# 3D space visualisation

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## Abstract

The paper describes a new method of stereoscopic visualisation for removing dependence of „3D" applications on display size and resolution. This problem we can solve by run-time stereo images generation with display parameters or by special scene computation for each potential display type. If scenes are very complicated, then these ways could be impossible. But there exists another possibility for solution of dependence. We call it „Constant change of difference" - DC (difference change). Pictures for left and right eye are computed separately in this method, but they are not composed to one stereo image. The composition is run-time executed with display parameters. We do not need any other computation.

**Keywords:** 3D, stereo vision, difference, constant difference, visualisation, stereo visualisation

## 1. Introduction

Experiments that refer to 3D vision already have been well known for a long time. The Greek mathematician Euclid pronounced idea that space vision is possible by two eyes only [3]. Creating of artificial stereovision is based on physiological features of eye and on way of processing pictorial information in brain [7].

The paper reassumed to projects solved at UWB in the last years [11][3]. Projects delt with the basis of stereoscopy and made first experiments in stereoscopic area. Our project goal is to determine possibilities and boundaries of using 3D visualisation for visualisation of volume data.

Constant change of difference (DC) composes left eye and right eye scenes horizontally shifted each other. The shift depends on differences between original display device (for this device we generate stereoscopic image - we use its parameters) and actual display device. The shift is constant for all points in scene. Its size is optional, but it has limitation which will be discussed below.

Using DC for visualisation of 3D scenes we will achieve partial independence on display devices and we do not need to make complicated run-time computations.

## 2. 3D environment

Let us have an object defined by points A,B and C, and a projection plane that is parallel with the observer plane. In observer plane lay both eyes (or cameras). We assume, that eyes lay in horizontal plane too and all planes are vertical. Creating a stereo picture, we have to make two projections from each point. By this way we get projections for right and left eye [figure a]. Displaying these projections so that left eye could see left eye projection only and right eye could see right projection only; we will percept a 3D image [1].

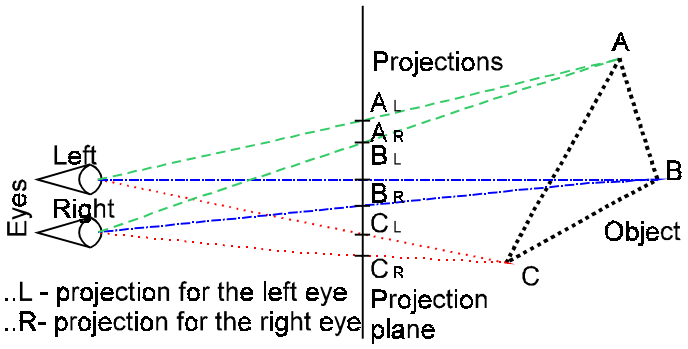


**Figure A 3D space scheme**

All the points in the scene have two images on projection plane. These images differ only in horizontal co-ordinates because eyes lay in horizontal plane. Therefore we can determine distance of left and right eye projections such that these distances are parallel for all points. This distance is called difference on projection plane. Shortly we call it *difference*.

All points in the scene can lay in front of, behind or on the projection plane. The points that lay in front of projection plane (between observer and projection plane) have positive parallax. The points that lay behind of projection plane have negative parallax [4].

Let us have a point that lie in three dimensional scene [figure b]. Followed distances, parameters and other property are defined and derived:

- observer plane
- projection plane
- object plane

All three planes are parallel each other and all three planes are vertical. All plane are parallel to *xy* plane. We define: projection plane have *z* co-ordinate equal to zero.

- *s* eye spacing; this value is based on observer's physical characteristic
- *q* distance between right eye and given point
- *lp* distance between the observer and the projection plane
- *lo* z co-ordinate of the given point (point depth)

vectors of *lp* a *lo* distances are perpendicular on the projection plane

- *d* difference of projections on the projection plane
- *tp* distance between left eye and left projection of the given point
- *to* distance between left projection of the given point and given point
- $\alpha$ angle between *tp* and line that is perpendicular to projection plane
- $\beta$ angle between *to* and line that is perpendicular to projection plane

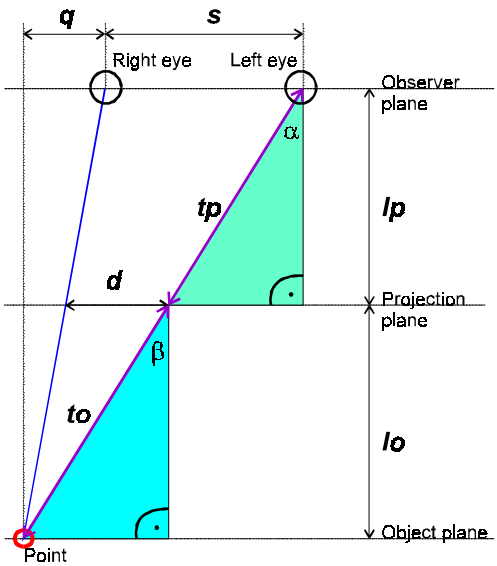


**Figure B Point in 3D space**

The parameters $s$ and $lp$ are dependent on observer's features and position. Angle $\alpha$ is equal to angle $\beta$. Other parameters depend on position of given point.

### 2.1 Difference and point position

Let us have relation between the difference on the projection plane $d$ and the position $lo$ of the object point. From [figure b] we can provide the equation (follows method is easy and is not presented):

$$lo = \frac{d \cdot lp}{s - d}$$

Graphical demonstration of this relation ($s$ = 6cm, $lp$ = 70cm):

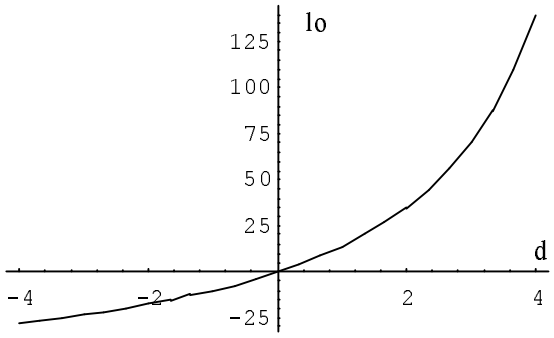


**Figure C Relation between the difference and the position of object points**

Previous relation implies:

1. Depth of object points is dependent on projection plane difference. This dependence is non-linear.
2. If object plane is parallel with projection plane, then all points that lie on object plane have the same difference.

### 2.2 Limitation of 3D space

The main limitation is eye convergence. If eyes focalize on specific object, then eyes' axes inclined with some angle. This angle has limitation. Limitation is maximum of eye angle. The maximum is about 90° [7].

If the angle is between minimum and maximum, then eyes converge. Out of aforesaid interval eyes diverge. The eye axiom says: if eye diverge, then observer do not percept scene correctly [10]. On this account is maximal difference on projection plane equal to $s$, where $s$ is eye spacing [11].

## 3. Constant change of difference

Let us have a scene. We can define projection for left and right eye for all points $b_i$ in scene. Projection $br_i$ for right eye and $bl_i$ for left eye. Horizontal distance of these points is their difference on projection plane $d_i$. All differences must adhere condition from chapter 2.2. If we change output device (actual display device is greater) than can be convergence condition break. We need method for maximal exploitation of scene space with preserve possibility display stereo image on another output device.

Let use only positive parallax - scene objects can lie behind of projection plane only. Than we can use DC method for adaptation stereo images to actual display. If maximal value of difference (on actual display) is greater than condition

of eye convergence allow, we shift left and right images against itself. We change difference of all points by constant. The shift lessen maximal difference value and move part of scene in front of projection plane. We call this shift „Constant change of difference“ - DC.

Constant change of difference (DC) is demonstrated on the next two pictures. New parameters and distances in pictures are:

- *lc* z co-ordinate value change
- *Cd* constant change of difference *d*

[figure d] show dependence of point position on DC. Follow figure show position change of composite object after DC.

We can express change of co-ordinates by next relation:

$$lc = \frac{lp(d + Cd)}{s - (d + Cd)} - lo$$

We must also adhere eye convergence condition in this case (chapter 2.2). There must be adhered relation:

$$|d + Cd| < s$$

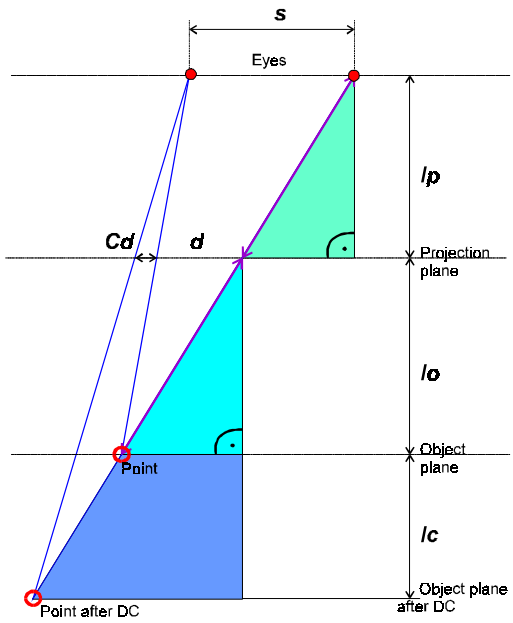


**Figure D Constant change of difference**

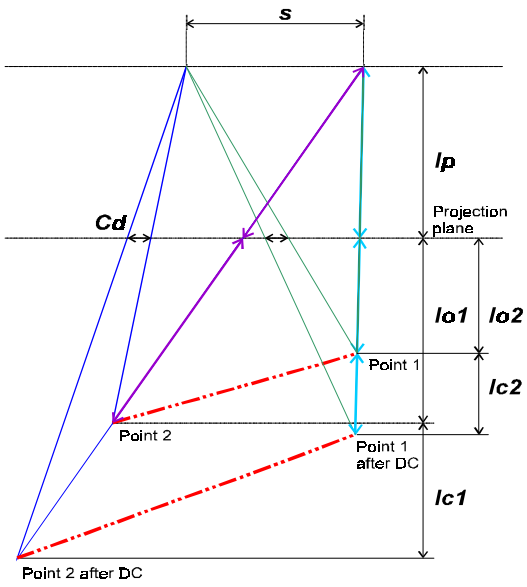


**Figure E Change of object points**

Graph of position changes by constant *Cd* is presented on [figure f]. This graph does not show change of difference correctly. As is shown above, we must adhere maximal difference condition (chapter 2.2). Sum of difference *d* and constant difference *Cd* must be smaller than maximal difference.

By this condition, possibilities of scene generation are limited. If we want a possibility to change scene by DC, we cannot use entire scene space. We have to use only part from maximal difference interval in generation time. Relation between difference and position of object points is showed in chapter 2.1.

## 4. Scene deformation

Scenes deformations arise by some scene generation technique [11,2]. If we use DC process, scenes are deformed too. The reason is non-linear dependence of position of object points on its projection plane difference.

Since the relation between difference and position of object points is non-linear, DC makes non-linear position change. Non-linear change of object points deform scene (object in the scene).

This deformation cannot be removed by other parameters adjustment. Influence of scene deformation on sensation was tested by experiments.

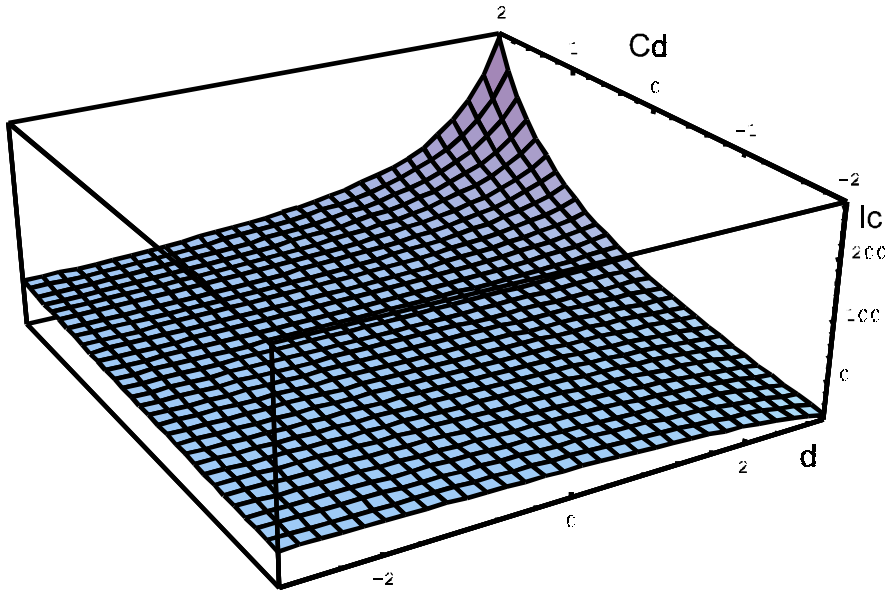


**Figure F Graph of constant change of difference**

## 5. Experiments

It is necessary to make tests with large testing group and many testing pictures to verify of presumptions. The main reason for this is human nonesuch perception. Implication of this is impossibility to use average results. We must use value convenient to tested group generality.

For each problem or set of problems was created series of static pictures. Pictures were generated with changes according to the tested problem. Standard series had 21 pictures. Picture number 10 was generated as a standard stereo image. Experiments had following five goals...

### *5.1 Experiments goals*

For experiment we ask five questions:

1. Must be adhered eye convergence condition?
2. How do we feel depth and its limitation?
3. Is constant change of difference usable?
4. How does scene deformation influences resultant perception?
5. How affect black box resultant perception?

Complete tables of results are stored on server Herakles (vide URL address in title - page 1)

## 5.2 Experimental equipment

We practise experiments on two computers PC with Pentium processor with graphics card P80 (ATI Mach64 chip set) and 3D-Max glasses [4]. 3D-Max glasses works on principle of LCD displays that are shading synchronously with interlaced monitor picture. Even rows belong to left eye image and odd rows belong to right eye image. Glasses are necessary for 3D sensation in our case [9]. Occasion of glasses wear is great disadvantage against autostereoscopic displays [5][8].

In our configuration, monitor works with refresh rate (vertical frequency) 110Hz. It is frequency after switch to interlaced mode. Both glasses displays work with frequency 110Hz, but LCD displays are shaded for one time period. Therefore observer percept it like a frequency that correspond 55Hz or less.

For one computer configuration we made special „black-box“ for shielding ambient light and monitor screen reflections.

## 5.3 Experiment results

### 5.3.1 Eye convergence condition

Experiments showed that it is impossible for human to feel maximal theoretical difference (chapter 2.2). We determine empirical values of maximal difference. The values are in next table.

| Type of picture | Empirical value of maximal difference [cm] |
|---|---|
| Dynamical scenes (animation) | 4 |
| Real scenes (look from window) | 3 |
| Real scene without background | 2,5 |
| Artificial scene | 2 |
| Artificial scene without background | 1,5 |

**Figure G Maximal difference**

We cannot determine how glasses type affect this results. For precise determination we need comparing with another stereoscopy tools (helmet, mirror system and the like).

### 5.3.2 Depth feeling

For depth feeling there was used experiment which showed general cylinder in tested scene. Initially cylinder lays in front of projection plane. In next two steps we move cylinder behind projection plane and next we move projection plane behind cylinder. Last step replaces camera's position.

Experiments show that people feel depth by experience first. In our test, the major part misapprehend third step principle. First two steps were described by all tested subject.

Depth limitation was not registered in any test. We must reflect that tested human did not know how scenes had to look.

### 5.3.3 Constant change of difference

Experiments show usability of constant change of difference for devices, that have similar parameters. DC usability is dependent on width difference and pixel resolution first. Graphs of beginning and end of 3D vision are presented in next

graphs [figure h]. Columns labelled „?-?-**I**“ are related to beginning of pictures series. Columns labelled „?-?-**II**“ are related to end of pictures series. Series have 21 pictures. Picture with number between 0 and 9 have negative DC. Picture from 11 have positive DC. Change to next/previous picture means that picture is shifted using DC. DC main value *Cd* is 5 pixels. One pixel's width is 0,28mm. We shift left and right images by 1,4mm in one step. Maximal difference is changed by 14mm in first and last images.
The other results are commented in chapter 5.3.5. Some graphs are referred there too.

### 5.3.4 Scene deformations affect

No one tested human watched scene deformation. No one of questioned people was able to say what kind of deformation has been displayed.

We can derive rule: Constant change of difference has not major influence to eventual human sensation.

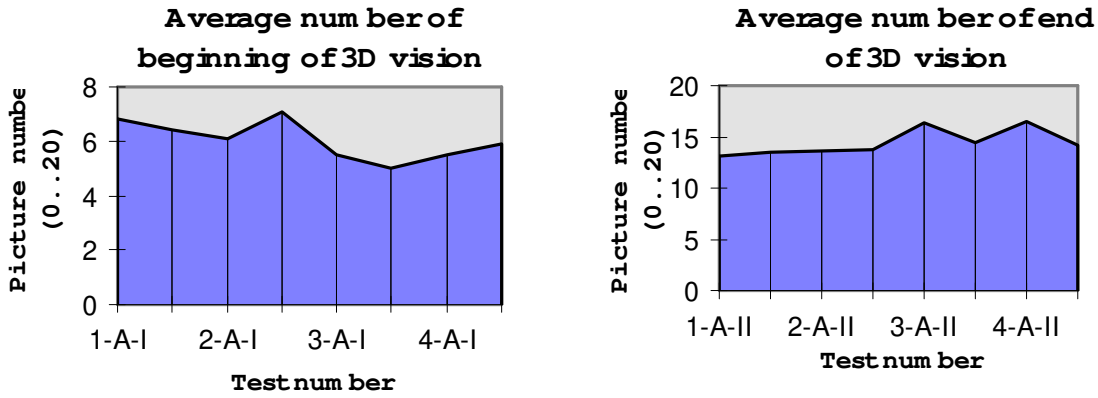


**Figure H Graphs of 3D vision**

### 5.3.5 Black box affect

These tests have surprising results. Generally we expect that better conditions for tested humans means „better“ results. Tests show that our assumption was incorrect. Humans that were tested in black-box perceived less than the others.

The results are shown on [figure i]. Picture number in graph means that observer started/stopped to see scene threedimensionaly. Blue columns signed as „With“ are columns of tested people who used black box.

The results are not fundamental in regard of tested human number. But we do not expect other results with greater tested human group.

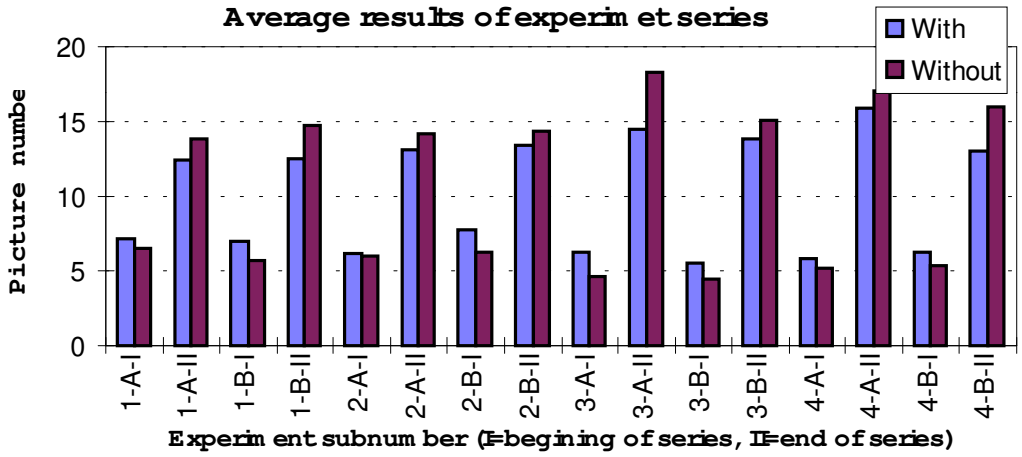


**Figure I Graph of experiment results**

# 6. Conclusion

Experiments show that DC is usable for readjustment 3D scenes to actual conditions. and actual output display. Constant change of difference has limitations. First limitation is maximal difference. Second limitation is reducing of space depth.

## *6.1 What we obtain and what we lose with DC*

**We obtain**

- limited transfer flexibility (between display devices)
- possibility to adjust resultant pictures to:
  - ♦ actual situation (observer distance, display size, pixel size)
  - ♦ light condition, observer condition or observer mood
  - ♦ quality of stereo vision tools

**We lose**

- part of scene space - scene depth
- new scene is deformed

# 7. References

[1] **Watt, A.:** 3D Computer graphics, Addison-Wesley, Reading, 1993

[2] **Woods, A., Docherty, T.:** Image distortions in stereoscopic video systems, Stereoscopic displays and applications IV, Proceeding SPIE vol. 1915, 1993

[3] **Kresl, V.:** Analýza a syntéza stereoskopických obrazů Diploma thesis, University of West Bohemia Plzen, 1991

[4] 3D Max user reference manual, Kasan electronics, 1994

[5] **TEKTRONIX 1990 catalogue:** Stereoscopic 3D color displays, str. 467 - 469

[6] **Vrba, M., Kajuch, L.,** Stereoskopia a stereoskopická fotografia, SVTL Bratislava, 1963

[7] **Gross, M.,** Physiological Aspects of Human Vision and Computer Graphics Eurographics '91, Tutorial Note 3, ISSN 1017-4656

[8] **Lang, S. R., Travis, A. R. L., Castle O. M., Moore, J. R.,** A 2nd generation autostereoscopic 3-D display

[9] **Collender, R. B.,** Methods for Electronic 3D Moving Pictures Without Glasses

In True 3D Imaging Techniques and Display Technologies,
Proceeding SPIE, vol. 761, page 2-22, 1987
[10] Graphics Developers Handbook, chapter 1
http://www.sterographics.com/hb1.htm .. hb5.htm, Stereographics Inc.
[11] **Šefčík, J.,** Systém pro stereoskopické zobrazování
Diploma thesis, University of West Bohemia Plzen, 1996