Welcome again, and thank you for participating in our study. By taking part in this study, you will be helping us measure several visualization methods. Please note that we will test our methods, not you. You can leave for a break or quit anytime during the experiment.

The study includes five parts. (1) background survey (you just finished it); (2) a pre-study training with a short test(3) the experiment; (4) a post-study questionnaire; and (5) an interview for your comments.

Let us start the training.

1. Introduction

What we will see today include five three-dimensional (3D) vector field visualization methods. The vector field is calculated from a quantum physics simulation. Each vector can be described by its vector length and orientation. One attribute with the data is that the magnitudes have a large range - the difference between the largest and the smallest vectors is 10^{12}. This large range makes perceiving information difficult. In this study, we test five visualization approach, all using the scientific notation, to represent the large dynamic range data. The maximum data range is set to 10^4.

The program is **interactive and supports the following three actions**.

- Rotate the data by holding down the left-mouse button while dragging.
- Zoom in and out by Right-mouse dragging will let you zoom in and out.
- Task-specific interaction for answering questions (please see below).

2. Scientific Notation for Representing Vector Length

Now let's look at how the vector magnitude can be represented in the scientific notation using the digit and the exponent. A vector magnitude can be written in scientific notation, e.g.,

$$A * 10^B ,$$

where A, the digit term, is a real number with a range of [1, 10), and

B, the exponential term, is an integer.

In this study **the range of B is [0, 3] (inclusive).**

Here are some examples of vector length in scientific notations.

1000: 1.00e+3 (A = 1, B=3)

243.6: 2.436e+2 (A=2.436, B=2)

10: 1.00e+1 (A = 1, B=1)

53: 5.30e+1 (A=5.3, B=1)

4389.7: 4.39e+3 (A=4.39, B=3)

2: 2.00e+0 (A=2, B=0)

Please pause the audio and do Test 1.

Now let's look at five ways to **depict** *the two variables A and B in the scientific notation for showing the vector length*.

3. Five Encoding Approaches

3.0. Overview

We use **two to three visual variables to represent the digit** and the **exponent** for each vector**.** Here is the summary table of the five combinations you will see in the experiment.

	Exponent (B)	Digit (A)
Method 1: Dual-height:	outer-cylinder radius	inner-cylinder radius
Method 2: Radius-height:	cylinder radius	cylinder height
Method 3: Color/Radius-height:	color and cylinder radius	cylinder height
Method 4: Color-height:	color	cylinder height
Method 5: Texture-height:	percentage of black	cylinder height

3.1. Method 1: Dual-height

Each of the digit and the exponent in the vector magnitude is mapped to two co-centric cylinders: the **height** of the internal cylinder is mapped to the digit term A; and the **height** of the external cylinder to the exponential term B (Fig. 1). The diameters of the internal and the external cylinders are 1 and 2 units correspondingly.

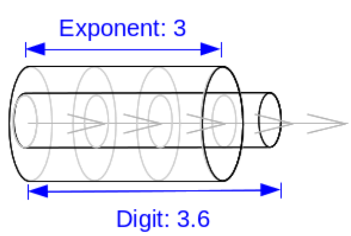

Figure 1. Method 1: dual-height. Here the number is 3600 (3.6e+3 or 3.6e3).

A fish-bone legend and band are also displayed to represent the scale. A legend in general is a special object that helps identify object scale in visualizations. For example, geographic maps have legend; legend must be used in nearly all scientific graphs. Here, the legend is drawn using a dark grey line along the axis of the cylinder with a fixed length of 5 units. Each unit is marked using a fish-bone like marker.

In order to help you see the data, some light grey **circles** (or **bands**) are also drawn around the cylinders. The distance between two bands is one unit.

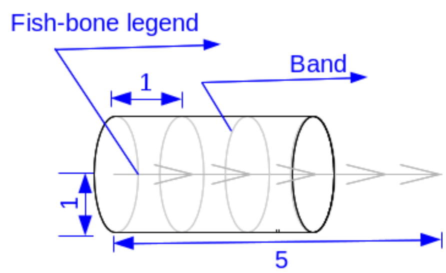

Figure 1. The fish-bone legend and band

Please look at the computer scene for some examples.

Please pause the audio.

3.2 Method 2: Radius-height

A vector is represented by a single cylinder: the **radius** is mapped to the exponent and the **height** to the digit term (Fig. 2). Therefore, the larger the volume of the cylinder, the higher the magnitude. A 5-unit fish-bone legend is drawn to show the scale for both the radius and the height.

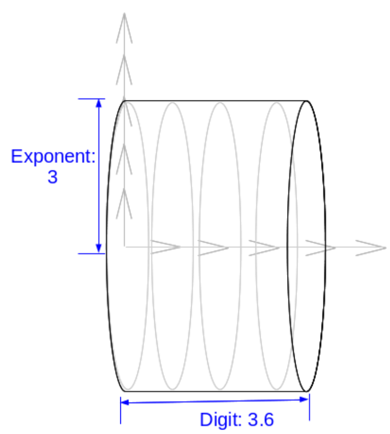

Figure 3. Method 2: radius-height. Here the number is 3600 (3.6e+3 or 3.6e3).

Please look at the computer scene for some examples.

Please pause the audio.

3.3 Method 3: Color/Radius-height

A vector is represented by one cylinder: the **radius** and **color** are mapped to the exponent and the **height** to the digit term (Fig. 4). Therefore, the larger the volume of the cylinder, the higher the magnitude and the brighter (more yellow) the cylinder, the higher the magnitude. Again, A 5-unit fish-bone legend is drawn to show the scale for both the radius and the height. This method is the only technique where the exponent is double-encoded using color and radius.

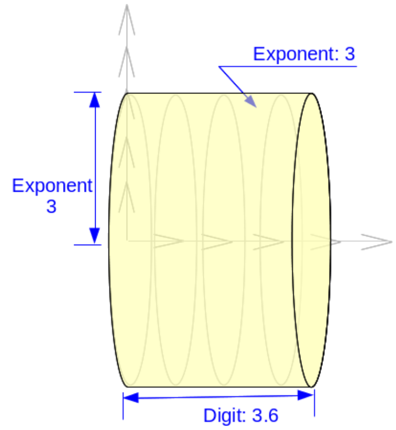

Figure 4. Method 3: color/radius-height. Here the number is 3600 (3.6e+3 or 3.6e3).

Please look at the computer scene for some examples.

Please pause the audio.

3.4 Method 4: Color-height

A vector is represented by one cylinder: the **color** is mapped to the exponent and the **height** to the digit term (Fig. 5). Therefore, the brighter the cylinder, the higher the magnitude. A 5-unit fish-bone legend is marked along the central-line of the cylinder.

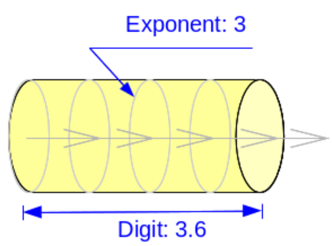

Figure 5. Method 4: color-height. Here the number is 3600 (3.6e+3 or 3.6e3).

Please look at the computer scene for some examples.

Please pause the audio.

3.5 Method 5: Texture-height

A vector is represented by one cylinder: the **texture (percentage of the black color)** is mapped to the exponent and the **height** to the digit term (Fig. 6). The mapping between texture and exponent is as followed:

Percentage of black in the hue	Exponent
90%	3
60%	2
30%	1
0%	0

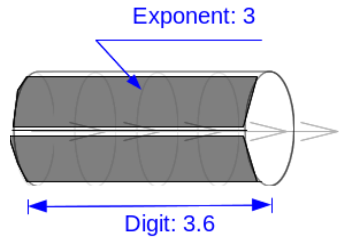

Figure 6. Method 5: texture-height. Here the number is 3600 (3.6e+3 or 3.6e3).

Please note that the the texture on a cylinder is generated by repeating the texture segment.

Please look at the computer scene for some examples.

Please pause the audio.

Please pause the audio to do Test 2.

3. Tasks

Now let's look at the tasks.

Introduction: There are **four task types**, each of which includes four sub-tasks for each encoding approach.

Giving an answer is mandatory. All tasks ask you to input your confidence level, ranged from 1 to 7, with 1 being the least and 7 being the most confident for the most recent answer you provided.

Task 1. What is the magnitude of point A?

Your task is to read the marked vector and type in the magnitude, given an encoding approach.

Please click "done" once you know the answer and you are not allowed to go back to see the data. A screen will appear where you can type in your answer. Both numerical values or scientific notations (Ae+B or AeB) are supported. You can edit your answer just like any other editing tools, i.e., use 'Backspace' on your keyboard to delete a symbol.

During the training, an answer will be shown on the screen. You are allowed to go back to see the data and correct your answer. During the formal study, you are not allowed to go back.

Please look at the computer scene for some example tasks.

Please pause the audio.

Task 2 What is the ratio between the vector magnitudes at points A and B (A/B)?

Your task is to calculate A/B in terms of magnitude. Please note that A is always larger than B.

You will use the same way as the task 1 to answer this question.

Please look at the computer scene for some example tasks.

Please pause the audio.

Task 3. Which magnitude is larger, point A or point B?

Your task is to compare A and B in terms of magnitude.

You will select your answer by clicking one button, “A” or “B”.

Please look at the computer scene for some example task.

Please pause the audio.

Task 4. Which point has maximum magnitude with exponent equal to X? Please mark the answer with the middle mouse button.

Your task is to find the point with maximum magnitude from data with exponent equal to X where X is an integer in range of [0, 3]. During the experiment, “X” is provided.

To answer this question, please click the vector with the **middle mouse button** , and the selected vector will be marked by two red triangles and then click the “done” button to go to the next screen. You can change your answer before you click the “done” button.

Please note that this task has a preset time constraints. The current task will automatically expire after 30 seconds and will move on to the answer page. Thus, estimate the number before it expires.

Please look at the computer scene for some example task.

Please pause the audio.

Please do the tasks as accurate and as fast as you can. **Accuracy is more important than speed.**

If you need to take a break, please answer the current question, and then click the “Pause” button on the screen. When you get back, click “Resume” to continue.

Are you ready to start the formal testing?

This is the end of training.