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Characterizing Process Variables in a Study of Design Behaviors

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Introduction

The act of 'design' has been a rich and difficult subject of study in the context of information systems for many years (see, for example, [Adelson and Soloway 1985, Guindon et al 1986, Sen 1997]). A number of design studies have been conducted, relying on techniques such as verbal protocols or videotapes to gain insight into the many facets of system design. Typically, such studies (a) have been planned around a simple design task, (b) have involved a single design session, and (c) have focused the data analysis on identification of repeated design behaviors or problems.

These studies thus have not (a) accounted for behaviors that may be manifested only in complex design tasks, (b) allowed interpretations that may be possible only by observing behaviors in multiple sessions, and (c) provided attention to duration and the sequencing of tasks. In so far as they have ignored the above, they have lacked a process theoretic perspective.

A process theoretic perspective allows analysis of variables over time to understand how they behave individually and relate to each other [Monge 1990]. Though processual studies of system development have been reported [Sabherwal and Robey 1995], they have focused on project management issues rather than detailed design tasks

This is the key distinguishing feature of the present study. The purpose of the study is to examine the behaviors of novice designers over the duration of a small project emphasizing the notion of process variables – based on Monge's [1990] framework. In the research stream on the study of design behaviors, our approach thus represents a shift in focus from a task-based view of design to a process-based one.

Related Work

We examine below a representative sample of efforts in this stream with a view to highlighting the distinguishing features of our research approach.

Adelson and Soloway [1985] examine the design behaviors of expert and novice designers for an assigned design task (in familiar and unfamiliar domains) by videotaping the designers in action during a *single* session. The videotapes are analyzed to *extract repeatedly occurring, common behaviors*, such as formation of mental models, simulation etc.

Guindon et al [1986] identify breakdowns that affect design processes of professional software designers. They, too, analyze a *single* videotaped design session to *identify categories of breakdowns*: knowledge-related, cognitive limitations, and lack of knowledge.

More recently, Sen [1997] proposes a cognitive model for demand-side reuse that illustrates how *design reuse activities are clustered* within different panels of a blackboard model such as control, global design, specific design etc. To verify the model, he relies on verbal protocols of designers engaged in constructing a data model collected during a *single* two-hour design session.

These studies rely on data collected from single sessions, and simple design tasks. Further, they focus on extracting repeated behaviors [Adelson and Soloway 1985], identifying categories of breakdowns [Guindon et al 1986], and clustering reuse tasks [Sen 1997]. To address the shortcomings (discussed in the Introduction) of these and similar studies, our research design includes a slightly more complex design task that naturally requires multiple design sessions. Accordingly, we also perform multiple observations that are spread across the entire duration of the design project.

A Process-oriented Perspective

To structure our research design, we draw on the framework presented by Monge [1990] for understanding process variables. He suggests collection of data at multiple points in time and applying verbal or mathematical formulations to this data for interpretation. The interpretations he suggests include: continuity, magnitude, rate of change, trend, periodicity, and duration (see Table 1).

In addition to these, he also suggests a number of ways of 'relating' these variables, such as lag, concomitant cause etc [Monge 1990, p. 417]. This framework forms the basis of our data analysis.

Table 1. Dimensions of Process Variables

Continuity	presence of consistent nonzero value
Magnitude	amount of the variable at each point
Rate of Change	how fast the magnitude changes
Trend	long term change in the magnitude
Periodicity	amount of time between values
Duration	length of time with a nonzero value

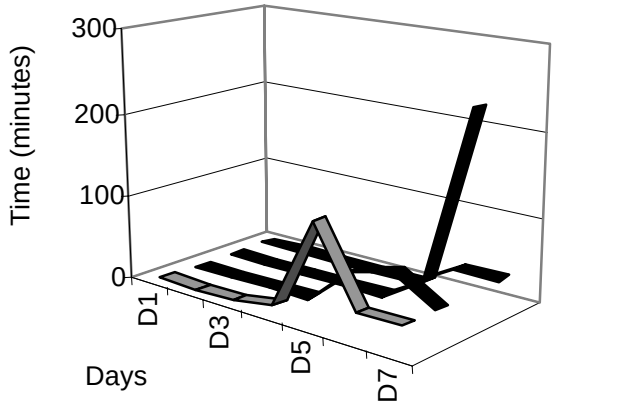

Figure 1. Participant 10

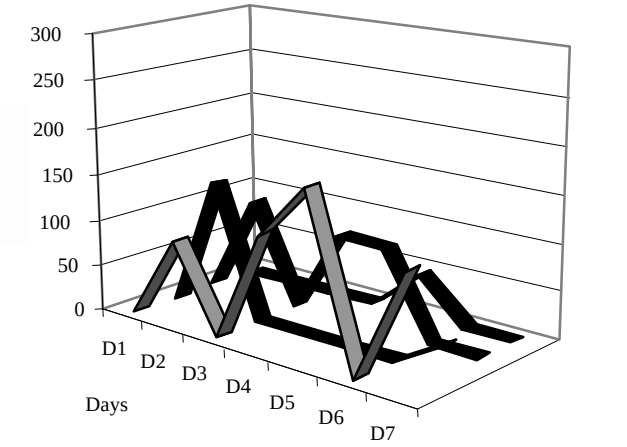

Figure 2. Participant 03

Research Setting and Data Collection

To reflect the process perspective, we adapted a research setting that consisted of a week-long design project. Voluntary participation for the study was sought from students completing a graduate level Object-Oriented System Design course at a major university. The case description asked the participants to design an Electronic Journal Publishing and Subscription System. They were provided the description of system requirements [http://cis.gsu.edu/~spurao/research/ BPCase.html] along with a partial list of use cases [Jacobson et al 1992]. The deliverables for the project were a complete class diagram [Rational 1998] and interaction diagrams [Rational 1998] for two use cases. During the project, the students could consult the UML notation [Rational 1998], analysis patterns [Coad 1996], books [Booch 1994] and other material [http://cis.gsu.edu/~spurao/cis813].

The research design was considered to be non-controlled, following Kerlinger [1986]. Data was collected in the form of self-reported daily activity summaries in response to electronic questionnaires [http://cis.gsu.edu/ ~spurao/research/BPds-template.html], and daily copies of the working papers (copies of hand drawn diagrams or printouts from CASE tool). The daily activity summaries included two parts. The first was quantitative data: (a) time spent on reviewing requirements, (b) consulting UML summary, (c) consulting analysis patterns, (d) consulting other sources, (e) drawing class diagrams, and (f) drawing interaction diagrams. The second part included qualitative data such as the specific portion of the requirements document visited, for what purpose etc. The first subset, quantitative data, forms the basis of the current paper. As we proceed with analysis of the qualitative data, we expect that it will further inform tentative hypotheses that we may form (or inferences we may draw) from the former.

As may be expected, the longer design task precludes constant observations such as videotaped design sessions or verbal protocols. Due to the complexity and length of time introduced by multiple design sessions, our research plan needs to sacrifice some of the richness seen in prior studies of design. The gains, on the other hand, are in the area of examining how different design behaviors (variables) are manifested across multiple design sessions. As we learn more about these design behaviors from the analysis of the data we gather, we expect that additional experiments can be conducted to further probe some or all of these behaviors.

Results

Since this paper primarily focuses on the quantitative data, the analysis reported below primarily revolves around the quantitative variables. The six variables reported by the participants (a through f above), were collapsed into four for analysis, representing time spent on four activities: (a) reading/reviewing the case description, (b) consulting other resources, (c) drawing class diagrams, and (d) drawing interaction diagrams. Graphs for these variables were created for all twelve participants. Figures 1 through 3 show these for three participants[1]. In these figures, the vertical axis shows time spent; and the time-points (days 1-7) are shown on the horizontal axis.

Participant 10 (P10, Figure 1)[1] is a late starter as seen by zero magnitude for all variables on the first three days. He, however, does not take a break once work begins. On the fourth day, he begins work by looking for *"general information"* in the case description. On day six, he again reviews the case description looking for classes and use cases, and consulting analysis patterns. For the seventh day, he plans: *"I have to finish everything tomorrow, so I guess the answer should be everything that I haven't finished."* From day four, all activities show an increasing trend. The activity 'read/ review case description' (first shaded line) has a positive magnitude and a fast rate of change; the third activity 'draw class diagrams' shows the most dramatic increase in magnitude and rapid rate of change. The activities 'consult other resources' (second shaded line) and 'draw interaction diagrams' (fourth shaded line) both have an increasing trend but the rate of change is slower than that of the other variables.

Similar interpretations can be made for participant 03 (P03, Figure 2)[1], and participant 15 (P15, Figure 3)[1]. P03 starts early. The rate of change for the activity 'read/review case description' (first line) is rapidly increasing and the trend is positive. The activity 'consult other resources' (second shaded line) has a positive magnitude on the first day, but it quickly falls to and stays at zero. The activity 'draw class diagrams' (third shaded line) appears to have a steady trend. The last activity 'draw interaction diagrams' has only one non-zero magnitude late in the week.

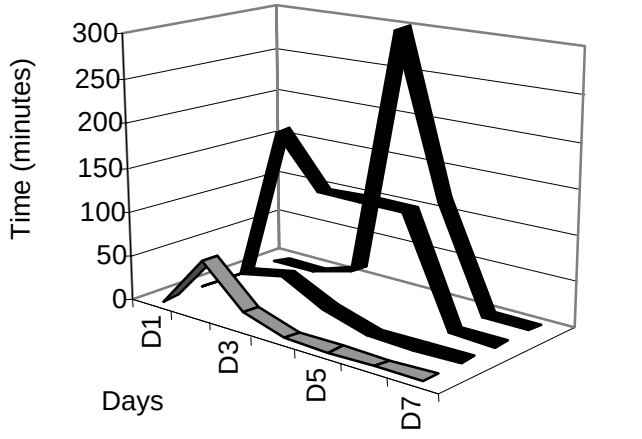

Figure 3. Participant 15

Participant 15 is another early starter. She begins on day two by engaging in all activities except 'draw interaction diagrams.' Work on day three shows most time spent on 'drawing class diagram.' The activities 'read/review case' and 'consult other resources' both show a downward trend and a slow rate of change after the second day. On the other hand, the activities 'draw class diagrams' and 'draw interaction diagrams' have a rapid rate of change and an increasing trend.

As can be seen from the three examples shown above, it is possible to start interpreting the design process using the dimensions suggested by Monge [1990] (see table 1). For our purpose, the applicable dimensions are: continuity, magnitude, rate of change, and trend. Periodicity and duration are not relevant since the observations occur at fixed time intervals.

Discussion

In general, the participants fell into four broad categories: early starters, late starters, laggards, and extreme laggards, which may be considered typical of the way people work. Some general patterns suggested by Monge's framework could also be discerned for participants from the different categories. The four dimensions discussed in the previous section form the basis for identifying these patterns. Specifically, we use three indicators: discontinuity (variables having both zero and nonzero values at different points in time), concomitant cause (a possible cause and effect relationship), and lag (elapsed time between the change in one variable and the resulting change in another).

For the early starters, some discontinuity was observed. Most early starters 'took a break' and 'planed to revisit' the design task. This is indicated by the zero magnitude across all variables on a given day. For this group, the activities 'Read/review case description' and 'Consult other resources' appeared to be concomitant causes for the activity 'Draw class diagrams'; which in turn appeared to be a concomitant cause for the activity 'Draw interaction diagrams.' Inferences about concomitant causes can be drawn from observing the magnitude and trend dimensions. A cause has positive magnitude that drops immediately preceding a positive magnitude in the effect. The trend of a cause is typically downward across the period; the trend of an effect is typically upward or steady across the same period. There was also a lag between the activities 'Draw class diagram' and 'Draw interaction diagrams' as evidenced by the initial increase in magnitude occurring on different days.

Late starters typically began their design task around day three. No discontinuity was evident in their activity pattern as indicated by the positive magnitude of one or more variables once an upward trend is observed in the variables. The activities 'Read/review case description' and 'Consult other resources' still appeared to be concomitant causes not only for the activity 'Draw class diagram' but also for the activity 'Draw interaction diagram.' No lag was observed between the activities 'Draw class diagram' and 'Draw interaction diagram' which is illustrated by the simultaneous positive magnitude in these variables.

The laggards did not begin work until day five or six and extreme laggards did a majority of their work on the last day. For both of these groups, variables are not discontinuous, no concomitant causes are apparent and no lag is evident. All variables show positive magnitudes, increasing trends, and continuity once work has begun late in the design period.

Table 2. Possible Hypotheses Based on Monge [1990]

Discontinuity	***Taking a Break & Revisiting the Design Process indicate Discontinuity in the Design Task***
Concomitant Cause	***Reviewing Requirements is a Concomitant Cause for Draw Class Diagram***
Lag	***A Lag occurs between Draw Class Diagram & Draw Interaction Diagram***

Conclusions

This paper has presented the first segment of our project, resulting in a plausible characterization of some process variables that occur during design. Further analysis of the qualitative data is necessary to support/refute or further interpret the data and/or hypotheses presented above.

To assess the impact of the interpretations we have made above on the eventual design quality, we plan to juxtapose the behaviors of these variables against expert assessments of designs generated by participants in the four categories. This analysis will also benefit from interpre-tations of textual descriptions of the design tasks gathered along with the quantitative variables introduced in this paper.

References

References are available at http://cis.gsu/edu/~spurao/AIS98BushPuraoRefs.html.

[1]Legend: ▒ Read/Review Requirements, □ Consult Other Resources, ■ Draw Class Diagrams, ❒ Draw Interaction Diagrams