**
Case 4	1.000	0.918	1.000	0	**2.918**

	Backlink Entropy				
	Move 2	Move 3	Move 4	Move 5	**Total**
Case 1	0	0	0	0	**0**
Case 2	0	0	0	0	**0**
Case 3	0	1.000	0.918	0.811	**2.730**
Case 4	0	1.000	0.918	1.000	**2.918**

	Horizonlink Entropy			
	n-1	n-2	n-3	**Total**
Case 1	0	0	0	**0**
Case 2	0	0	0	**0**
Case 3	0	0	0	**0**
Case 4	0.811	0.918	1.000	**2.730**

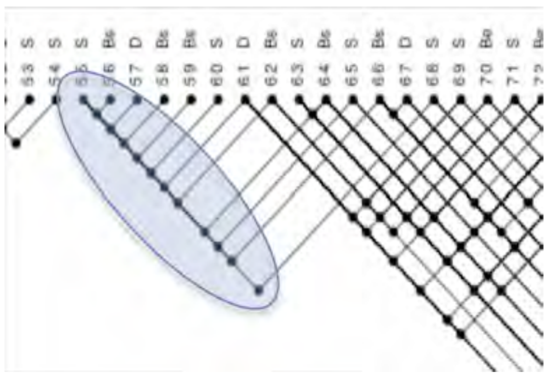
Cumulative entropy of each case

Case 1	Case 2	Case 3	Case 4
0	**0**	**5.459**	**8.566**

Fixation, functional fixedness

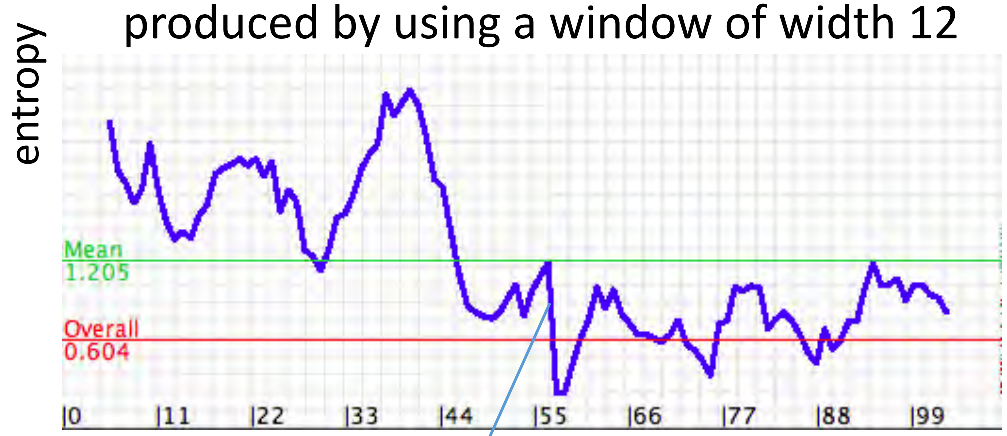
Assuming that moves / segments in a linkograph are the manifestation of ideas and entropy indicates the idea development potential.

Manifest in linkograph as heavy linking from later design issues to a single or small group of earlier design issues…
results in a sharp drop in info content (entropy) of the design activity as it now focuses on a single or a small number of issues.



Subset of linkograph showing where fixation is located

dynamic entropy of the linkograph produced by using a window of width 12



fixation causes a sharp drop in entropy

Gero, J. S. (2011). Fixation and commitment while designing and its measurement

Dynamic Models

information about changes that occur during any design session.

In order to capture the dynamic nature of designing, LINKODERer treats the coded protocols using three additional approaches:

1. fractioning
2. trimming
3. windowing

1. **fractioning**: the input dataset is divided into sections and each section is treated individually. The resulting measurements account for the situation at the related fraction of the protocol, e.g., the beginning of the design session.

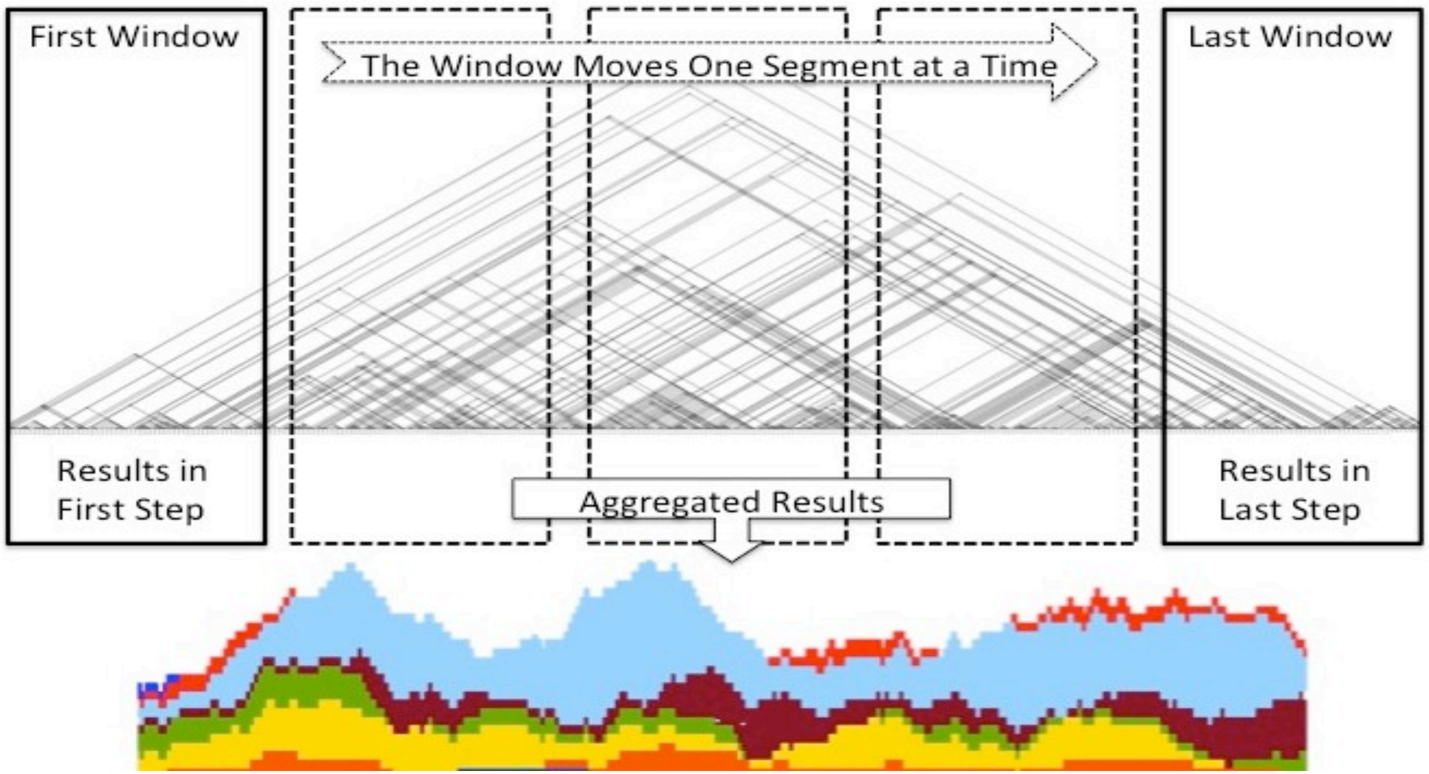
Comparisons are possible between the fractions of a single case or similar fractions from multiple cases.

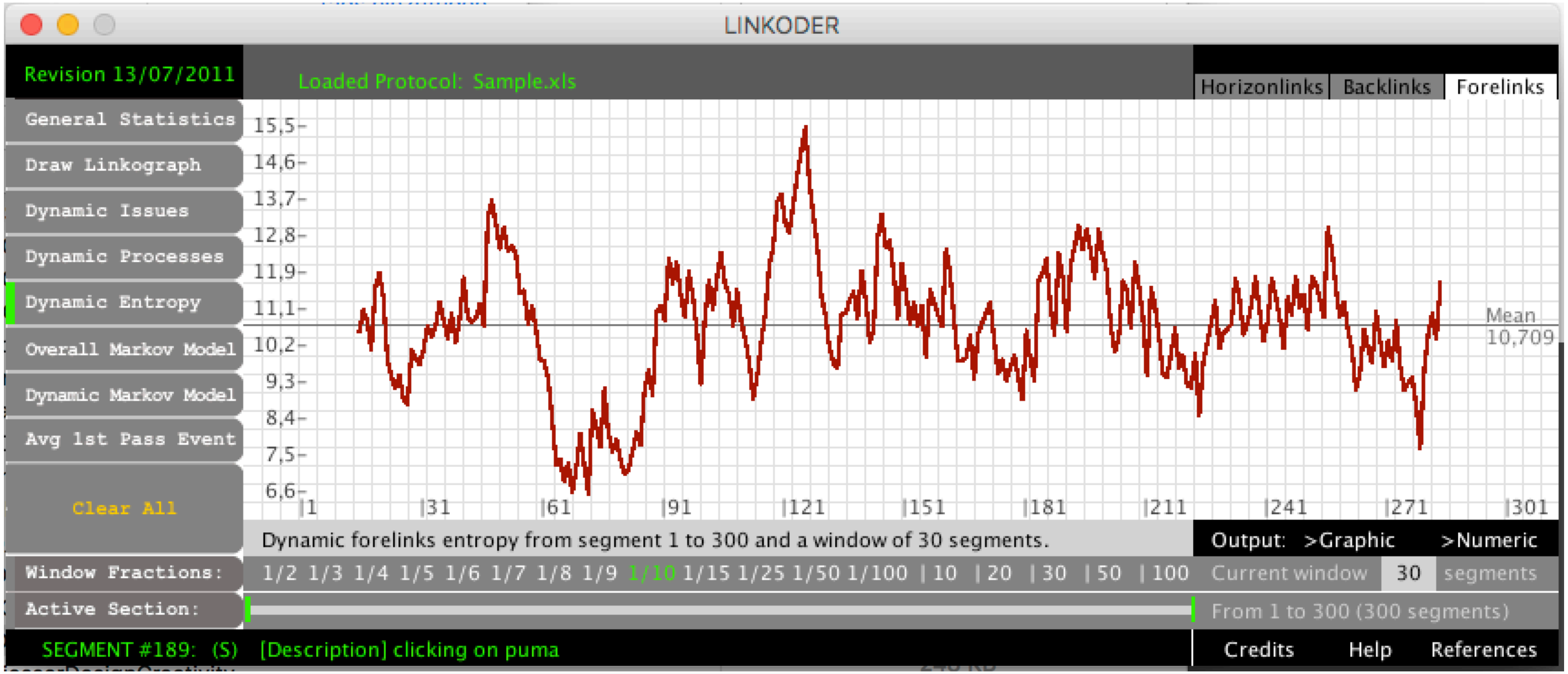
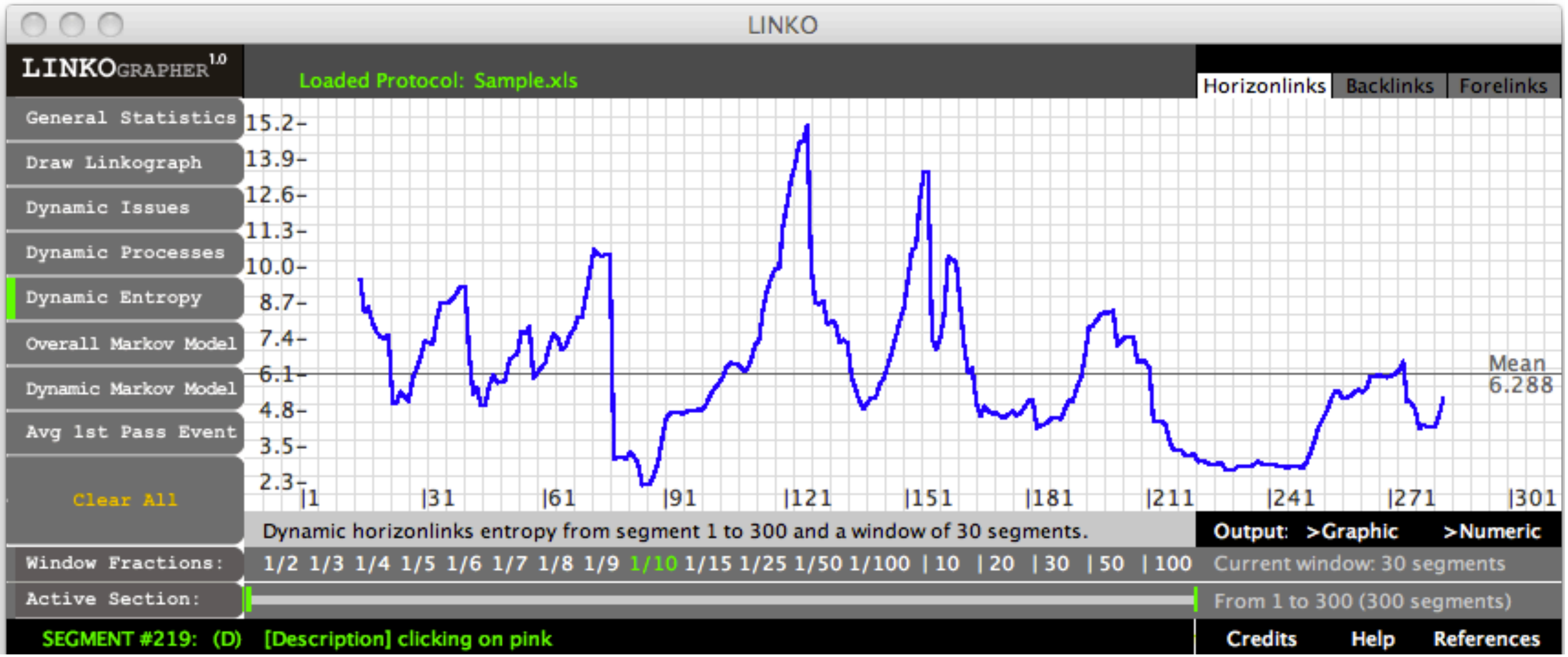
2. **trimming** is the process of selecting a set of contiguous events and excluding all events preceding and following that set. This allows for analyses of a subset of the protocol by itself.

3. Windowing: a fixed number of segments are selected and the analyses carried out for those as a window.

The window then is moved from the beginning to the end of the protocol, one segment at a time. Aggregating the results gives an overall insight into the dynamism of the design session for each.

allows for regulating the results of protocol studies to generate equally sized datasets; eg.: if dataset A has 1000 and B has 1200 segments, performing an analysis with window sizes of 100 for A and 120 for B will generate similarly sized results; makes direct comparison possible.




LINKODER
Revision 13/07/2011
Loaded Protocol: Sample.xls
Horizonlinks
Backlinks
Forelinks
General Statistics
Draw Linkograph
Dynamic Issues
Dynamic Processes
Dynamic Entropy
Overall Markov Model
Dynamic Markov Model
Avg 1st Pass Event
Clear All
15,5
14,6
13,7
12,8
11,9
11,1
10,2
9,3
8,4
7,5
6,6
1
31
61
91
121
151
181
211
241
271
301
Mean
10,709
Dynamic forelinks entropy from segment 1 to 300 and a window of 30 segments.
Output: >Graphic >Numeric
Window Fractions:
1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/15 1/25 1/50 1/100 | 10 | 20 | 30 | 50 | 100
Current window 30 segments
Active Section:
From 1 to 300 (300 segments)
SEGMENT #189: (S) [Description] clicking on puma
Credits
Help
References

LINKO
LINKOGRAPHER 1.0
Loaded Protocol: Sample.xls
Horizonlinks
Backlinks
Forelinks
General Statistics
Draw Linkograph
Dynamic Issues
Dynamic Processes
Dynamic Entropy
Overall Markov Model
Dynamic Markov Model
Avg 1st Pass Event
Clear All
15.2
13.9
12.6
11.3
10.0
8.7
7.4
6.1
4.8
3.5
2.3
1
31
61
91
121
151
181
211
241
271
301
Mean
6.288
Dynamic horizonlinks entropy from segment 1 to 300 and a window of 30 segments.
Output: >Graphic >Numeric
Window Fractions:
1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/15 1/25 1/50 1/100 | 10 | 20 | 30 | 50 | 100
Current window: 30 segments
Active Section:
From 1 to 300 (300 segments)
SEGMENT #219: (D) [Description] clicking on pink
Credits
Help
References

Markov Models

1st order Markov model: the next state of the system only depends on its current state;

to predict the probability of design issues coming after each other in strict time-order sequence (6 x 6 matrix)

2nd order Markov model: not only the current state but also its previous state affects the next state of the system. In FBS coding scheme, the move from a previous state to a current state is considered a design process.

the 2nd order Markov model of a coded protocol describes the probability of a particular design issue following a particular design process (8 x 6 matrix in Linko).

Pourmohamadi & Gero: LINKOgrapher: An Analysis Tool To Study Design Protocols ICED11.

Markov Models

first order Markov model: the next state of the system only depends on its current state;

to predict the probability of design issues coming after each other in strict time-order sequence (6 x 6 matrix)

Syntactic and Semantic 1st order Markov models from segment

Syntactic

Current state	R	F	Be	Bs	S	D
R	�	�	�	�	�	�
F	�	�	�	�	�	�
Be	0,00	0,00	0,00	0,00	1,00	0,00
Bs	0,00	0,00	0,00	0,20	0,40	0,40
S	0,00	0,00	0,14	0,29	0,29	0,29
D	0,00	0,00	0,33	0,67	0,00	0,00

propability for next state

Extract: engineering design meeting1

Bs. P (S > D)
Linkograh:
18 segments
7 (S > …) transitions
2 (S > D) transitions
Übergangswahrscheinlichkeit

$P_{(S>D)} = 2/7 = 0{,}29$

Pourmohamadi & Gero: LINKOgrapher: An Analysis Tool To Study Design Protocols ICED11.

Markov Models

Extract: engineering design meeting1

Syntactic and Semantic 1st order Markov models from segment 1 to 18.

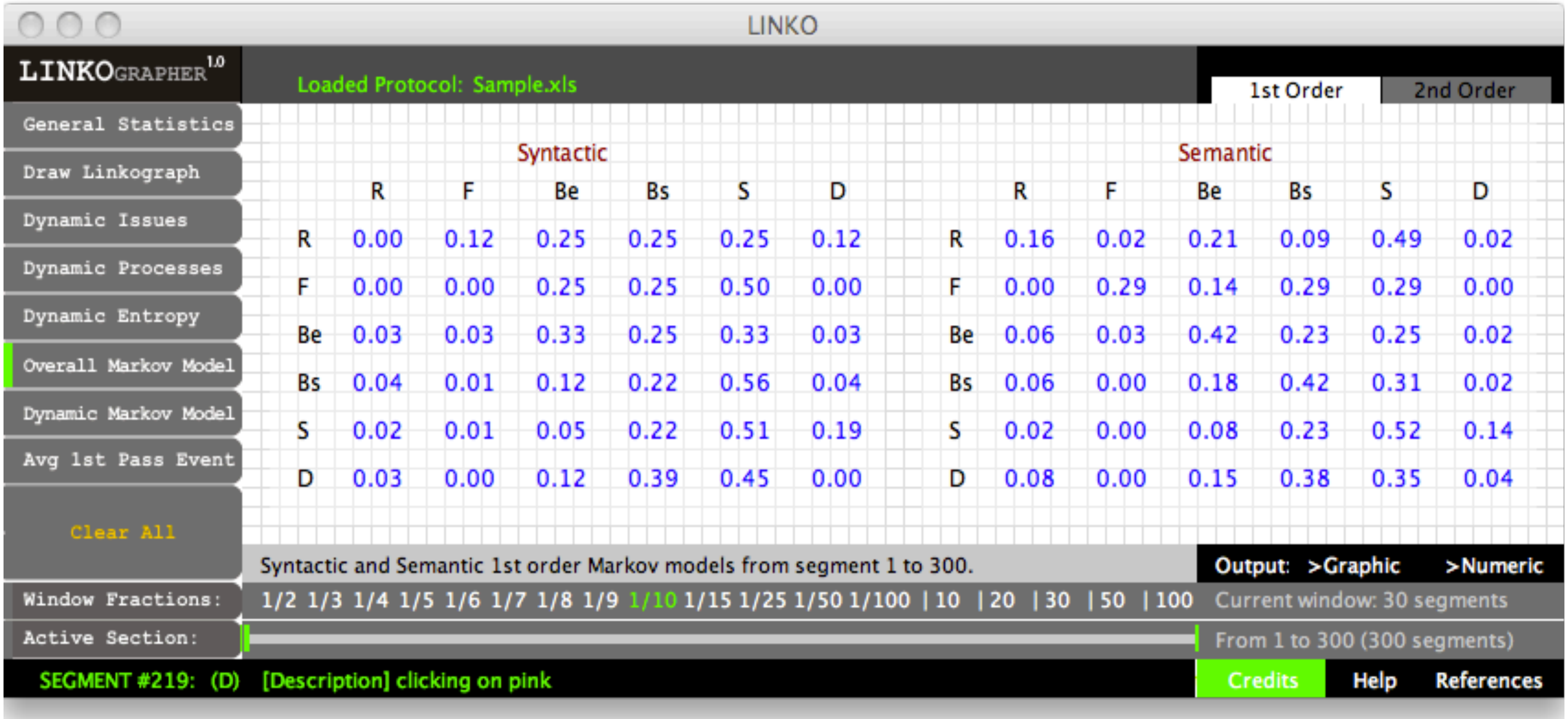
Current state

	Syntactic						Semantic					
	R	F	Be	Bs	S	D	R	F	Be	Bs	S	D
R	�	�	�	�	�	�	�	�	�	�	�	�
F	�	�	�	�	�	�	�	�	�	�	�	�
Be	0,00	0,00	0,00	0,00	1,00	0,00	0,00	0,00	0,00	0,00	1,00	0,00
Bs	0,00	0,00	0,00	0,20	0,40	0,40	0,00	0,00	0,06	0,53	0,24	0,18
S	0,00	0,00	0,14	0,29	0,29	0,29	0,00	0,00	0,08	0,42	0,42	0,08
D	0,00	0,00	0,33	0,67	0,00	0,00	�	�	�	�	�	�

by LINKOgrapher

propability for next state

propability for next state


LINKO
LINKOGRAPHER 1.0
Loaded Protocol: Sample.xls
1st Order
2nd Order
General Statistics
Draw Linkograph
Dynamic Issues
Dynamic Processes
Dynamic Entropy
Overall Markov Model
Dynamic Markov Model
Avg 1st Pass Event
Clear All
Syntactic
R F Be Bs S D
R 0.00 0.12 0.25 0.25 0.25 0.12
F 0.00 0.00 0.25 0.25 0.50 0.00
Be 0.03 0.03 0.33 0.25 0.33 0.03
Bs 0.04 0.01 0.12 0.22 0.56 0.04
S 0.02 0.01 0.05 0.22 0.51 0.19
D 0.03 0.00 0.12 0.39 0.45 0.00
Semantic
R F Be Bs S D
R 0.16 0.02 0.21 0.09 0.49 0.02
F 0.00 0.29 0.14 0.29 0.29 0.00
Be 0.06 0.03 0.42 0.23 0.25 0.02
Bs 0.06 0.00 0.18 0.42 0.31 0.02
S 0.02 0.00 0.08 0.23 0.52 0.14
D 0.08 0.00 0.15 0.38 0.35 0.04
Syntactic and Semantic 1st order Markov models from segment 1 to 300.
Output: >Graphic >Numeric
Window Fractions:
1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/15 1/25 1/50 1/100 | 10 | 20 | 30 | 50 | 100
Current window: 30 segments
Active Section:
From 1 to 300 (300 segments)
SEGMENT #219: (D) [Description] clicking on pink
Credits
Help
References

first order Markov Transition Matrix

engineering design meeting1, Brain Storming session

	R	F	Be	Bs	S	D
R	0.50	0	0	0	0.50	0
F	0	0.26	0.47	0.04	0.23	0
Be	0	0.07	0.33	0.18	0.38	0.05
Bs	0	0.01	0.20	0.40	0.34	0.05
S	0	0.03	0.14	0.30	0.45	0.08
D	0	0.01	0.14	0.21	0.59	0.05

Kan & Gero: A Generic Tool To Study Human Design Activities. ICED'09. p 9-130

Study: Software Design Cognition

2 software designers;

their task was to design a traffic flow simulation program.

Overall Markov 1stOrder syntactic

P =

	R	F	Be	Bs	S	D
R	0,29	0,00	0,12	0,00	0,41	0,18
F	0,00	0,00	0,67	0,00	0,00	0,33
Be	0,00	0,01	0,21	0,23	0,39	0,16
Bs	0,02	0,00	0,47	0,15	0,29	0,07
S	0,03	0,01	0,26	0,20	0,19	0,31
D	0,01	0,00	0,42	0,15	0,43	0,01

probability matrix P describes the transition of the six FBS states (R, F, Be, Bs, S and D)

Kan & Gero (2010). Using a Generic Method to Study Software Design Cognition

Study: Software Design Cognition

2 software designers

1st Order Markov syntactic

P1, P2, P3 are the probability transition matrices of the 3 fractions of the session

$$P_1 = \left(\begin{array}{c|cccccc} & R & F & Be & Bs & S & D \\ \hline R & 0.33 & 0.00 & 0.13 & 0.00 & 0.33 & 0.20 \\ F & 0.00 & 0.00 & 0.67 & 0.00 & 0.00 & 0.33 \\ Be & 0.00 & 0.02 & 0.09 & 0.16 & 0.42 & 0.30 \\ Bs & 0.04 & 0.00 & 0.40 & 0.16 & 0.28 & 0.12 \\ S & 0.07 & 0.04 & 0.16 & 0.14 & 0.16 & 0.44 \\ D & 0.03 & 0.00 & 0.40 & 0.18 & 0.43 & 0.00 \end{array}\right)$$

$$P_2 = \left(\begin{array}{c|cccccc} & R & F & Be & Bs & S & D \\ \hline R & 0.00 & 0.00 & 0.00 & 0.00 & 1.00 & 0.00 \\ F & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ Be & 0.00 & 0.00 & 0.26 & 0.08 & 0.49 & 0.17 \\ Bs & 0.00 & 0.00 & 0.40 & 0.23 & 0.34 & 0.03 \\ S & 0.01 & 0.00 & 0.26 & 0.24 & 0.23 & 0.26 \\ D & 0.00 & 0.00 & 0.37 & 0.17 & 0.43 & 0.03 \end{array}\right)$$

$$P_3 = \left(\begin{array}{c|cccccc} & R & F & Be & Bs & S & D \\ \hline R & 0.00 & 0.00 & 0.00 & 0.00 & 1.00 & 0.00 \\ F & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ Be & 0.00 & 0.00 & 0.24 & 0.39 & 0.31 & 0.07 \\ Bs & 0.02 & 0.00 & 0.57 & 0.09 & 0.25 & 0.07 \\ S & 0.00 & 0.00 & 0.38 & 0.21 & 0.17 & 0.23 \\ D & 0.00 & 0.00 & 0.53 & 0.05 & 0.42 & 0.00 \end{array}\right)$$

Kan & Gero (2010). Using a Generic Method to Study Software Design Cognition

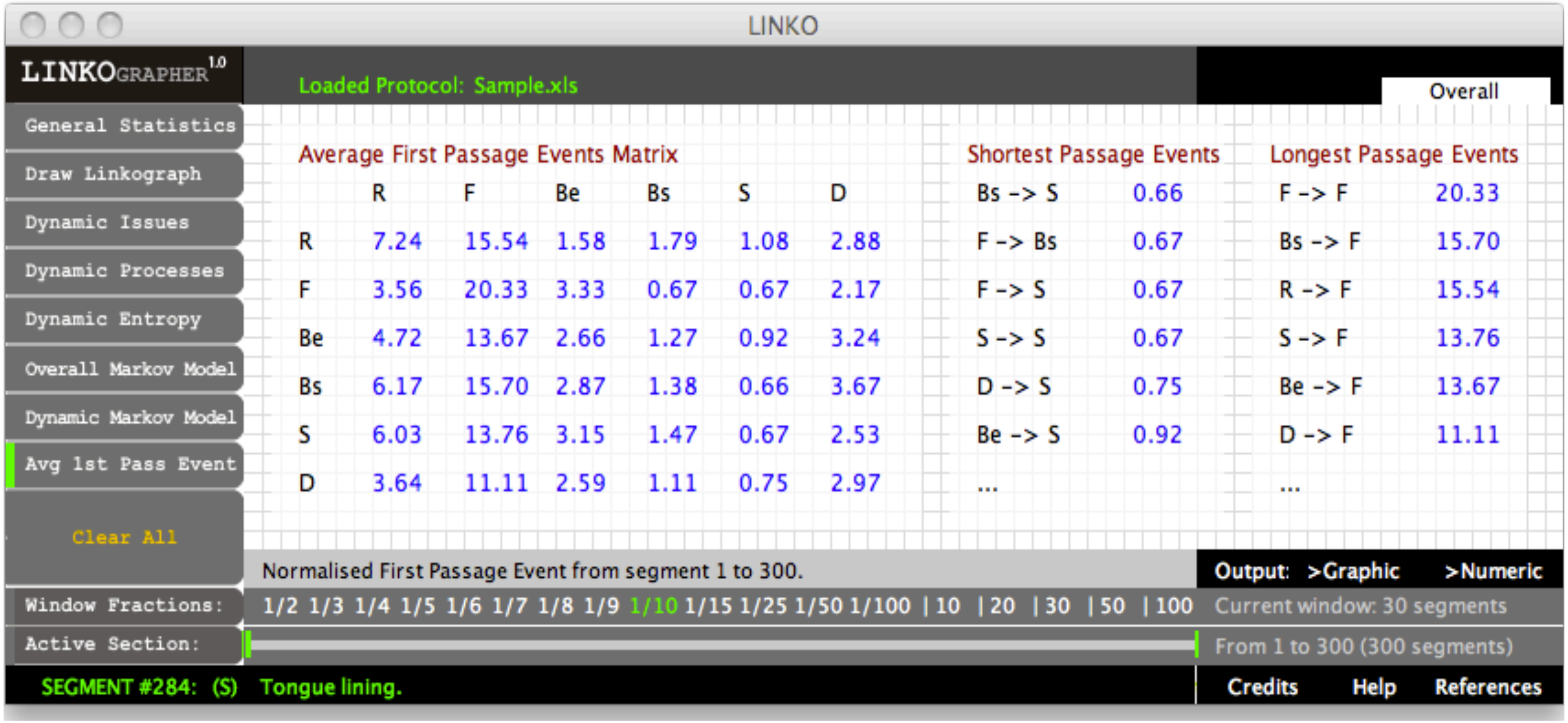
Markov Models
average first pass event model

determines **how many states it takes to transit from one specific state to another**

how many segments the designer needs to move from one design issue to another one. (6 x 6 matrix)

The mean first passage times matrix can be used to validate hypotheses such as design processes take longer to get from function – intention (F) to structure – a design proposal (S) than from behavior (B) to structure (S).

Pourmohamadi & Gero: LINKOgrapher: An Analysis Tool To Study Design Protocols ICED11.
Kan & Gero: A Generic Tool To Study Human Design Activities. ICED'09


LINKO
LINKOGRAPHER 1.0
Loaded Protocol: Sample.xls
Overall
General Statistics
Draw Linkograph
Dynamic Issues
Dynamic Processes
Dynamic Entropy
Overall Markov Model
Dynamic Markov Model
Avg 1st Pass Event
Clear All
Average First Passage Events Matrix
R F Be Bs S D
R 7.24 15.54 1.58 1.79 1.08 2.88
F 3.56 20.33 3.33 0.67 0.67 2.17
Be 4.72 13.67 2.66 1.27 0.92 3.24
Bs 6.17 15.70 2.87 1.38 0.66 3.67
S 6.03 13.76 3.15 1.47 0.67 2.53
D 3.64 11.11 2.59 1.11 0.75 2.97
Shortest Passage Events
Bs -> S 0.66
F -> Bs 0.67
F -> S 0.67
S -> S 0.67
D -> S 0.75
Be -> S 0.92
...
Longest Passage Events
F -> F 20.33
Bs -> F 15.70
R -> F 15.54
S -> F 13.76
Be -> F 13.67
D -> F 11.11
...
Normalised First Passage Event from segment 1 to 300.
Output: >Graphic >Numeric
Window Fractions:
1/2 1/3 1/4 1/5 1/6 1/7 1/8 1/9 1/10 1/15 1/25 1/50 1/100 | 10 | 20 | 30 | 50 | 100
Current window: 30 segments
Active Section:
From 1 to 300 (300 segments)
SEGMENT #284: (S) Tongue lining.
Credits Help References

Markov Models
average first pass event model

	R	F	Be	Bs	S	D
R	$m_{1,1}$	$m_{1,2}$	$m_{1,3}$	$m_{1,4}$	$m_{1,5}$	$m_{1,6}$
F	$m_{2,1}$	$m_{2,2}$	$m_{2,3}$	$m_{2,4}$	$m_{2,5}$	$m_{2,6}$
Be	$m_{3,1}$	$m_{3,2}$	$m_{3,3}$	$m_{3,4}$	$m_{3,5}$	$m_{3,6}$
Bs	$m_{4,1}$	$m_{4,2}$	$m_{4,3}$	$m_{4,4}$	$m_{4,5}$	$P_{4,6}$
S	$m_{5,1}$	$m_{5,2}$	$m_{5,3}$	$m_{5,4}$	$m_{5,5}$	$m_{5,6}$
D	$m_{6,1}$	$m_{6,2}$	$m_{6,3}$	$m_{6,4}$	$m_{6,5}$	$m_{6,6}$

m_{ij} … average number of steps required to get from one state to another

Kan & Gero: A Generic Tool To Study Human Design Activities. ICED'09

Markov Models
average first passage

engineering design meeting1, Brain Storming session

$$
M_{bs} = \begin{array}{c|cccccc}
 & R & F & Be & Bs & S & D \\
\hline
R & \approx\infty & 35.91 & 7.66 & 5.77 & 2.38 & 18.72 \\
F & \approx\infty & 25.13 & 3.26 & 5.30 & 3.57 & 18.52 \\
Be & \approx\infty & 32.12 & 4.49 & 4.42 & 3.07 & 17.40 \\
Bs & \approx\infty & 34.36 & 5.34 & 3.39 & 3.16 & 17.32 \\
S & \approx\infty & 33.91 & 5.66 & 3.77 & 2.85 & 16.72 \\
D & \approx\infty & 34.30 & 5.75 & 4.11 & 2.48 & 17.05
\end{array}
$$

Kan & Gero: A Generic Tool To Study Human Design Activities. ICED'09. p 9-132

Markov Models
average first passage

2 software designers. Their task was to design a traffic flow simulation program.

	R	F	Be	Bs	S	D
R	49,1	168,4	3,9	6,7	2,5	5,0
F	70,0	168,4	1,9	6,2	3,7	4,5
Be	69,3	167,3	3,2	5,0	2,7	5,3
Bs	68,3	168,2	2,5	5,4	2,9	5,8
S	67,6	166,7	3,1	5,2	3,2	4,6
D	68,6	168,1	2,7	5,4	2,6	6,0

Kan & Gero (2010). Using a Generic Method to Study Software Design Cognition

Markov Models average first passage

transition matrices of the **3 fractions of the session**

2 software designers. Their task was to design a traffic flow simulation program.

	R	F	Be	Bs	S	D
R	20,1	61,6	4,4	8,3	2,8	3,6
F	30,4	61,3	2,1	7,7	3,6	3,1
Be	29,6	60,0	4,1	6,7	2,6	3,2
Bs	28,8	61,3	3,1	6,8	2,9	3,8
S	27,9	59,6	3,8	6,9	3,3	2,8
D	29,1	61,1	3,2	6,7	2,6	4,2

	R	F	Be	Bs	S	D
R	192,8	∞	4,3	6,6	1,0	6,4
F	194,2	∞	4,2	6,9	3,4	6,8
Be	193,9	∞	3,3	6,4	2,1	5,6
Bs	194,3	∞	2,9	5,6	2,5	6,6
S	191,8	∞	3,3	5,6	2,8	5,4
D	194,1	∞	3,0	6,0	2,3	6,5

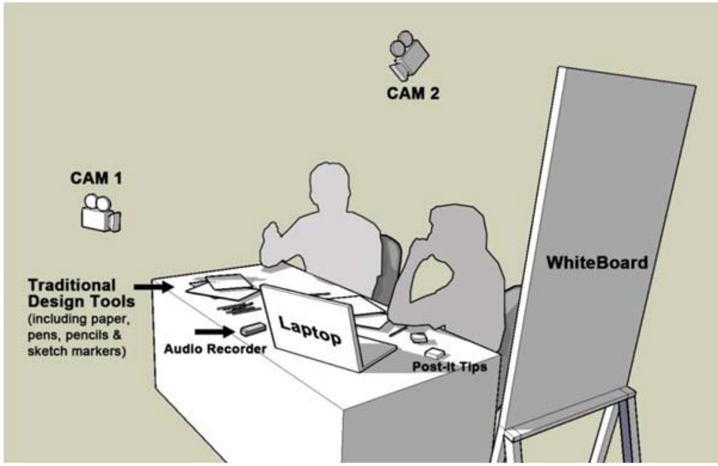
	R	F	Be	Bs	S	D
R	188,8	∞	3,3	5,0	1,0	8,8
F	187,7	∞	3,3	4,8	4,4	9,8
Be	187,1	∞	2,6	3,3	3,3	9,1
Bs	183,8	∞	2,0	4,3	3,4	9,2
S	187,8	∞	2,3	4,0	3,7	7,8
D	188,2	∞	2,1	4,4	2,9	9,6

Kan & Gero (2010). Using a Generic Method to Study Software Design Cognition

(Vergleichs-) Studien

The assignments for experiment were conceptual design under two different situations.

1) to design a coffee maker for an existing market (Task CM), which was treated as a variant or adaptive design task
2) a visionary concept design, to design a next-generation personal entertainment system/ device for the year 2025 (Task PES).



Experiment Setup (Jiang & Yen, 2010)

Four teams of final-year Industrial Design (ID) students participated in this study voluntarily. Their average age was 23 years old.

Hao, Gero, Chiuan: Exploring The Effect Of Design Tasks On Conceptual Design Activities.IASDR11

Frequency distribution of design issues for Industrial Design Student-teams working on different tasks

adaptive design task: Coffee Machine (CM)

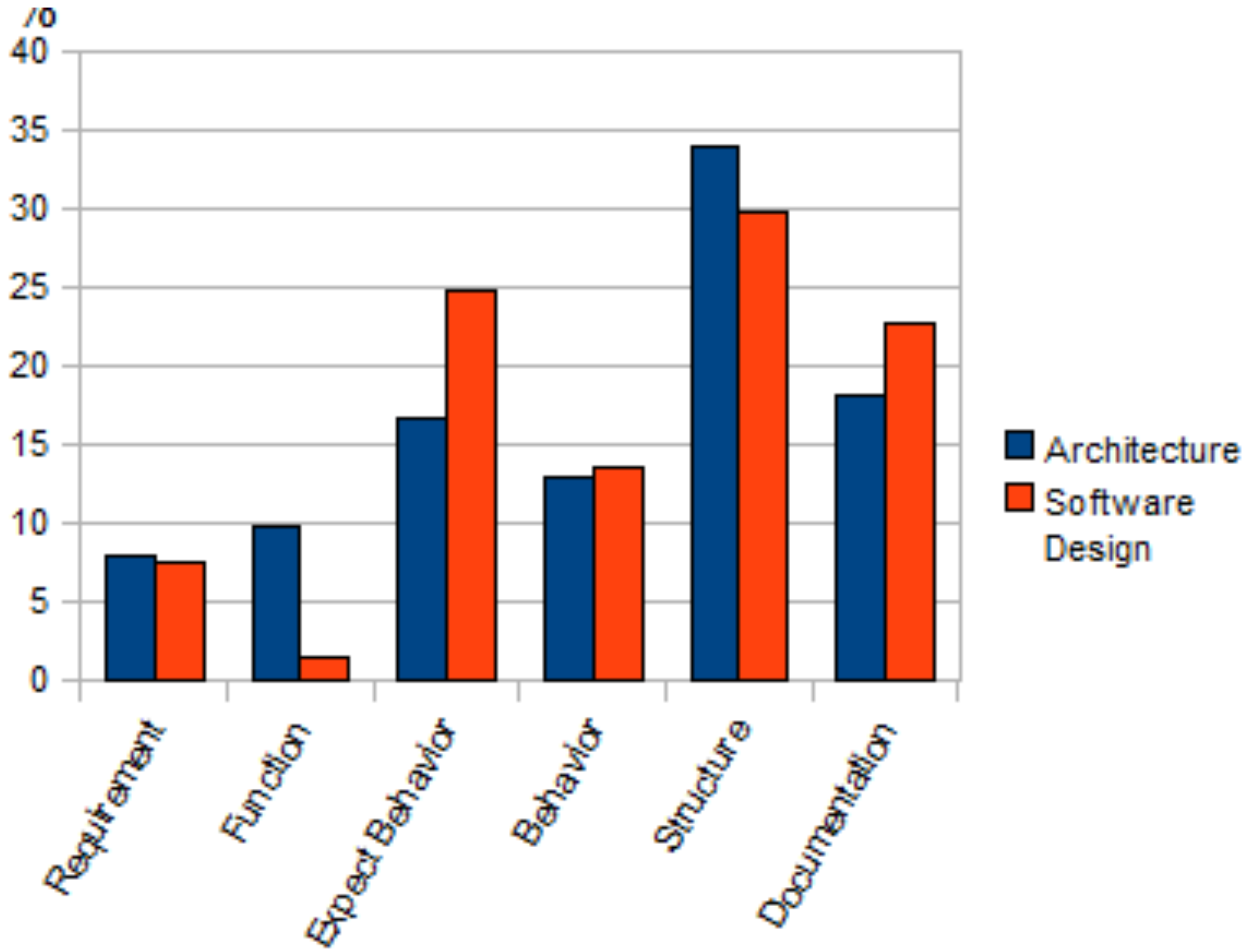
Team	R (%)	F (%)	Be (%)	Bs (%)	S (%)	D (%)
ID1	1.9	28.0	22.7	13.6	12.2	21.5
ID2	0.5	33.4	19.7	14.0	9.1	1.9
ID3	1.8	24.9	26.9	16.3	14.5	15.5
ID4	1.6	25.5	22.9	18.9	16.8	14.3

visionary concept design (PES task)

	R (%)	F (%)	Be (%)	Bs (%)	S (%)	D (%)
ID1	0.9	22.1	12.7	17.0	22.5	24.8
ID2	0.4	26.1	11.4	19.0	18.5	24.6
ID3	1.3	25.9	18.5	20.8	19.7	13.9
ID4	0.8	20.4	19.7	25.9	20.6	12.5

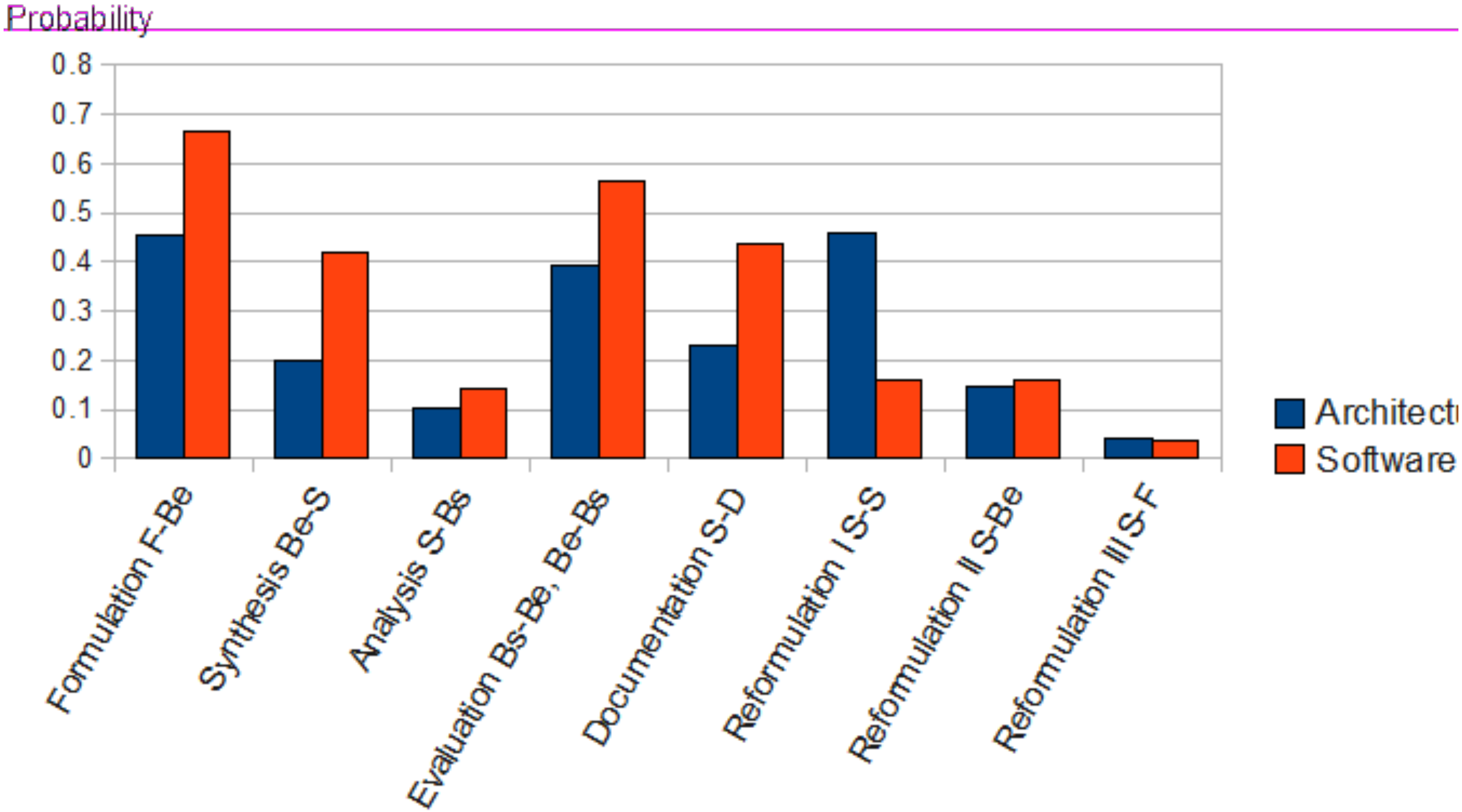
Hao, Gero, Chiuan: Exploring The Effect Of Design Tasks On Conceptual Design Activities.IASDR11

Comparison between architects and software designers of the distributions of design processes



Gero,J. (2010) Generalizing Design Cognition Research. DTRS8.

Comparison between architects and software designers of the distributions of design processes



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