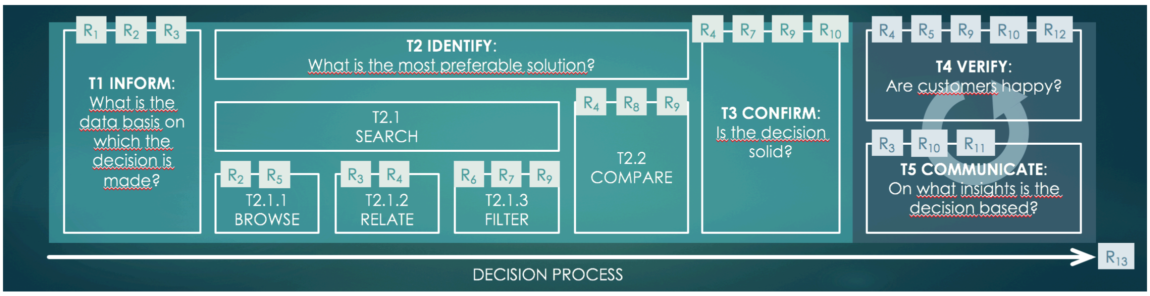
EuroVis 2020 – Submission 1031
PAVED: Pareto Front Visualization for Engineering Design

Supplementary Material for
Section 2.2: Data and Task Analysis – Analysis Tasks and Workflow

1. General approach to the task abstraction

The task abstraction was put together from two sources of information: 1) the domain-specific decision process and tasks for selecting the most-preferred among a number of design alternatives and 2) existing task taxonomies that have been proposed in visualization literature.

We performed a literature review of 12 papers published between 1990 and 2013 (listed in Section 2) that convey different perspectives on the topic of visualization tasks. From these works, we extracted a collection of visualization tasks, initially without consideration of duplicates, the tasks' level of abstraction or their applicability to our topic. In a second step, we removed the duplicates (also tasks that were just named differently) and filtered the remaining tasks according to their relevance for our work. We then mapped the filtered tasks to the domain-specific decision process by arranging them along two axes: abstraction (vertical axis) and position in the decision process (horizontal axis). In a final step, we assigned the design requirements to the respective tasks from which they were derived.
The result of this mapping is the below graphical scheme of the task abstraction (shown in the paper in Figure 2).



2. Considered literature

We provide the references of the 12 papers considered for the literature review here, sorted according to the publication year.

- Roth, S. F., and Mattis, J.: Data characterization for intelligent graphics presentation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 1990, pp. 193-200.

- Wehrend, S., and Clayton, L..: A problem-oriented classification of visualization techniques. In *Proceedings of the First IEEE Conference on Visualization: Visualization '90*. IEEE, 1990, pp. 139-143.
- Zhou, M. X., and Feiner, S. K.: Visual task characterization for automated visual discourse synthesis. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems.* ACM, 1998, pp. 392-399.
- Card, M.: *Readings in information visualization: using vision to think*. Morgan Kaufmann, 1999.
- Shneiderman, B.: The eyes have it: a task by data type taxonomy for information visualizations. In *Craft of Information Visualization*, 2003, pp.364-371.
- Amar, R. A., and Stasko, J. T.: Knowledge precepts for design and evaluation of information visualizations. *IEEE Transactions on Visualization and Computer Graphics*, 2005, *11*(4), pp.432-442.
- Amar, R., Eagan, J., and Stasko, J.: Low-level components of analytic activity in information visualization. In *IEEE Symposium on Information Visualization.* IEEE, 2005, pp. 111-117.
- Pirolli, P., and Card, S.: The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis. In *Proceedings of International Conference on Intelligence Analysis.* 2005, vol. 5, pp. 2-4.
- Valiati, E. R., Pimenta, M. S., and Freitas, C. M.: A taxonomy of tasks for guiding the evaluation of multidimensional visualizations. In *Proceedings of the AVI workshop on Beyond time and errors: novel evaluation methods for information visualization. ACM,* 2006, pp. 1-6.
- Munzner, T.: A nested model for visualization design and validation. *IEEE Transactions on Visualization and Computer Graphics*. 2009, *15*(6), pp.921-928.
- Brehmer, M., and Munzner, T.: A multi-level typology of abstract visualization tasks. *IEEE Transactions on Visualization and Computer Graphics*. 2013,19(12), pp. 2376-2385.
- Schulz, H. J., Nocke, T., Heitzler, M., and Schumann, H.: A design space of visualization tasks. *IEEE Transactions on Visualization and Computer Graphics*. 2013,19(12), pp. 2366-2375.

3. Selected tasks and underlying analysis questions

In the following, we provide questions, which an analyst might ask, for each of the leaf tasks in the hierarchy.

T1: INFORM

- Validation of the simulation
  - Does the simulation model produce plausible results?
- Overview of the solution space

  - How diverse are the solutions?
  - Are there clusters of similar solutions?
  - Are there outliers?
- Overview of the objective space
  - What is the distribution of solutions within each objective range?
  - What is the nature of conflicts between objectives?

T2: IDENTIFY

T2.1: SEARCH

T2.1.1: BROWSE

- Region of interest
  - What are combinations of desired objective ranges (e.g. that include a known successful solution)?
  - What types of trade-offs between objective values are available?
  - What is the ranking of solutions for each objective?
  - Which topology provides the majority of Pareto-optimal solutions?
  - How do the objective values change when moving through the solution space/region of interest?
- Navigation based on a focal solution
  - What are the absolute values of a solution?
  - Which alternative can be selected should a gain in a certain objective be desired?
  - What are options of gain and with what losses do they come?
  - How do other solutions differ from the focal solution?
- Navigation through the preferences space
  - What is the effect of preference variations on the best choice of the solution?
  - For how long does a solution stay in the region of interest?
  - For how long does a topology stay the most preferable?

T2.1.2: RELATE

- With respect to objectives
  - How are good/bad values of objective X related to good/bad values of the remaining objectives?
  - How do changes in objective X affect the remaining objectives?
  - How much can I gain in objective X when accepting worsening in objective Y?

- With respect to solutions
    - On what combinations of objectives is a solution superior/dominated?
    - What is the relation between two subsets of solutions?
    - Where is the focal solution located within a subset of solutions (e.g. with respect to each objective)?
    - How are design parameters related to a subset of solutions of interest?
- With respect to topologies
    - What is the relation between two topologies?
    - Which topologies perform well for which objectives?

T2.1.3: FILTER

- Objectives of interest
    - Which objectives can be excluded to reduce complexity?
    - Which pairs of objectives exhibit the most critical conflicts?
- Region of interest according to trade-offs
    - Which solutions implement the known/desired trade-offs?
    - Which solutions are the best regarding a global (i.e. weighted) quality score?
- Region of interest according to preferences
    - Which solutions lie within desired value ranges?
    - Which solutions satisfy the joint preferences of the different stakeholders?
- Undesired regions of the solution space
    - Which solutions are considered undesired (e.g. infeasible, extremal objective values, too expensive, …) and can be eliminated?

T2.2: COMPARE

- Compare solutions based on their objective values
    - What is the trade-off between two solutions?
    - Which solution has better values the majority of objectives?
    - Which improvements/deteriorations in individual objectives cancel each other out?
    - What is the difference between two solutions with respect to non-objectives like sensitivity, …?
- Compare similar solutions or different sets of solutions

    - How do solutions that are similar w.r.t. a subset of objectives perform in the remaining objectives?
    - What is the performance difference between two topologies?
    - How are similar solutions different in their sizes of the dominated areas in the objective space?

T3: CONFIRM

- Quality
    - Does the selected solution satisfy the desired constraints in the most important objectives?
    - What are the solution’s values for objectives that were not considered for the decision?
    - How well does the selected solution perform compared to other favorite solutions?
- Sensitivity
    - How does the quality of a solution change as design parameters are slightly varied?
- Confidence
    - What is the confidence in the selected solution?
    - What additional simulations should be performed?
    - What consequences (e.g. manufacturing costs, etc.) might arise from choosing the selected solution?
    - What will the built drive of a solution look like?

T4: VERIFY & T5: COMMUNICATE

- Decision
    - How did the decision evolve?
    - On what insights is the decision based?
    - What alternative solutions to the one provided were encountered during the search?
    - Why is the suggested solution superior to the alternatives?
- Decision refinement
    - What alternatives are reasonable w.r.t. refined preferences of the customer after observing the decision made by the engineer?
    - What alternatives are available regarding additional criteria involving installation costs, needed manufacturing steps, the accessibility of corresponding machines, etc.?
    - How does a reduction in budget affect the achievable performance?

- General recommendations
    - Why should certain solutions be avoided?
    - What can be achieved given a required power and available budget?
    - Which topology can be used for which type of intended use?
    - Which amount of money should be made available at least to reach a satisfying drive design?
    - What are utopian visions of what is possible?