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|  | Initial Proposal | |
| | n-Dimensional Graphing Calculator | CS 4091 |
| | September 13, 2023 | Jake Mason & Upmanyu Rohit |

1 Problem

Consider a real valued function of one variable $f : \mathbb{R} \rightarrow \mathbb{R}$. By a graph G of the function f , we mean a subset of \mathbb{R}^2 ,

$$G = \{(x, y) \in \mathbb{R} \times \mathbb{R} : y = f(x)\}.$$


There exist many applications for visualizing the graph of single variable functions. Several hand held calculators can graph single variable functions. For example, Texas Instruments has a lineup of graphing calculators including the leading TI-Inspire. There are also online applications such as Desmos and GeoGebra with similar capabilities.

Now consider a real valued function of n variables $f : \mathbb{R}^n \rightarrow \mathbb{R}$. The graph G of f is defined similarly to that of single variable functions,

$$G = \{(\mathbf{x}, y) \in \mathbb{R}^n \times \mathbb{R} : y = f(\mathbf{x})\}.$$

However, this graph is a subset of \mathbb{R}^{n+1} . It is not obvious how one should visualize this graph. A 3 dimensional world offers efficient visualization of two-variable functions at best. There are no well known calculators capable of visualizing a real function of n variables.

The problem is that functions of n variables are common in nature. It is hard to find a system where values are only dependent on one variable. We seek an application capable of visualzing the graph of functions of n variables. Such an application will offer details on functions where previously calculations had to be carried out by hand.

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2 Solution

We propose the design of a calculator capable of visualizing the graph of a real valued function of n variables, where $n \geq 1$. Our goal is to first design an application with 2 dimensional and 3 dimensional graphing capabilities. We can then implement functions of n variables and view them using projections onto 2 or 3 dimensional subspaces. Consider a function of n variables

$$f : \mathbb{R}^n \rightarrow \mathbb{R}.$$

We can project this function onto the x_i, x_j plane by setting


$$g : \mathbb{R}^2 \rightarrow \mathbb{R} \quad g(x_i, x_j) = f(0, \dots, x_i, \dots, x_j, \dots, 0)$$

where x_i and x_j fall in the i^{th} and j^{th} positions respectively. A similar result holds for projecting onto 3 dimensional space. We may also consider projections onto arbitrary planes. A plane in 3 dimensional space can be obtained through the equation

$$ax + by + cz = d$$


with $a, b, c, d \in \mathbb{R}$. Projecting a function onto such a plane may involve careful rotation of the coordinate axes.

With the general idea set, we plan to implement this design with a user interface for entering functions and selecting a graph view.

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3 Milestones & Tasking

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|--------------------------------|---|
| 2D Graphing By Sept. 30 | Program Initialization Draw to the screen Input functions of 1 variable Store functions of 1 variable Display graph of function Allow translation of graph view |
| 3D Graphing By Oct. 31 | Input functions of 2 variables Store functions of 2 variables Display graph (already using projections) Allow rotation of graph view |
| nD Graphing By Nov. 30 | Input functions of n variables Store functions of n variables Allow choice of projective axes Allow choice of projective plane Display graph onto projected surface |
| Extra By Nov. 30 | Calculate properties of functions such as max, min, avg Display features of graph view such as range, stretch, axes Allow saving of graphs for later use |
| Testing | Verify graphs of well known functions |
| Deployment | Show application to mathematics majors and professors Take feedback and make necessary adjustments Continue support for new product |

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4 MOSCOW

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|----------------|---|
| MUST: | Method for displaying graphs of single variable functions on screen Method for storing functions of n variables Method for displaying projections of n variable functions Method for user to input n variable functions Run at stable 60fps with no warnings/errors |
| SHOULD: | Parser to allow function input as text Display properties of function such as max, min, avg |
| COULD: | Run on both Windows and Linux Allow saving of graphs for later use |
| WOULD: | Parser to allow function input as \LaTeX |