Optical Illusions in Computer Graphics

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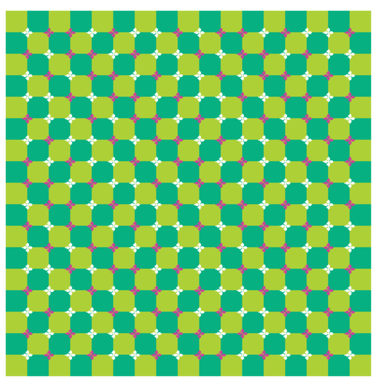
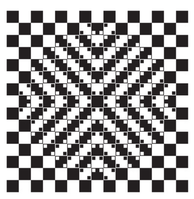
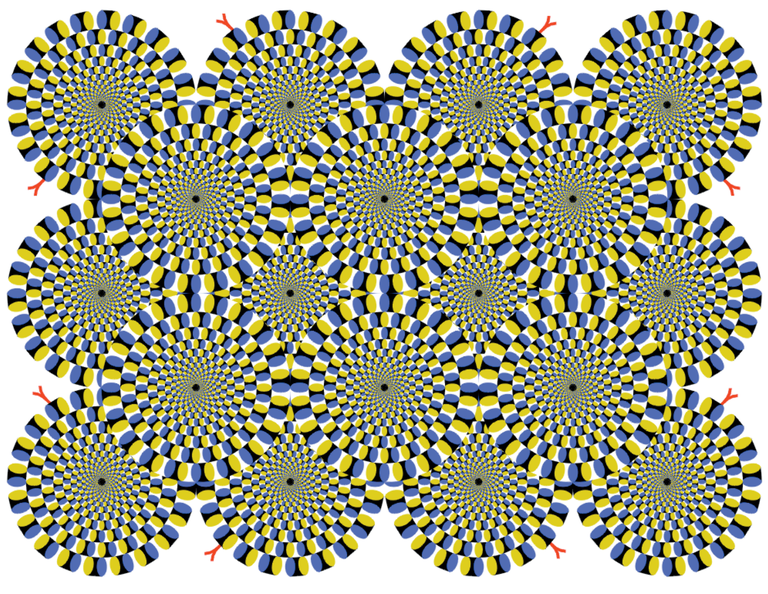
Abstract

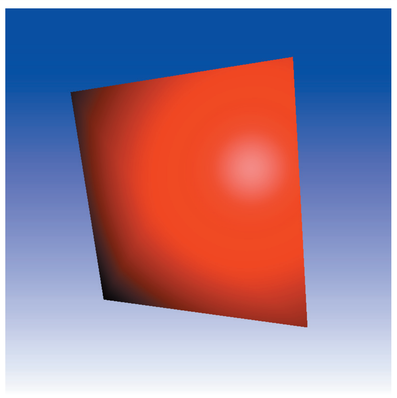
In general terms, all techniques of computer graphics are fundamentally optical illusions. Optical illusions that result from errors in perception are currently unused in the field of computer graphics, remaining merely as novelties in expressionistic art and children's books. Through the use of illusions that result in the viewer failing to properly perceive parallel lines, it is possible to convey extra information beyond the basic geometry of the scene. Specifically, we demonstrate how such illusions may be utilized to convey Z-axis information on two dimensional displays. This is compared to techniques with similar code complexity and techniques with similar information complexity. Minimum required processing power is extremely low, indicating immediate applications in hand-held and embedded devices.

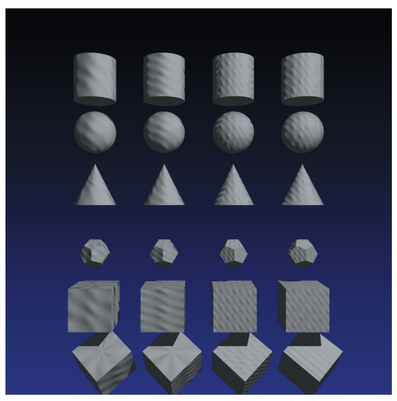
Illusion Images courtesy of
Akiyoshi Kitaoka
Department of Psychology, Ritsumeikan University, Kyoto, Japan
http://www.ritsumei.ac.jp/~akitaoka/index-e.html







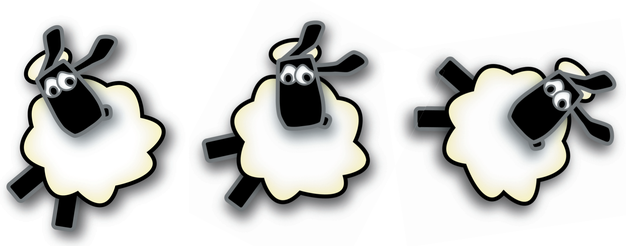




http://www.elude.ca/sadie/phongpoly.png

http://www.cgl.uwaterloo.ca/~b8chan/cs488/bump.png

Shading gives the illusion of detail that is not present in the rendered geometry



Frames of animation represent discrete moments in time, giving the illusion of continuous motion.

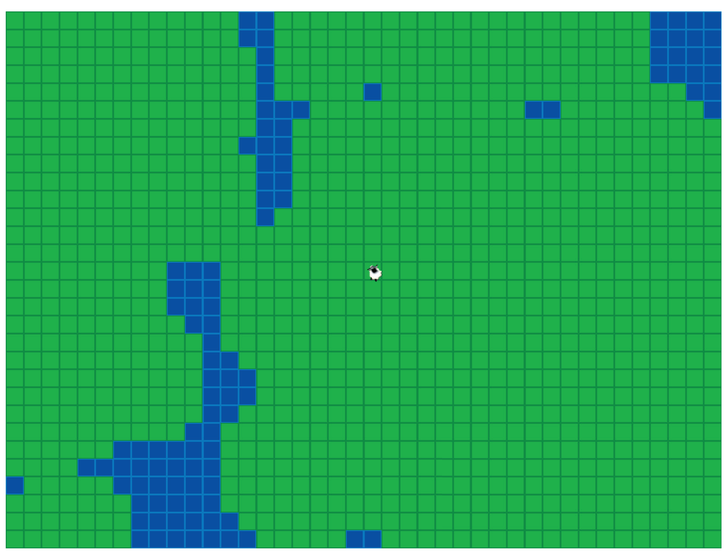
Experimental Survey

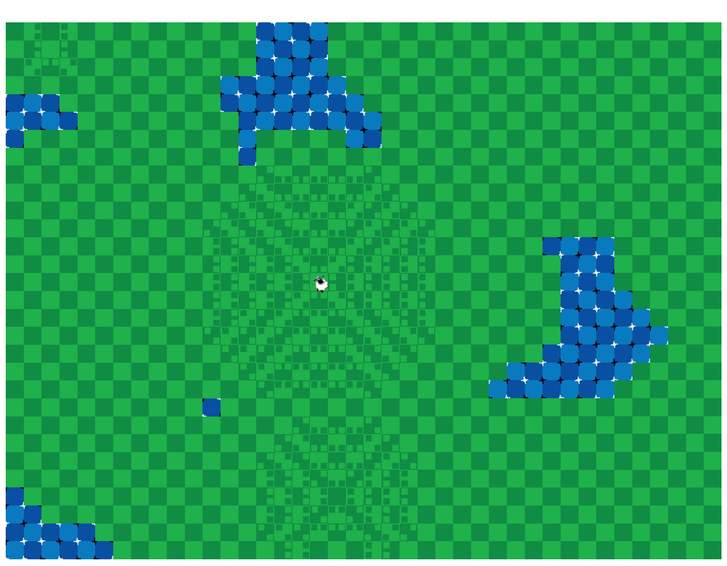
After studying the Primrose and Bulge illusions [Kitaoka], we hypothesize that use of optical illusion may enable one to convey extra information, information that may remain hidden when using similar graphical techniques that do not utilize optical illusion. In order to test the hypothesis, we designed an experiment to determine the usability of a system that utilizes optical illusions as a means of conveying extra data.

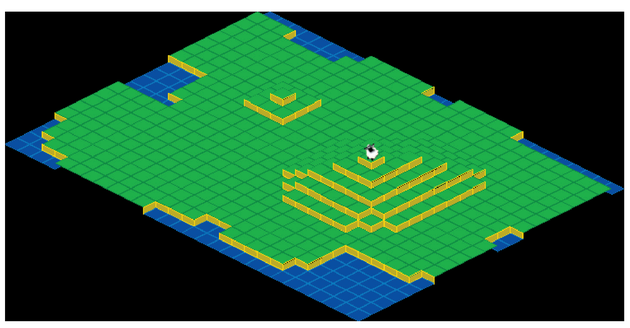
The experiment is centered around a three dimensional, geographic map. The map is partitioned along longitudinal and latitudinal lines, creating individual tiles. These tiles are referenced by X and Y coordinate locations on the map. Each tile stores a value that represents the average altitude of the land contained in that tile. The "extra data" that the experiment will test is therefore the height of the individual tiles.

The tile map data is rendered in three different manners.
1.) An orthographic projection of the map, utilizing a two-value color coding scheme to indicate areas of "land" and "water," is used as a control against providing no height information. In this environment, users must select points at random.
2.) An orthographic projection of the map, utilizing the two-color coding scheme as well as optical illusions to indicate the areas of increasing slope of "land," is the experimental rendering technique. In this environment, users may or may not be able to determine the height of the hills.
3.) An isometric projection, utilizing the two-value color coding scheme as well as perspective to indicate the height of individual tiles, is used as a control against providing explicit height information. In this environment, users can determine the height of hills quite easily.

One of the three rendering techniques is chosen at random for a testing session. A test subject is sequentially presented with a total of five randomly generated maps, each rendered using the rendering technique for the test session. The user is given a task; they must select the tallest hill on the map. This task is reinforced with an animation of a small sheep running to the location that the user selected. After the task is complete for the five maps, session's rendering technique and the user's success rate is recorded. [http://members.gamedev.net/capn_midnight/optical_illusion/survey/]







Results

The survey was administered through the web site GameDev.net, "the leading online community for game developers of all levels." [http://www.gamedev.net/info/about/] through the interactive forum system [http://www.gamedev.net/community/forums/topic.asp?topic_id=311825]. The survey was advertised by pinning the associated thread to the top of the most active section of the web site, the General Discussion Forum.

A total of 110 test sessions were ran, with a total of 550 tasks completed. The success and failure rates for each rendering method were tabulated and summarized.

Renderer	Total Runs	Total Success	Total Failure	% Success	%Failure
1.)	140	7	133	5.000%	95.000%
2.)	220	172	48	78.182%	21.818%
3.)	190	186	4	97.895%	2.105%

Early in the survey process, a rendering bug was discovered that made selection of the tallest hills nearly impossible when using the experimental map renderer. The bug was corrected and the survey continued, essentially making it equivalent to first control renderer. Because of this, test sessions that resulted in zero or one successes when using the experimental renderer were treated as corrupted data and the results were re-tabulated.

Renderer	Total Runs	Total Success	Total Failure	% Success	% Failure
1.)	140	7	133	5.000%	95.000%
2.)	195	170	25	87.179%	12.821%
3.)	190	186	4	97.895%	2.105%

Each of the map renderers were profiled for performance data. A random set of maps of increasing size were rendered a thousand times for each rendering method, and the number of milliseconds that elapsed during the one thousand renderings was recorded along with the size of the map that was rendered.

Map Size (W x H)	Renderer 1	Renderer 2	Renderer 3
3 x 4	266	187	672
6 x 8	297	297	1734
9 x 12	453	468	2437
12 x 16	735	734	4359
15 x 20	1094	1140	6078
18 x 24	1609	1593	9343
21 x 28	2172	2204	13125
24 x 32	2890	2906	16390
27 x 36	3547	3532	21250
30 x 40	4078	4250	22266
Total	17141	17311	97654

In conclusion we see that real, usable data is transmitted to users via optical illusions at no extra cost of rendering time.