Supplemental Material

Visual Parameter Space Analysis: A Conceptual Framework

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Abstract

This supplemental material provides (1) additional methodological details of the conducted literature analysis and (2) a list of all 112 papers that we considered for this analysis.

1 Identification of Relevant Literature

The selection process of papers to be included in our work “Visual Parameter Space Analysis: A Conceptual Framework" was based on a broad initial literature study. We started off with a search on parameter space analysis papers in core relevant visualization conferences and journals:

- IEEE Transactions on Visualization and Computer Graphics (TVCG, including InfoVis and SciVis special issues)
- IEEE Conference on Visual Analytics Science and Technology (VAST)
- Computer Graphics Forum (including EuroVis special issue)
- IEEE Pacific Visualization Symposium (PacificVis)
- IEEE Computer Graphics and Applications
- Computers and Graphics
- The Visual Computer
- MICCAI
- VMV

Then, we also had an eye on other related areas in a second step, e.g.:

- IEEE Transactions on Pattern Analysis and Machine Intelligence
- Computational Statistics
- Computer Vision
- Machine Learning
- Machine Graphics and Vision
- ACM SIGGRAPH
- Eurographics Symposium on Computer Animation
- ACM SIGMOD International Conference on Management of Data
- ACM Symposium on User interface software and technology (UIST)

Based on the references given in those selected papers of visualization as well as the related areas, we finally also included related work from more application-driven angles:

- Journal of Geophysical Research: Oceans
- Frontiers in Neuroinformatics
- Psychological Review
- Journal of Applied Mechanics Technometrics
- Journal of Marine Research
- Journal of the Royal Statistical Society

We broadly surveyed titles and abstracts of papers published in these venues, guided by our own previous experience and by following promising references. Our literature list, which we generated from this process, contained in total 112 papers. In a second step, we classified these papers as “core-relevant” (21 papers), “related” (37), “slightly related’ (27), and “marginally related” (27) with respect to our focus on and understanding of *visual parameter space analysis*. Note, that when we started the literature identification process, the scope of our work was broader. In particular, our initial focus also included work related to more general *uncertainty visualization*. After we decided to narrow down the scope more specifically to visual parameter space analysis, papers that address aspects of uncertainty only were classified as "marginally related".

2 Analysis Process

The 21 core-relevant papers were analyzed in two main phases, a "training" and a "validation" phase.

Phase 1 (training): 14 of the "core-relevant" papers have undergone a detailed open coding process to figure out which tasks are of interest, which goals and objectives the papers are sharing, and which strategies have been applied to support these tasks and goals. We used this analysis to inform and refine an initial version of the framework that we developed based on our own experience working in visual parameter space analysis. This open coding process in turn was based on three rounds of iteration:

Phase 1.1: In the first round, 10 of the 14 papers were coded by the first and the second author [1, 3, 7, 12, 14, 16, 17, 18, 19, 21]. We very broadly coded all aspects that might be potentially of interest for our framework. We also coded another paper that turned out not to be core-relevant to our analysis [83], due to its focus on output visualization. The results were analyzed using affinity diagramming and then discussed amongst all authors.

Phase 1.2: The other 4 papers were coded by all authors [8, 13, 15, 20]. A fifth paper that was coded in this phase turned out to be not core-relevant [35]. Discussions of these papers resulted in further refinements of the framework, agreeing on a shared understanding among all authors, as well as the finalization of concrete inclusion/exclusion criteria as described below.

Phase 1.3: All 14 papers, were re-visited in order to adapt their classification according to the framework changes that have been undertaken. To do so, each paper was re-coded by pairs of two authors and then discussed among them to agree on a final classification.

Phase 2 (validation): We coded the remaining 7 of the 21 core-relevant papers to validate the final version of our framework [2, 4, 5, 6, 9, 10, 11]. In this phase, we classified the papers without adapting the framework anymore. Again, each paper was separately analyzed by two authors. Subsequently, the results were discussed and merged together to a final classification.

Naturally, there was some overlay between literature identification (Section 1) and analysis (this section).

3 Inclusion/Exclusion Criteria

In phase 1.2., we specified three inclusion/exclusion criteria. We used these criteria to reiterate and refine our set of "core-relevant" papers.

1. Criterion—Match our definition of parameter space analysis. All core-relevant papers should follow our definition of parameter space analysis: "Parameter space analysis (PSA) is the systematic variation of model input parameters, generating outputs for each combination of parameters, and investigating the relation between parameter settings and corresponding outputs." (Section 1.1 in the paper). This definition was based on the initial analysis of 10 papers (phase 1.1) and our own previous experience.
Following this definition had several implications. First, a simulation or an algorithmic model needs to exist in order to sample and analyze the parameter space. We therefore excluded papers that discuss solutions for purely measured data. For measured data, sampling is of no primary concern to the analysis chain. Second, we excluded papers that discuss visual representations for model outputs only, without a dedicated focus on the relation between inputs and outputs. Third, we also primarily focused on model validation and usage rather than on model building, where a full model does not exist yet.

2. Criterion—Focus on visual approaches. Our focus was on papers using interactive visualization techniques for parameter space analysis. We specifically excluded purely automatic solutions (e.g., machine learning approaches).

3. Criterion—Concrete applications. Finally, to allow us to properly evaluate tasks, we put a strong focus on the presentation of concrete applications. In particular, we sought for papers that demonstrated the proposed solutions with specific use cases or application scenarios. We excluded several papers that did not provide enough application details to meaningfully code analysis tasks. For papers with a substantial similarity in the presented application scenarios, we selected one representative for our analysis of core-relevant papers.

4 Analysis of Remaining Papers

The remaining papers were analyzed in another step. For the "related" and "slightly related" categories, we extracted aspects of interest on a case-by-case basis in order to suitably address them in the paper. The category of "marginally related" papers has not been actively considered any further in this work. We include the full literature list of all 112 papers below.

5 List of All 112 Papers

Core-relevant Papers

[1] S. Afzal, R. Maciejewski, and D.S. Ebert. Visual analytics decision support environment for epidemic modeling and response evaluation. In *IEEE Conference on Visual Analytics Science and Technology (VAST) 2011*, pages 191–200, 2011.

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