Zooids

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Chapter Information

Title of the Piece or Project	Zooids
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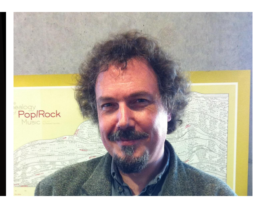
Author/Artist portrait(s)	     mathieu.jpg perin.jpg Sean Follmer Square small.png fekete-2012.jpg dragicevic-pierre.jpg
List any Clients, Collaborators, and Contributors or Funders that should be recognized	
Year of the Piece/Project	2018
Piece/Project Venue	IEEE VIS 2018
Piece/Project Website	https://www.mathieulegoc.me/dynamic-composite-physicalizations
Description of the Piece/Project	*Zooids* are small wheeled robots that can coordinate to create physical charts and interfaces. Working together, *Zooids* can give physical form to

	well-known interactive visualizations and also let us explore new visualization and interaction paradigms.
Companion Website URL	makingwithdata.org/zooids

Project Motivation and Inspiration

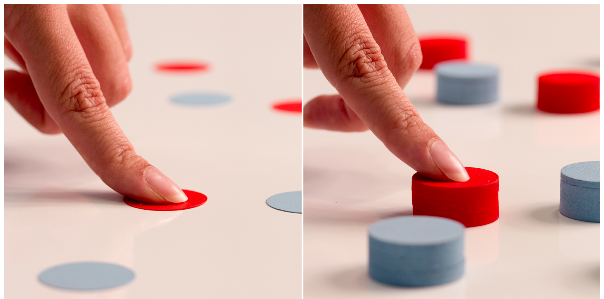
Physical data visualizations tap into our lifelong experience of perceiving and manipulating the physical world, either alone or with other people. However, most physical visualizations are either monolithic and static, or require human intervention to be rearranged. We drew inspiration from existing physical interactive systems and data storytelling practices with physical tokens (like those of the influential Swedish professor Hans Rosling) to develop *Zooids*, tiny wheeled robots that can move rapidly on any horizontal surface. We used *Zooids* to explore physical data visualizations that can (1) be manipulated by humans, and (2) update themselves through computerized mechanisms.

Images of the Final Piece

(00_teaser.JPG 01_preview.png)

Practices and Processes

Looking at Token Manipulation(02_token_study.png)

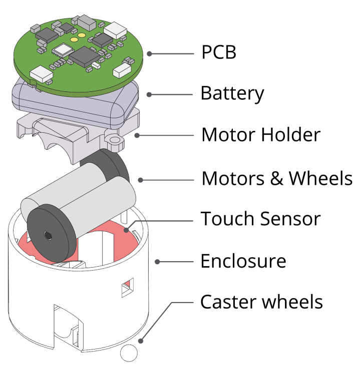


To better understand how people manipulate collections of small items and the possible benefits of tangible tokens over touch interfaces, we ran a study where we asked participants to quickly sort and arrange dozens of colored tokens. Tokens were provided in two versions: thick graspable objects, and flat objects meant to emulate touch interfaces. Our experiments suggested that people found the task more enjoyable and efficient when the tokens could be grasped. We also saw that the way people grasped objects was often indicative of the action that was going to follow.

Adding Sensing to Tokens (03_smarttokens_teaser.png)

Based on the insights from our study, we created SmartTokens, tokens with embedded electronics that could sense how people touched, moved, and manipulated them. Each SmartToken included a 3D-printed cylinder, a custom circuit board, a small battery, six sensors for detecting touches, and a wireless transmitter for reporting inputs to a computer. The form factor of SmartTokens was chosen so that they could be easily grasped, and roughly five of them could fit comfortably in one hand.

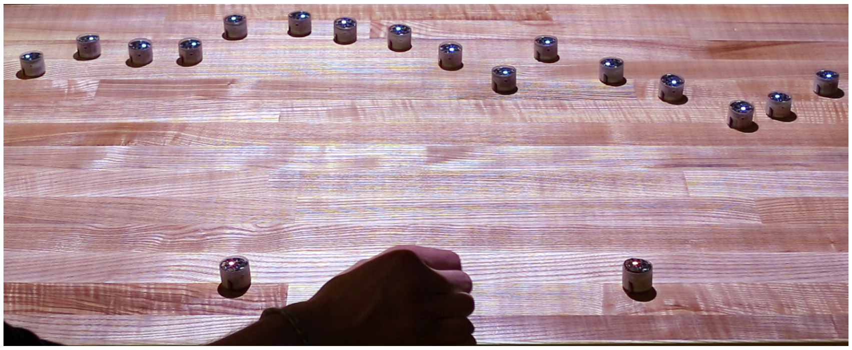
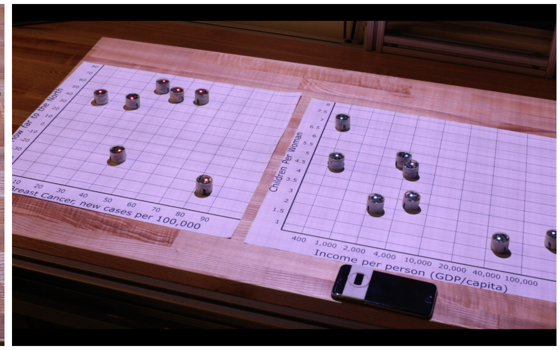
Adding Movement to Tokens



(07_zooids_exploded.png 09_zooids_teaser.png)

Next we augmented our SmartTokens with wheels to create small self-propelled robots we called *Zooids*. These robots can act as physical pixels which can change color and rapidly reposition themselves to create shapes. *Zooids* are also compact enough for people to grasp, lift, and manipulate several of them simultaneously. Their small size also lets them blend into existing environments and move other objects.

A First Prototype

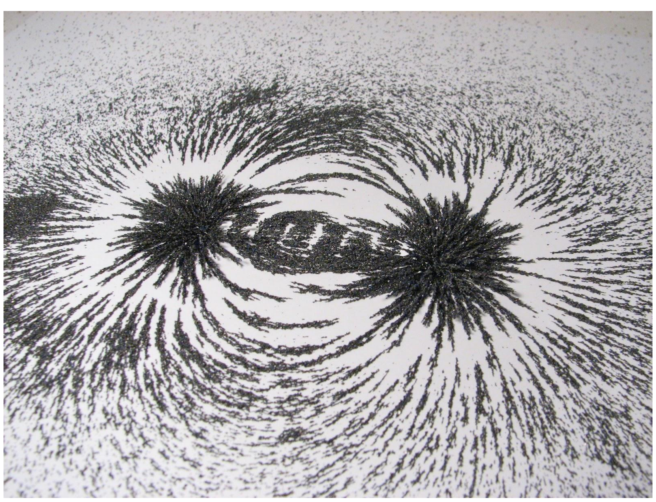
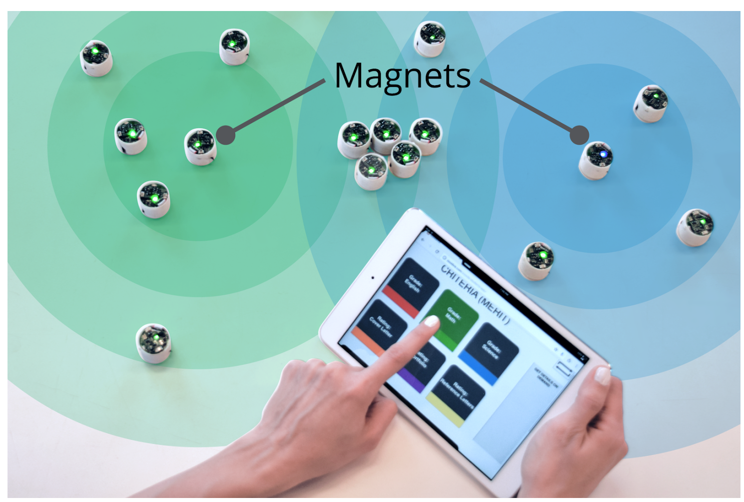



(13_linechart_2.png 14_scatterplot.png)

We first explored how *Zooids* could be used to create basic physical graphics such as dynamic line charts and scatterplots. However, people had a hard time understanding what the charts showed until we added additional visual information such as titles, axes, and labels. They were also missing “details-on-demand” mechanisms that people could use to get more information about the data points. To address this, we added paper backgrounds to some charts as well as small screens that viewers could use to inspect data from individual *Zooids*.

Richer Interactive Charts

We then used *Zooids* to create more complex interactive visualizations based on a “dust and magnet” metaphor, which viewers could use to explore multi-dimensional data. For example, some *Zooids* may represent individual countries (the “dust”) while others represent data dimensions (the “magnets”) such as population or average income. Placing a population magnet would cause all of the *Zooids* representing countries to move towards it, attracted by a force proportional to their population. By adding and moving additional magnets, viewers could quickly rearrange the *Zooids*, dynamically revealing relationships between countries.

(15_magnetic_particles.jpg 16_zooids_magnet.png Credit-Particles: CC-BY 2.0 Windell H. Oskay, www.evilmadscientist.com)

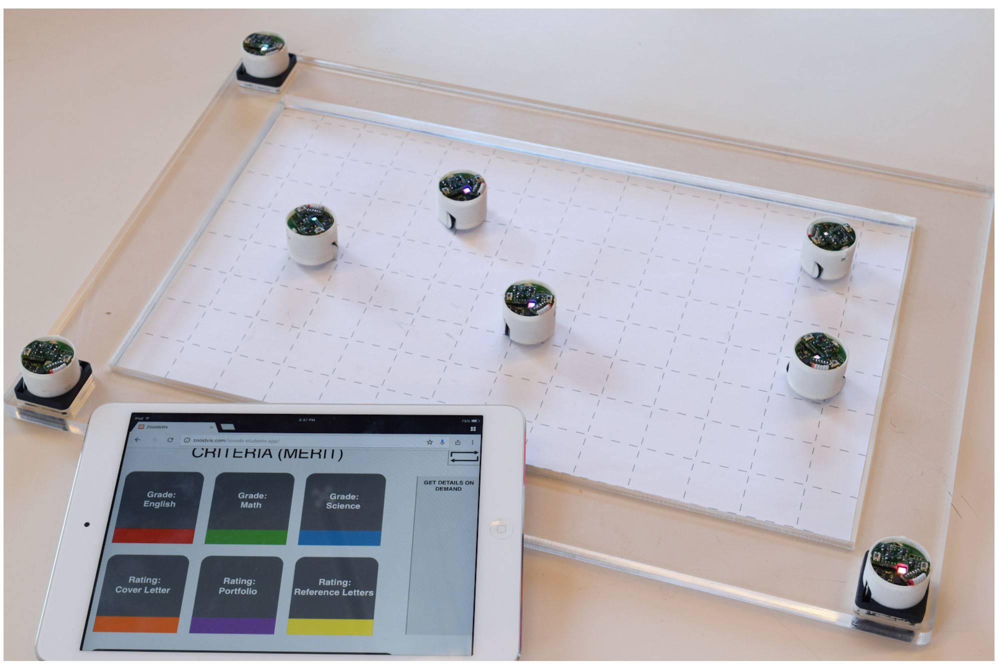
Just as particles of iron react to surrounding magnets, our grains of dust react to the presence of magnets and move at a distance that reflects their value in the dimension of each of the surrounding magnets. Because the *Zooids* are physical, viewers could also use everyday objects like sticky notes to organize and annotate the space.

Adding Context

(17_details_on_demand.png)

Viewers could also use the companion app to configure the *Zooids* or see the raw data for each individual element. For example, when using *Zooids* to examine a dataset of student records, a viewer could place individual robots on the tablet to see precise details such as name, age, or grades.

Scatterplots On-Demand



(19_scatterplot_on_demand.png)

Our dust and magnets visualizations made it easier to explore trends and relationships, but hard to read exact values. As an alternative, we also built a physical scatterplot frame that let viewers place magnets on either of its axes. Assigning a data dimension to an axis would cause all of the dust *Zooids* in the frame to organize along it, creating dynamic scatterplots and making data points easier to compare.

Materials and Tools

Powerpoint and Paper Sketching
UX prototyping and Wizard-of-Oz prototypes

Altium Designer
Electronics design

Solidworks
3D modeling

Crossworks Studio
Embedded software programing (C for ARM microcontrollers)

XCode, OpenFrameworks (C++), and Javascript
Software development and user interfaces

Open source code and components for the project are available at:
https://github.com/ShapeLab/SwarmUI
https://github.com/ShapeLab/ZooidsCompositePhysicalizations

Reflections

The physical charts presented here are proofs of concepts, illustrating how dynamic physical objects could become common for users to collaboratively explore data. Many challenges emerged during this exploration, and we had to compromise on several factors. In our quest to create a versatile, tangible user interface, we designed our system to create homogeneous collections of *Zooids*. They are all indistinguishable from one another, making it difficult to distinguish "dust" *Zooids* from "magnet" *Zooids*. Their circular shape also limits the types of representations to "dot-based" visualizations.

Our prototypes also highlight the value of designing interactions that avoid creating more hassle and repetitive tasks. As datasets can become rather large, the last thing we want is to have to move dozens and dozens of *Zooids* by hand. Interaction techniques such as Dust and Magnets can help manipulate many *Zooids* at once, yet for now most data exploration involves manipulating *Zooids* one by one.

Large datasets also require large numbers of *Zooids*. The robotics and sensing technologies we use are becoming smaller and smaller. However, in their current form, it remains challenging—both in terms of real estate and cost—to accommodate datasets with hundreds of data points. Scalability, providing context, and showing detail remain challenges for *Zooids* and for most physical charts. However, in a world where data is becoming ubiquitous, we see great opportunities for interactive physical charts to become more pervasive, maybe even part of our everyday lives at home.