Biomole: Visualizing functional co-occurrence

Marjan Eggermont*
University of Calgary

Søren Knudsen†
University of Calgary

Richard Pusch‡
University of Calgary

Sheelagh Carpendale§
Simon Fraser University

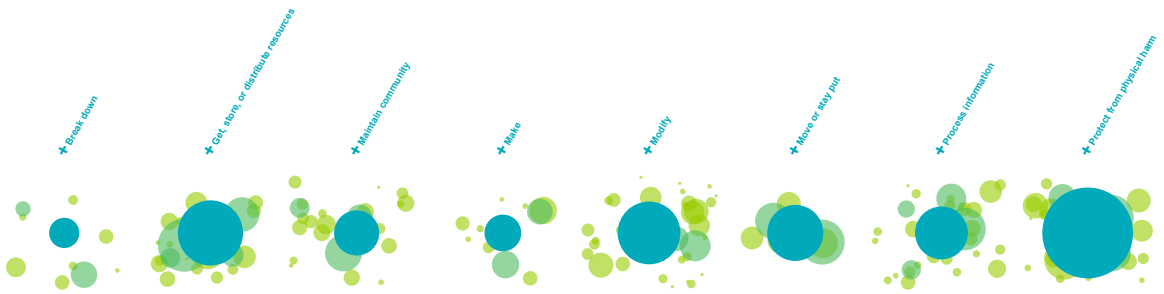

Figure 1: The Biomole tool. When first opened, it shows circles for every node in the hierarchy of functions. Dragging circles to lower rows allows for "painting" with the data.

Abstract

We present Biomole, an interactive visualization designed to explore a data set created to support bio-inspiration design published by the Ask Nature organization. The Ask Nature data set contains a hierarchy of functions which we encode within different visual elements of Biomole; most importantly interactive data painting of functions allows people to search for functional co-occurrence. The movement of the visual elements is a metaphorical nod to the bio-inspired nature of the data and the uncertainty of the design solution space.

1 Introduction

We present a tool that visualizes the Ask Nature "catalogue of nature's solutions to design challenges". The catalogue describes research results from the biological sciences, summarized for students and professionals that are interested in bio-inspired design. Our motivation started after informal discussions with engineering educators who mentioned in passing that the Ask Nature website in its current iteration does not function optimally for their students and for the educational outcomes they hope to achieve in their engineering design courses. The discussions led to closer inspection of the website which allows designers to find information about functional morphology to gain insight during the design process.

Ask Nature's content is structured into a hierarchy of functions and attributes using the biomimicry taxonomy (see excerpt in Figure 2). For example, species that move by attaching temporarily to a host would be under the group Move or stay put, in the sub-group Move, and listed under the function Attach temporarily. The search functionality on the website is linear. Once a designer decides on a functional group, subgroup, and ultimately function, a summary page shows a research summary of the function, one or more visuals, references, and an idea incubator. The engineering educators flagged the images and idea incubator (often a design suggestion) as posing a risk of student design fixation. While the incubator is perfect for design novices, the suggested ideas are too definitive when students at university level are asked to create novel design solutions.

Design fixation is an area of research well established in engineering design education and is currently defined as "a state in which someone engaged in a design task undertakes a restricted exploration of the design space due to an unconscious bias resulting from prior experience, knowledge or assumptions" [2]. Issues identified as design fixation range from premature commitment to a particular problem solution [8], students duplicating features of examples provided to them, in their own designs [9], and designers fixating to features of examples presented in picture or sketch form and duplicating those features in their solutions [9]. Unsurprisingly, design fixation is not unique to engineering design education. For example, similar findings have been reported in studies of interaction design [4] and service design [6].

To overcome these limitations, we created "Biomole" — a visualization tool that allows people to explore the Ask Nature data set more openly (see Figure 1). We describe the design process that led to Biomole and, in particular, how we considered the issues of design fixation that might occur during the conceptualization phase of bio-inspired design processes. We discuss our choice of movement to communicate uncertainty in the design space and the interaction provided in the tool.

2 Characterizing Design Processes

Design processes in general are iterative processes that start by identifying needs, generating ideas and developing possible solutions, making and testing prototypes, and modifying and improving solutions or potentially redefining needs. There are many variations on the process, but these variations are largely semantic. In this paper we focus on a bio-inspired design process as it might happen

Root	Group	Subgroup	Function
	Move or stay put (283)	Attach (115)	• Attach permanently (47) • Attach temporarily (85)
		Move (187)	• Move in/on liquids (83) • Move in/on solids (69) • Move in/through gases (46)

Figure 2: An example subsection of the biomimicry taxonomy showing that shows "the move or stay put" group and children below it in the hierarchy.

*e-mail: meggermo@ucalgary.ca
†e-mail: sknudsen@ucalgary.ca
‡e-mail: rapusch@ucalgary.ca
§e-mail: sheelagh@sfu.ca

in an engineering design course, and certainly has happened in the context we have observed. Idea generation is a key aspect during this process, and is the phase where engineers develop as many solutions to address a problem or need while keeping design constraints in mind. The ideal goal is a solution-independent concept that identifies desired functionality.

3 Biomole

Ask Nature, as mentioned previously, is a catalogue of nature's solutions to design challenges. Students and professionals can find biology research that has been formatted for non-biologists and be inspired by strategies in nature that satisfy a certain function. The goal of the site is to abstract this information into a sustainable product or system. We designed Biomole as a first step to allow designers to focus on the question: "What do I want my design to do (function), not what do I want my design to look like (form)." Currently the search path on Ask Nature is linear in nature and does not allow for a functional co-occurrence search.

The biomimicry taxonomy, discussed in the introduction, is a system of classification. The taxonomy categorizes the different ways that organisms and natural systems meet functional challenges. It is also the backbone of the Ask Nature website. On Ask Nature, the ways that organisms and other living systems meet functional challenges are called strategies. The biomimicry taxonomy organizes these biological strategies by function, that is, by what the strategy does for the organism or living system. Organizing biological content by function is valuable because it allows us to look for potential solutions to similar challenges we face as humans.

The Ask Nature website currently describes about 1800 strategies: functional solutions used by lifeforms to solve challenges. In our work, we focused on groups, subgroups, and functions, as well as URLs that link search results to Ask Nature descriptions and titles that briefly describe an organism's morphological trait combined with a functional verb resulting in an action or consequence. We aimed to create a bio-inspired information visualization. Using a design method from a different domain broadened our solution space as suggested by Vande Moere and Purchase [5], introduced new metaphors [1], and a new way of working [3]. We found the behavior and strategies of slime mold to be useful as inspiration in our design, while we also relied on established approaches in visualization design. For example, we considered allowing "the nature of a particular data set [to] influence the type of analysis being done." [7]

We also kept our conversations with engineering educators in mind. We considered how we might create a tool that could be used before heading to Ask Nature to avoid design fixation by not showing images and not giving initial ideas that might steer away from really identifying and narrowing the functions that students were "problem solving for".

The final design is intended to allow designers to focus solely on functions (see also Figure 3). A designer starts with a functional group and can expand the group into sub-group and functions, for example Move or Stay Put, Attach, Attach temporarily. To see the functional co-occurrences of a given function, the user brushes the

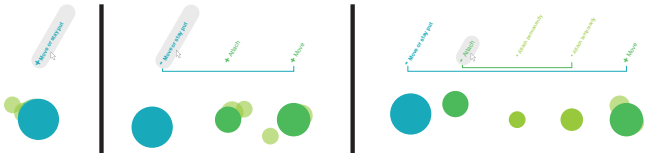

Figure 3: By expanding the tree hierarchy, it is possible to allocate more horizontal space for a group and sub-groups. The sub-groups and functions are shown below a group while it is contracted.

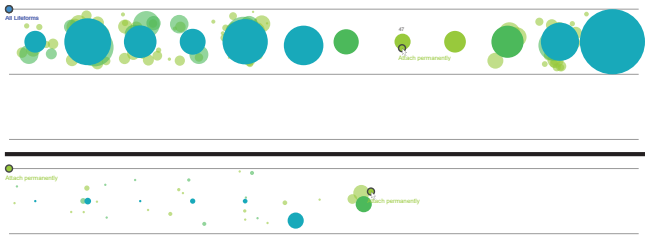

Figure 4: By dragging data marks across a blank data pane, it is possible to 'paint' with the data mark.

sphere across a second row in the tool. Where co-occurrence exists, new spheres appear. Clicking any of the spheres results in a summary list which links to corresponding organism pages on Ask Nature.

Concretely, to support exploring the hierarchical data set and make sense of it, we allow people to select and explore data marks that they find interesting. By dragging data marks across a blank data pane, it is possible to "paint" with the data mark (see Figure 4). This data "painting" results in a pane that shows other parts of the hierarchy where species that were present in the "paint" (the dragged data mark) are also present, meaning that these species also rely on those strategies.

4 Conclusion

We presented Biomole, a functional co-occurrence tool that also aims to avoid design fixation. We used data brushing as a way to allow people to explore species and functions within and across parts of the Ask Nature hierarchy by "painting" with data. The tool uses movement as a bio-inspired search and uncertainty metaphor. While keeping the nature of the data in mind, we explored new visualization techniques borrowing ideas from the slime mold.

References

[1] V. M. Andrew. Form follows data the symbiosis between design & information visualization, 2005.

[2] N. Crilly and C. Cardoso. Where next for research on fixation, inspiration and creativity in design? *Design Studies*, 50:1–38, 2017. doi: 10.1016/j.destud.2017.02.001

[3] T. Faste and H. Faste. Demystifying "design research": Design is not research, research is design. In *IDSA Education Symposium*, vol. 2012, p. 15, 2012.

[4] S. T. Hassard, A. Blandford, and A. L. Cox. Analogies in design decision-making. In *Proceedings of the 23rd British HCI group annual conference on people and computers: celebrating people and technology*, pp. 140–148. British Computer Society, 2009.

[5] A. V. Moere and H. Purchase. On the role of design in information visualization. *Information Visualization*, 10(4):356–371, 2011. doi: 10.1177/1473871611415996

[6] D. P. Moreno, M. C. Yang, A. A. Hernández, J. S. Linsey, and K. L. Wood. A step beyond to overcome design fixation: a design-by-analogy approach. In *Design Computing and Cognition'14*, pp. 607–624. Springer, 2015. doi: 10.1007/978-3-319-14956-1_34

[7] A. J. Pretorius and J. J. Van Wijk. What does the user want to see? what do the data want to be? *Information Visualization*, 8(3):153–166, 2009. doi: 10.1057/ivs.2009.13

[8] D. Tolbert and M. E. Cardella. Work in progress: Design fixation in first-year engineering students' problem solving. In *2016 ASEE Annual Conference & Exposition*. ASEE Conferences, New Orleans, Louisiana, June 2016. https://peer.asee.org/27216. doi: 10.18260/p.27216

[9] N. E. E. Vimal Kumar Viswanathan and J. S. Linsey. Training tomorrow's designers: A study on the design fixation. In *2012 ASEE Annual Conference & Exposition*. ASEE Conferences, San Antonio, Texas, June 2012. https://peer.asee.org/22129.