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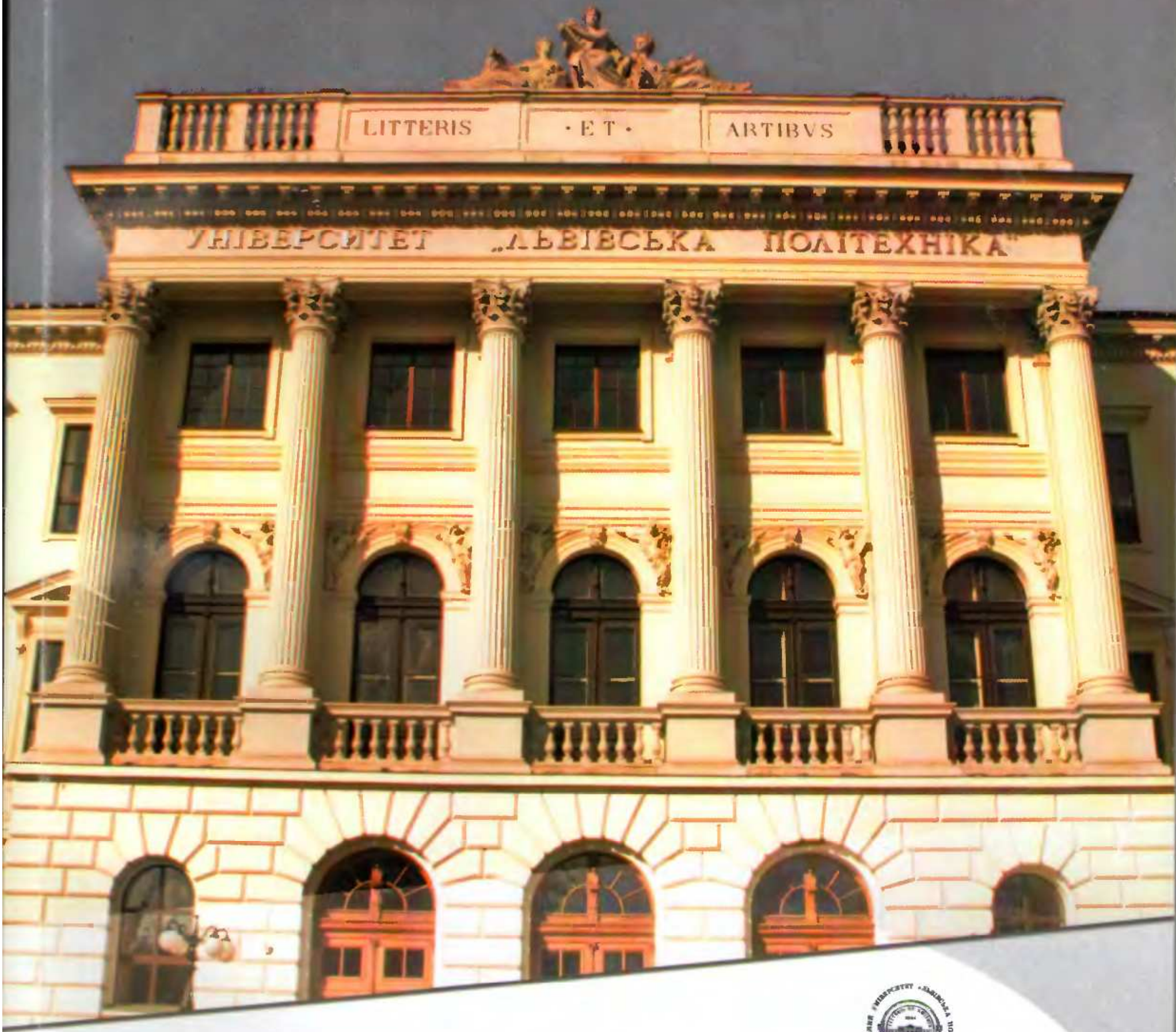

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КОМП'ЮТЕРНІ НАУКИ ТА ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ

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п'ятої Міжнародної науково-технічної конференції
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Modified algorithm of straight line segments generation for 3D displays

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Abstract* – *The article gives an overview of technologies for construction of three-dimensional information display systems, the proposed high speed algorithm of segments generating for three-dimensional display.

Keywords – 3D displays, straight line, segment, voxel, algorithm, increment matrix.

I. Introduction

One of the most efficient means that give us information from different branches of science and technique is the visualization which is based on three-dimensional displays. Such elaborations are widely used in aviation, medicine, TV and cinematography.

The binocular stereoscopy became the most widely used technology [1], which is built using two independent flat images – stereopair, that are perceived independently by left and right eyes. Obtaining of stereoscopic image is possible only if we use additional technological devices: helmets, polarized, colored or active glasses. The main disadvantage of this three-dimensional image obtaining method is discomfort of observer, temporary dysopia and violation of the vestibular apparatus. The necessity of three-dimensional information implementation improvement led to the development of autostereoscopy, which combines the technologies that create illusions dimensional image without additional devices usage. These systems are parallaxial, holographical and dimensional technologies.

The dimensional technologies are based on rotating replacing screens [2], plane-parallel and spherical screens [3-4], static three-dimensional screens that use certain real physical three-dimensional environment where the three-dimensional image of scene is formed. This environment can be formed using gas, glass and other materials.

Both software and hardware means should be developed when we want to build three-dimensional display which is based on dimensional technologies. The base three-dimensional segmentation algorithm for random straight line is described in [5]. The modified three-dimensional graphics primitives (straight line) generation method is proposed. This method increases productivity of algorithm and the main aim of its usage is real-time generation of three-dimensional scenes.

II. Straight line segments generation for 3D displays

The task of straight line segment generation can be formulated in such a way. We suppose that certain part Ω of three-dimensional Euclidean space, which is displayed by our display has the form of three-dimensional parallelepiped $\Omega \in R^3, 0 \le x \le X, 0 \le y \le Y, 0 \le z \le Z$. Let us assume that $X = Y = Z = H$, so Ω is three-dimensional cube.

Also let us suppose that Ω is filled by voxels - atomic elements that are displayed by three-dimensional display. Let us determine the voxel as cube with side equal to one. The centers of adjacent voxels are distanted from each other by unit segment according to coordinate axis. The set of voxels that fill Ω can be represented as three-dimensional array of voxels $V_{i,j,l}$ where i, j, l – indeces that can be equal to $0, 1, \ldots, \mathrm{int}(H)$.

The random straight line segment AB is set in Ω. Let us define voxel V_A as start voxel and voxel V_B as end voxel of rasterizing straight line segment AB. The task of straight line segment rasterizing is to determine the set of voxels that includes V_A and V_B. Also each voxel of this set (except start and end voxels) has only two adjacent voxels and the center of every voxel is at a minimal distance from the segment.

The method of this set determination is proposed in [6] and essence of this method is as follows. It is supposed (for simplicity) that the segment is in the first octant and all of its projections are positive. Start voxel V_0 is set by condition $A \in V_0$. Let us suppose that q-th detected voxels belongs to V_q sequence. It is necessary to determine the next q+1-th voxel from V_{q+1}. Seven voxels-pretendents $V_{q+1(k)}$, $k=1,2,\ldots,7$ that are adjacent to V_q are considered. The direction of adjacent voxels is determined by segments direction vector. The distances between their centers and segment that should be displayed are calculated. The next voxel from sequence V_{q+1} is determined as voxel-pretendent $V_{q+1(k)}$ with minimal distance to straight line. Thus the set of voxels V_q, $q = 0, 1, \ldots N$ is built where N is amount of voxels in rasterized representation of segment and $B \in V_N$.

III. Base algorithm modifications

The productivity of method from [6] can be improved in next way. We know that every chosen voxel will have the increment according to that axis which the segment is most stretched by. The matrix of adjacent **M** for determination of voxels-pretendents is shown in table 1.

TABLE 1

INCREMENT MATRIX FOR VOXELS-PRETENDENTS DETERMINATION

K	X priority				Y priority				Z priority			
	1	2	3	4	1	2	3	4	1	2	3	4
Δ_I	Sx	Sx	Sx	Sz	0	0	Sz	Sz	0	0	Sx	Sx
Δ_J	0	0	Sy	Sy	Sy	Sy	Sy	Sy	0	Sy	0	Sy
Δ_I	0	Sz	0	Sz	0	Sz	0	Sz	Sz	Sz	Sz	Sz

$$Sx=sign(U_X),\ Sy=sign(U_Y),\ Sz=sign(U_Z), \quad (1)$$

where U_X, U_Y, U_Z the components of directing vector **U** of given segment AB, $\mathbf{U}=(B-A)/|B-A|$.

The distance D_k between k-th voxel-pretendent $V_{q+1(k)}$ and given segment is calculated using such formula

$$D_k = | W_k - (W_k - U)U | , \quad (2)$$

where : $W=V_{q+1(k)}-A$.

Analogically to [6], the next voxel V_{q+1} in the set is determined as voxel-pretendent with minimal distance to straight line.

The proposed algorithm which is represented using pseudocode from [7] is shown in figure 1.

As we know that calculated distance is used only for comparison it can be calculated using (2) formula but excluding the operation of the square root.

This proposed modification reduces an amount of tried voxels from 7 to 4 and decreases the time of calculation at least in 1.75 times.

Also the symmetrical three-dimensional rasterizing can be taken into account. It means that only $N/2$ voxels generation is necessary. We should start from A (forward generation) and another part of voxels can be determined as symmetrical reflection of first part relatively to B (backward generation). "Reflected" modification of algorithm gives us an opportunity to reduce twice the running time of algorithm.

IV. Results

The generators work correctness condition (all the rasterizing voxels are "strung" on given segment) requires the maximal distance between the center of found voxel and segment (maximal error) to be less than a half of main diagonal of voxel.

As the side of voxel is equal to one that is why the maximal rasterizing error should be less than 0.866. Also the quality of rasterizing can be estimated by average error.

Start

Input A, B; Determination V_A, V_B;

Calculation U, Sx, Sy, Sz;

Formation M for voxels-pretendents

$q := 0$; $V_0 := V_A$; $V_q := V_0$;

while($V_q \neq V_B$)

  $\min := +\infty$;

  for i:=1 to 4 do

  // formation of voxel-pretendent

  $V_{next} := V_q + M^{<i>}$;

    if($D(V_{next}) < \min$)

    then $\min := D(V_{next})$;

      $V_{q+1} := V_{next}$;

    end if

  next i

  $q := q + 1$

end while

Output V_q for $q = 0,1,...,N$

finish

Pic. 1 - 3D segment generation algorithm

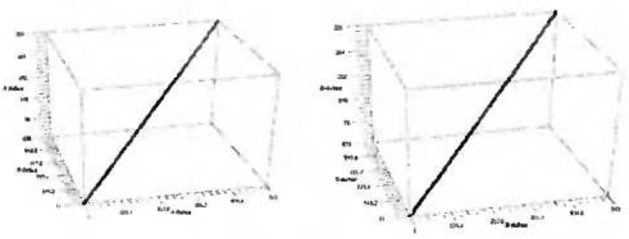
An experimental research of described modifications based on one thousand random segments generation in Ω where H = 1023 (1 megavoxel). Experiments were carried out on DualCore Intel Core i3 530, 2933 MHz (22 x 133) processor and Biostar T5XE CFX-SLI (2 PCI, 2 PCI-E x1, 2 PCI-E x16, 4 DDR3 DIMM) motherboard, Intel Ibex Peak P55, Intel Ironlake chipset, 3063 Mb (DDR3-1333 DDR3 SDRAM) system memory.

Figure 2 shows an example of one segment generation.

TABLE 2

1000 segments generation results

	Avera ge error	MAX error	1000 segments generation time (seconds)	Accele ration relative to the base
Base algorithm	0,396	0,7536	0,391 (2,87)	
1-st modificati on: priorities	0,385	0,7071	0,234 (1,765)	1,67
2-nd modificati on: «mirror»	0,392	0,7071	0,115 (0,656)	3,4



a) b)

Pic. 2 Examples of 3D straight line segment generation

a – priority directions; b - «mirror»
Starting point *A* (0, 10, 15)
End point *B* (543, 677, 326)

Conclusion

Analysis of the experimental results shows us

- all of the algorithms have maximal errors less than 0,866. It means that the work of algorithms is correct.

- 1-st modification of algorithm (priority directions) does not change an error, but time of generation is decreased in 1.67 times;

- 2-nd modification of algorithm («mirror») decreased the generation time in 3.4 times. This fact corresponds to primary estimation.

All of proposed three-dimensional segment rasterizing base algorithm modifications significantly increased the productivity of algorithm (in 3.5 times) but it is not enough for real-time generation of complex scenes. Further research should be directed into the algorithm optimization. The main aim of this optimization is to decrease time consumption using parallel and distributed calculations. For example based on CUDA technology.

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