

## PROBLEM

Visualization Recommendation (VisRec) algorithms frequently embed visualization expertise, yet the origin and authenticity of this expert knowledge often remain ambiguous. It is essential to recognize that preferred visualizations and their practical utility can vary significantly across different domains and problem areas. Consequently, specific domains may require unique sets of visualizations that differ from those used in other domains. By considering these diverse requirements during the design process, a more practical and effective VisRec strategy can be achieved, enhancing the usability and relevance for the intended audience.

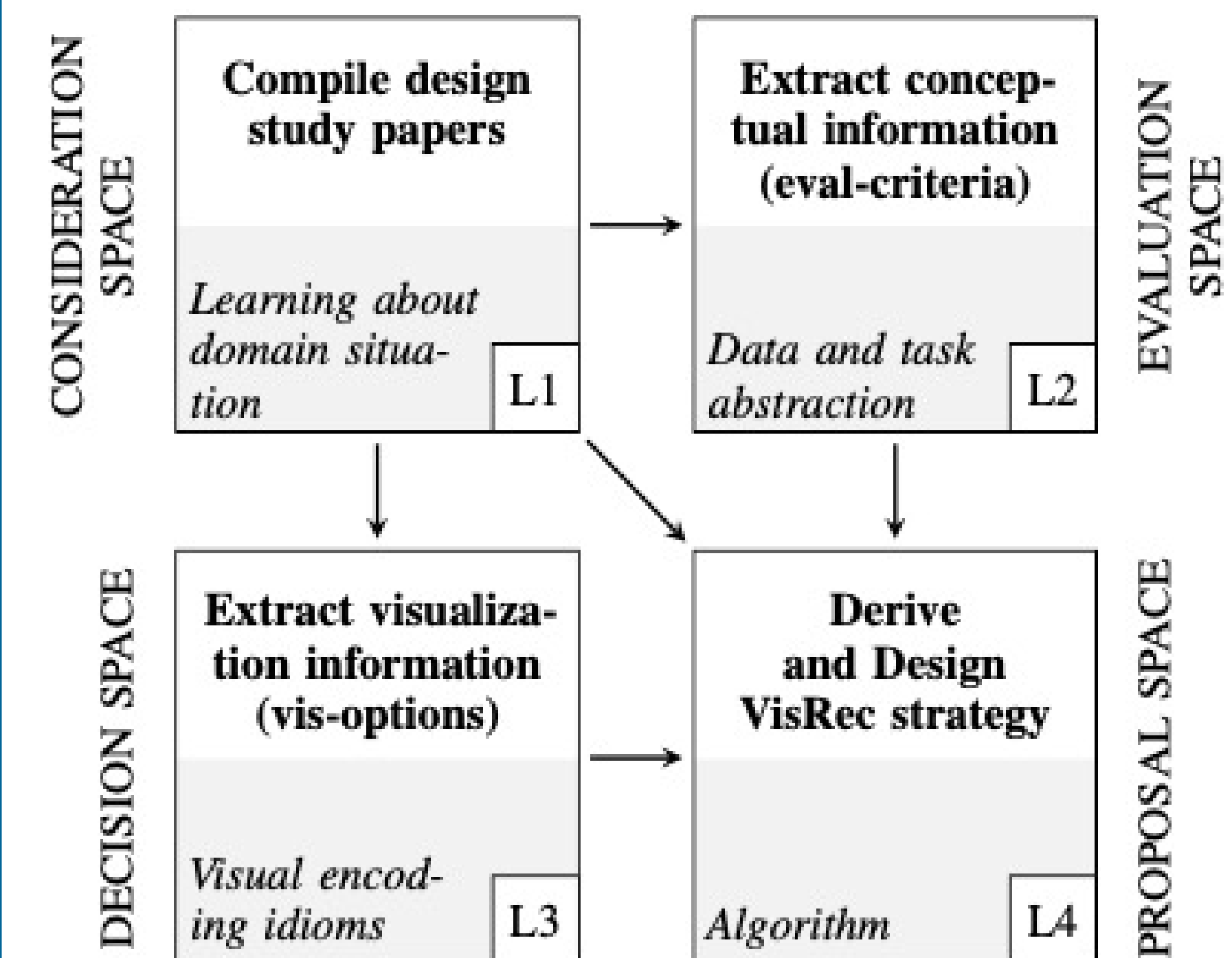
We introduce the concept of a **meta design study**, wherein visualization knowledge is systematically derived from design study papers in a certain domain or area, ensuring that a resulting VisRec strategy is grounded in the peer-reviewed knowledge of visualization experts.

## THEORY

The conventional framework for design studies follows the steps of the nested model of visualization design (learning about domain situation [L1]; data- and task-abstraction [L2]; derive visual encoding idioms [L3]; algorithmic considerations [L4]) in a top-down manner [3]. From a particular viewpoint, the visualization researcher conducting such a design study serves as a VisRec oracle, transforming a wide *Consideration Space* into a narrow *Proposal Space* of visualization options [5]. This perspective aligns with the concept that a full Design Space actually consists of a *Decision Space* (in our context, the visualization options to choose from) and an *Evaluation Space* (criteria for selecting appropriate options from the Decision Space) [2].

Based on these observations, a *meta design study* provides all components to formulate a *VisRec strategy*. A visualization researcher **compiles design study papers** for the problem area under investigation. Afterward, they **extract conceptual information** and **visualization information** from those compilations which can further be utilized to **derive and design a VisRec strategy**.

## CONCEPT



## PRACTICAL EXAMPLE

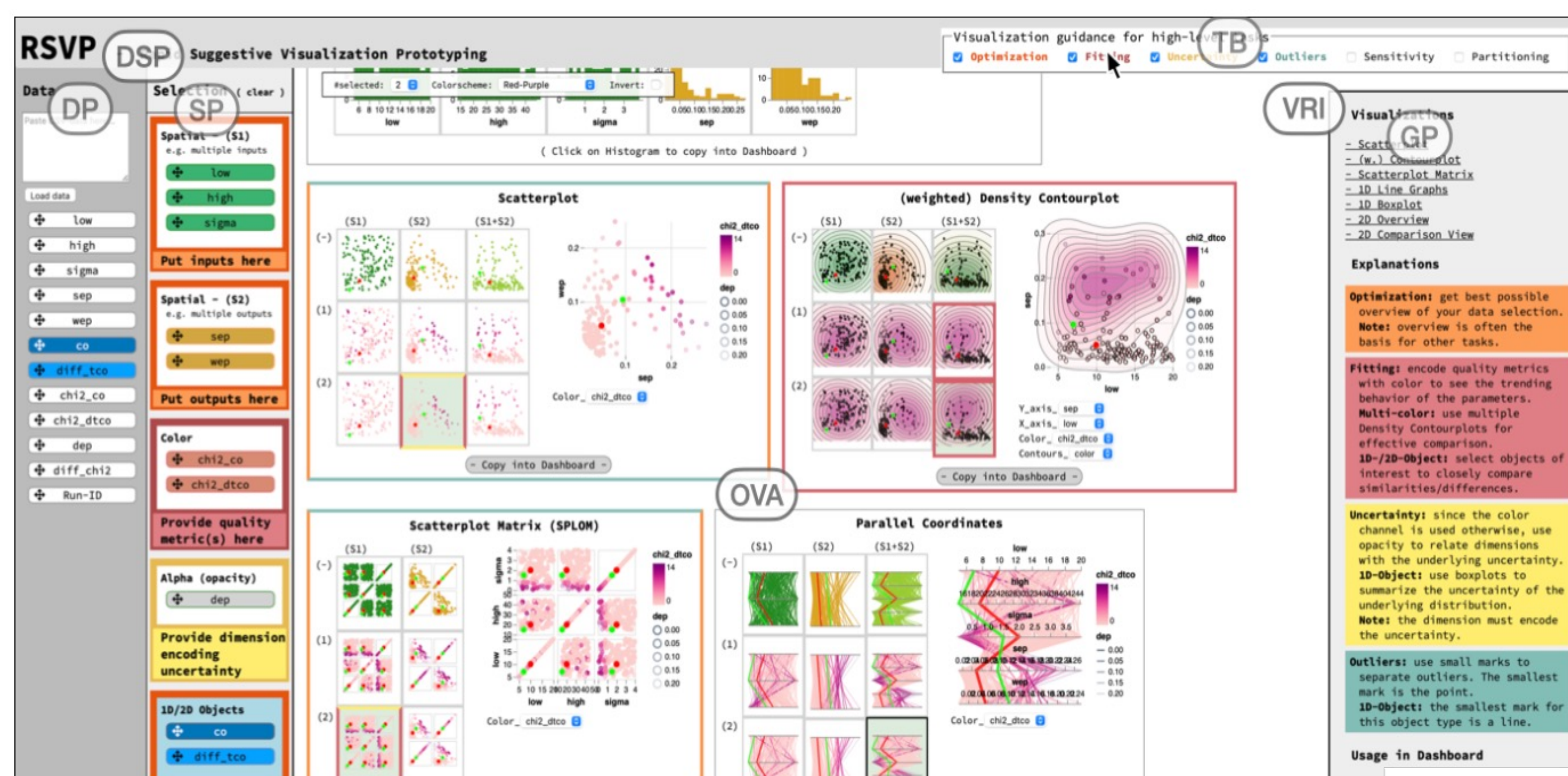
## EVAL CRITERIA L2

Data	Type		
Sampling	Multi-dimensional/ Multi-variate	(MDMV)	
	Complex Object	(CO)	
	Regular	(reg)	
	Stochastic	(stoch)	

Tasks	Optimization		$T_{opt}$
	Find best parameter setting		
	Fitting		$T_{fit}$
	Where does actual data occur		
	Uncertainty		$T_{unc}$
	How reliable is the output		
	Outliers		$T_{out}$
	Find odd or special outputs		
	Sensitivity		$T_{sens}$
	Regions with high / low impact		
	Partitioning		$T_{part}$
	Discern different model behavior		

## PAPER COMPILATION L1

We collected and analyzed **45 design study papers** involving **Visual Parameter Space Analysis (VPSA)** [4].



**RSVP**, the **Rapid Suggestive Visualization Prototyping System** [1], is derived from the insights of a meta design study over the body of knowledge on *Visual Parameter Space Analysis (VPSA)*. It implements the design space and a multi-view VisRec strategy from the meta design study in a non-obtrusive manner. The linked video presents an overview of the system; details and findings of the meta design study are highlighted in the surrounding information blocks.

## VIS OPTIONS L3

VIS OPTIONS	VIS OPTIONS		
(SP) Scatterplot	(wDCP) Density Contourplot	(MDMV)	
(SPLOM) Scatterplot Matrix	(rSPLOM) reduced SPLOM		
(PSc) Point Scales	(PC) Parallel Coordinates		
(Hist) Histograms	(1D-Line) 1D - Linegraph		
(1D-Box) 1D - Boxplot	(1D-Hist) 1D - Cumulative Hist		
(2D-Grid) 2D - Gridview	(2D-Jux) 2D - Juxtapos. views		
(2D-Sup) 2D - Superpos. views			

## VISREC STRATEGY L4

Filter: $T_{opt}$ stoch									
App	Hist	SP	SPLOM	rSPLOM	PSc	PC	wDCP	CO	Task
#1	S:5			S:5	S:5				$T_{opt}$ $T_{part}$ reg
#2			S:3+C+B					1D-Box	$T_{unc}$ $T_{sens}$ stoch
#3	S:6	S:8 (1)				S:8		2D-Grid	$T_{out}$ $T_{sens}$ stoch
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Excerpt showcasing a coding table with enhanced visual elements. The headers in white and blue indicate visualization options, light gray headers correspond to evaluation criteria. These criteria serve as filters for table rows, resulting in a refined display of applications and the corresponding visualizations that address the chosen criteria.

Task	Strategy	MDMV	CO
$T_{opt}$	Overview	<u>Spatial</u> expressivity	1D-Line, 2D-Grid
$T_{fit}$	Affiliation	Overview + <u>Color</u>	2D-Jux
$T_{unc}$	Attenuation	Overview + <u>Brightness</u>	1D-Box
$T_{out}$	Separation	<u>Point</u> -based (0D-mark)	(1D-Line)
$T_{sens}$	Con-/Divergence	<u>Line</u> -based (1D-mark)	1D-Hist, 2D-Sup
$T_{part}$	Summarization	<u>Area</u> -based (2D-mark)	2D-Grid (-)

High-level overview of the derived rules for the task-oriented part of the VisRec strategy for VPSA applications. We found that each task has a general solving strategy independent of the underlying data type. We further found that for MDMV types, tasks are typically associated with a distinct mark or channel.  $T_{opt}$

Dims#	In-reg	In-stoch; Out
(1)	(PSc+Hist)	(PSc)
2	wDCP+Hist	SP
3	SPLOM+wDCP+Hist	SPLOM
4	PC+wDCP+Hist	(r)SPLOM
5	PC+wDCP+Hist	rSPLOM
6	PC+Hist	rSPLOM
7-9	PC	PC
10+	(PC)	PSc

Guidelines for *spatial expressivity* to maximize data representation while minimizing occlusion and visual clutter. Rules are based on encoded dimensions, the sampling strategy, and if inputs or outputs are visualized.

## ACKNOWLEDGEMENTS

- This work was supported in part by National Science Foundation award 2007436.
- Parts of this work are currently under submission [1].
- The layout and design of this poster are based on the Eurographics'23 Poster Template.
- The QR code was generated with *QR-Code Generator & QR Creator* for iOS.

## REFERENCES

- [1] M.Klaffenboeck, M.Gleicher, J.Sorger, M.Wimmer, and T.Moeller. RSVP for VPSA : A Meta Design Study on Rapid Suggestive Visualization Prototyping for Visual Parameter Space Analysis. Submitted for publication, 2023.
- [2] A. MacLean, R. M. Young, and T. P. Moran. Design rationale: The argument behind the artifact. In SIGCHI Conference on Human Factors in Computing Systems, CHI '89, p. 247–252. Association for Computing Machinery, New York, NY, USA, 1989.
- [3] T. Munzner. *Visualization analysis and design*. CRC press, 2014.
- [4] M. Sedlmair, C. Heinzl, S. Bruckner, H. Piringer, and T. Moeller. Visual parameter space analysis: A conceptual framework. *IEEE Transactions on Visualization and Computer Graphics*, 2014.
- [5] M. Sedlmair, M. Meyer, and T. Munzner. Design study methodology: Reflections from the trenches and the stacks. *IEEE Transactions on Visualization and Computer Graphics*, 2012.



# Meta Design Studies: A Structured Approach for Deriving Domain-Oriented Visualization Recommendation Strategies

Manfred Klaffenboeck\*

Torsten Moeller†

Michael Gleicher‡

Michael Wimmer\*

## ABSTRACT

We introduce the concept of a meta design study as a structured approach to extract information from design study papers for the development of generalized tools in specific problem areas or domains. We explore the potential of meta design studies for creating domain-oriented visualization recommendation (VisRec) strategies. To demonstrate this concept, we present RSVP, a system derived from a meta design study conducted on Visual Parameter Space Analysis (VPSA). We outline the individual steps of the meta design study, highlight key concepts of the resulting VisRec strategy, and present a non-obtrusive implementation of this approach in RSVP.

**Index Terms:** Human-centered computing—Visualization—Visualization theory, concepts, and paradigms; Human-centered computing—Visualization—Visualization systems and tools

## 1 INTRODUCTION

Visualization Recommendation (VisRec) algorithms frequently embed visualization expertise, yet the origin and authenticity of this expert knowledge often remain ambiguous. It is essential to recognize that preferred visualizations and their practical utility can vary significantly across different domains and problem areas. Consequently, specific domains may require unique sets of visualizations that differ from those used in other domains. Indeed, it is crucial to acknowledge that different user groups may have divergent needs, and these ought to be incorporated directly into the Visualization Design Space as well as the VisRec strategy. By considering these diverse requirements during the design process, a more practical and effective VisRec strategy can be achieved, enhancing the usability and relevance for the intended audience.

We introduce the concept of a *meta design study* and demonstrate its application in developing practical, domain-oriented visualization recommendation strategies.

## 2 THE THEORY OF META DESIGN STUDIES

A meta design study offers a structured way to derive a visualization recommendation strategy from a literature survey using *axial coding* [2]. Following, we will describe *why* and *how* this is possible.

The conventional framework for design studies [8] follows the steps of the nested model of visualization design [5] in a top-down manner [6]. A visualization researcher is *learning about the domain situation* [L1] by collaborating with domain scientists on a specific real-world problem. This joint effort culminates in the abstraction of both data and tasks [L2]. The visualization expert then uses the gained knowledge to select appropriate *visual encoding idioms* [L3] adept at addressing the associated challenges. Finally, the visualization researcher needs to determine or, in some cases, even design *algorithms* [L4] capable of presenting the visualizations in a timely and acceptable manner.

From a particular viewpoint, the visualization researcher in this scenario serves as a VisRec oracle [9]. The researcher leverages

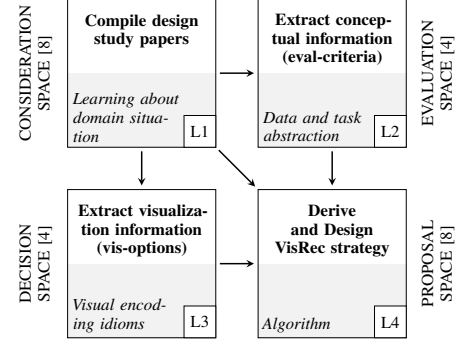


Figure 1: Overview of the individual steps involved in a meta design study.

their knowledge and insights regarding the domain, data, and tasks to transform a wide *Consideration Space* into a narrow *Proposal Space* [8] comprising visualization alternatives. This insight aligns with MacLean et al.’s finding, which states that a complete design space consists of a *Decision Space* (in our context, the available visualization options and their variations) and an *Evaluation Space* (criteria for selecting appropriate options from the Decision Space) [4].

A meta design study does not involve collaboration with a domain scientist except for evaluation purposes. Furthermore, a system designed in such a way tries to offer solutions for a wide array of real-world challenges instead of a specific problem. The absence of a dedicated visualization expert places the responsibility on the domain scientist to select an appropriate set of visualizations for a given problem. Consequently, the tool itself must fulfill the role of the visualization expert and offer the qualities of a VisRec oracle.

Based on the previous observations, a meta design study provides all the necessary components to formulate a visualization recommendation strategy (see Fig. 1). To begin, the visualization researcher **compiles design study papers** [L1] relevant to the investigated problem area. This compilation defines the domain- or problem-specific boundaries of the design space, which we refer to as the *Consideration Space* [8]. Afterward, the researcher **extracts conceptual information** [L2] primarily from the problem description and requirement analysis presented in the paper. This will help gain a better understanding of the domain under investigation and the data and tasks involved. The insights obtained regarding the data and tasks can then serve as evaluation criteria for the VisRec strategy, forming what is referred to as the *Evaluation Space* [4]. Next, the researcher proceeds with **extracting visualization information** [L3]. They analyze the applications described in the paper to identify the visualizations, interactions, and utilized visualization channels. These options and their variations constitute the *Decision Space* [4].

All the information gathered up to this point can now be utilized to **derive and design a VisRec strategy** [L4]. The information gets entered into a coding table [1], where the individual applications make up the rows, and the information about the data and tasks (the Evaluation Space) as well as the information about the visualizations and channels utilized (the Decision Space) is represented by columns. This arrangement facilitates filtering based on evaluation criteria, resulting in a selection of applications and their corresponding visualization information that aligns with the specified criteria. The insights obtained from this process can be utilized to formulate practical rules for a VisRec strategy (the *Proposal Space*) [8].

\*TU Wien, Vienna, Austria; klaffenboeck, wimmer@cg.tuwien.ac.at

†University of Vienna, Vienna, Austria; torsten.moeller@univie.ac.at

‡University of Wisconsin, Madison, Wisconsin; gleicher@cs.wisc.edu

Figure 2: Visually enhanced excerpt of the coding table derived from a VPSA meta design study. White/blue headers represent visualization options, lightgray headers evaluation criteria. Two applications are currently filtered out based on the selected criteria  $T_{reg}$  and  $stoch$ .

Task	Strategy	MDMV	Complex Object
$T_{reg}$	Overview	Spatial expressivity	1D-Line, 2D-Grid
$T_{aff}$	Affiliation	Overview + Color	2D-Jux
$T_{att}$	Attenuation	Overview + Brightness	1D-Box
$T_{sep}$	Separation	Point-based (1D-mark)	(1D-Line)
$T_{con}$	Con-/Divergence	Line-base (1D-mark)	1D-Hist, 2D-Sup
$T_{sum}$	Summarization	Area-based (2D-mark)	2D-Grid <sup>(1)</sup>

Table 1: High-level overview of the derived rules for the task-oriented part of the VisRec strategy for VPSA applications.

### 3 PRACTICAL EXAMPLE

We conducted a meta design study on the subject of Visual Parameter Space Analysis (VPSA) [7]. We’ve gathered and examined forty-five design study papers utilizing VPSA strategies [L1], establishing the boundaries of the domain-oriented *Consideration Space*.

Our analysis of data and tasks [L2] corroborated existing research in this area [7]. The majority of the applications we reviewed involved simultaneous analysis of five to fifteen dimensions. The input-output models were usually sampled using either regular  $reg$  or stochastic  $stoch$  methods, and typically, only a few hundred samples were produced for the visual analysis. The analytical tasks users commonly tried to solve were Optimization  $T_{opt}$  (finding the best parameter settings); Fitting  $T_{fit}$  (finding where actual model data occurs); Uncertainty  $T_{unc}$  (determining the reliability of the output); Outliers  $T_{out}$  (discerning odd or special outputs); Sensitivity  $T_{sens}$  (identifying input regions that have low or high impact on the outputs); and Partitioning  $T_{part}$  (grouping different types of model behaviour). These findings reprise the *Evaluation Space*.

Analyzing the applications allowed us to discern thirteen different commonly employed visualization options [L3], which were comprised of seven *multi-dimensional / multi-variate* and six *complex object* visualizations. Furthermore, visualizations were frequently divided for data representing *inputs* and direct *outputs* of the model. We also monitored if outputs were additionally *derived*. All these elements are essential parts of the *Decision Space*.

We recorded all the information in a coding table (see Fig. 2), following the procedure outlined in Sect. 2. This enabled us to utilize criteria from the Evaluation Space for filtering, allowing us to find applications and the corresponding sets of visualizations meeting the data constraints and supporting the chosen tasks. Using this approach, we were able to derive a rule-based data- and task-oriented VisRec strategy for multi-view recommendations [L4]. This strategy essentially defines the *Proposal Space*.

The high-level overview is presented in Tab. 1. We observed that the rules exhibited common high-level solving strategies that were independent of the underlying data type. Moreover, the rules derived from the analysis showed a remarkable degree of distinction in terms of the marks and channels employed for different tasks. These rules also adhered to widely accepted visualization guidelines [6], rendering them highly interpretable and easily explainable.

RSVP [3], depicted in Fig. 3, implements this VisRec strategy in a non-obtrusive manner. The system offers users guidance on encoding dimensions for a selected set of tasks and helps them choose appropriate visualizations from the available alternatives. Selected

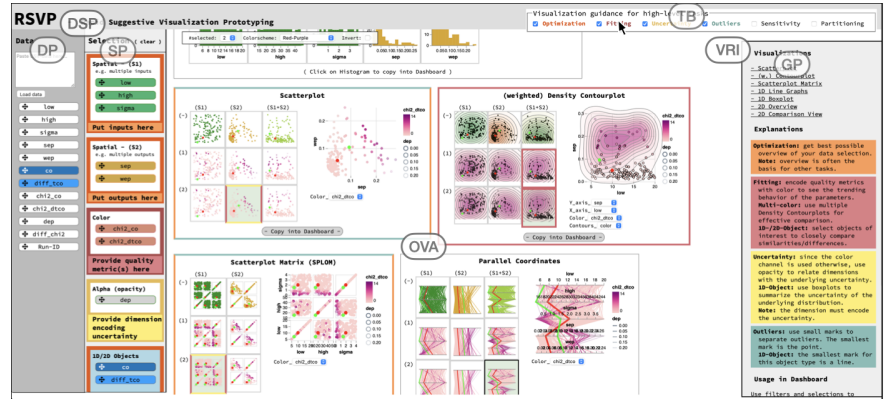


Figure 3: RSVP’s overview area (OVA) displays available visualization options for currently encoded dimensions in the data-selection panel (DSP). It utilizes small multiple displays to demonstrate data variations for *inputs*, *outputs*, and *derived* values. The visualization recommendation interface (VRI) consists of the taskbar (TB) for task selection and the guidance panel (GP) for providing context and explanations. Each task is assigned a distinct categorical color. Recommendations are then presented as accordingly (multi-)colored frames around visualizations and channels in (OVA) and (SP) respectively. Currently recommendations for  $T_{opt}$ ,  $T_{fit}$ ,  $T_{unc}$ , and  $T_{out}$  are shown.

visualizations can be copied into a dashboard that links various views, enabling interactive analysis of the model data. Although the system proposes recommended visualizations for copying into the dashboard, users have the flexibility to override them easily.

### 4 CONCLUSION AND FUTURE OUTLOOK

We introduced the concept of a meta design study and applied it to derive domain-specific data- and task-oriented VisRec strategies. Further, we presented RSVP, a system that implements a VisRec strategy derived from a meta design study for VPSA problems.

In future research, we aim to expand the application of meta design studies to other domains, further enhancing theoretical and practical foundations. Additionally, we seek to explore the potential of learning decision boundaries for recommendations directly from sparse coding data, reducing or even eliminating manual derivation.

**Acknowledgement:** Some of the presented contents are currently under submission [3].

### REFERENCES

- [1] A. Bryman. *Social research methods*. Oxford university press, 2016.
- [2] J. Kendall. Axial coding and the grounded theory controversy. *Western Journal of Nursing Research*, 21(6):743–757, 1999. PMID: 11512211. doi: 10.1177/019394599902100603
- [3] M. Klaffenboeck, M. Gleicher, J. Sorger, M. Wimmer, and T. Moeller. Rsvp for vpsa : A meta design study on rapid suggestive visualization prototyping for visual parameter space analysis. Submitted for publication, 2023.
- [4] A. MacLean, R. M. Young, and T. P. Moran. Design rationale: The argument behind the artifact. In *SIGCHI Conference on Human Factors in Computing Systems*, CHI ’89, p. 247–252. Association for Computing Machinery, New York, NY, USA, 1989. doi: 10.1145/67449.67497
- [5] T. Munzner. A nested model for visualization design and validation. *IEEE Transactions on Visualization and Computer Graphics*, 15(6):921–928, 2009. doi: 10.1109/TVCG.2009.111
- [6] T. Munzner. *Visualization analysis and design*. CRC press, 2014.
- [7] M. Sedlmair, C. Heinzl, S. Bruckner, H. Piringer, and T. Möller. Visual parameter space analysis: A conceptual framework. *IEEE Transactions on Visualization and Computer Graphics*, 20(12):2161–2170, 2014.
- [8] M. Sedlmair, M. Meyer, and T. Munzner. Design study methodology: Reflections from the trenches and the stacks. *IEEE Transactions on Visualization and Computer Graphics*, 18(12):2431–2440, 2012. doi: 10.1109/TVCG.2012.213
- [9] Z. Zeng, P. Moh, F. Du, J. Hoffswell, T. Y. Lee, S. Malik, E. Koh, and L. Battle. An evaluation-focused framework for visualization recommendation algorithms. *IEEE Transactions on Visualization and Computer Graphics*, pp. 1–1, 2021. doi: 10.1109/TVCG.2021.3114814