CREATING 3D MODELS OF OBJECTS BY THEIR STREREOIMAGES FOR VIRTUAL MUSEUMS

Ryabokon D.
International Research and Training Center of Informational Technologies and Systems. Kiev.
e-mail: dima@image.kiev.ua

Abstract

The technology of building 3D-models of objects by their stereoimages is considered. The foundation of this technology is a parallax estimation of the scene depth.

Introduction

A preservation and proclaiming of cultural heritage is very important today for present-day society. Due to development of computer techniques and multimedia possibilities we can store cultural wealth not only in common way, but in other – electronic one. In last years a lot of virtual museums were created, where exhibits are computer files, and visitors are internet users. Creation of such museums enables to get an information about famous human achievements. Such museums help to obtain an education and facilitate for cultural development of people.

In this work a creation of virtual 3D models of sculptures, buildings, architectural erections is described. An approach to be discussed is based on optimal labeling problem solving. This approach is used in various task in pattern recognition. A construction of 3D objects and environmental scenes is based on one stereopair processing. Cases of calibrated and non-calibrated images will be considered. A recovery of spatial configuration of objects in unknown cameras position case will be based on parallax estimation.

There are other techniques of 3D model recovery by shooting results like, for example, laser distance measuring or coded rays lighting. But the presented technology is mush cheaper in realization and does not depend on object sizes and natural lighting of scene during shooting. Distinctly from other, this technology permits to get a result in most natural way using a mechanism of human stereovision.

At the begging of work a principle of stereovision task solving is considered. Further an algorithm of stereoreconstruction and technology of 3D models recovery are described. Spatial models of objects will attract your attention at the last part.

1. The principle of 3D model creation

At fig. 1 stereopair of cube is presented. We will call a **parallax** of point that belongs to cube such value that equals to a difference of horizontal coordinates of point projection into left and right image. For example, point 1 has different horizontal coordinates in left and right images, but point 2 has the same horizontal coordinates and its parallax is equal to zero. Namely parallax of points at images gives information about their distance or depth.

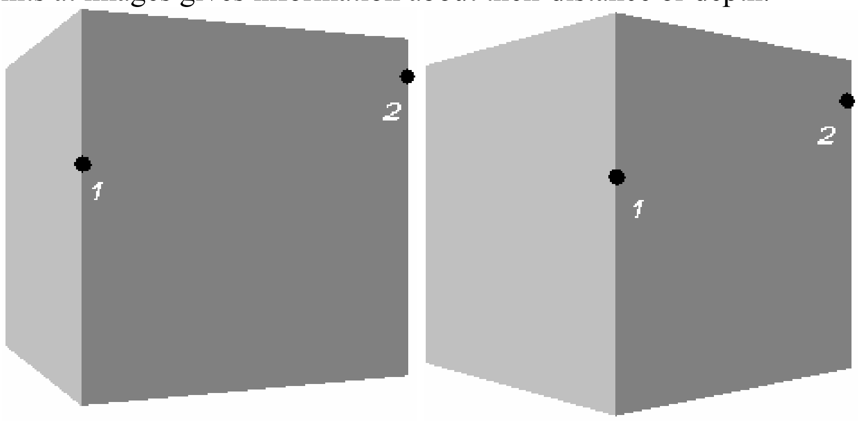

Fig. 1

If we find for every point at left image a corresponding point at right image than we can detect relative distances of image points.

Let T - be **field of view**, that defines as $T = \{(j,i) \mid 0 \le j < DY, 0 \le i < DX\}$, where

- DY – vertical size,
- DX – horizontal size.

Under **image** F we will consider a function, that for every element of field of view defines a triple of numbers

$$F : T \to \{(r,g,b) \mid 0 \le r \le 255, 0 \le g \le 255, 0 \le b \le 255\}.$$

We will call an **ideal stereopair** such two images, where every element (j,i) of first image and corresponding to it element (l,k) of second image are located in the same row, simlpy their vertical coordinates are the same.

Let **labeling** G be such function

$$G:\ T \times T \to \{0,1\};$$

$G(j,i,l,k) = 1$, if element (j,i) of left image corresponds to element (l,k) of right image;
$G(j,i,l,k) = 0$ otherwise.

The labeling must define for every element of let image at least one corresponding element of right image,

$$\forall i, \forall j \sum_{l,k} G(j,i,l,k) > 0 .$$

Let **pairs corresponding quality function** be such function, that for every pair of left and right image elements defines a non-negative number – the measure of likeness,

$$q : T \times T \to [0,65535].$$

The **quality of reconstructed relief** Q will be value

$$Q = \sum_{j,i,l,k|G(j,i,l,k)=1} q(j,i,l,k). \qquad (1)$$

The **problem of relief reconstruction** consist in detection of labeling G , that return a minimal value for function Q under following restriction.

The **horizontal continuity** restriction:

$$\forall i, \forall j, \forall k, \forall l (G(j,i,l,k) = 1) \Rightarrow (\exists l_1, \exists l_2, \exists l_3 \mid (|l_1 - l| \le L) \& (|l_2 - l| \le L) \& (|l_3 - l| \le L) \& \\ \& (G(j,i+1,l_1,k) + G(j,i,l_2,k+1) + G(j,i+1,l_3,k+1) > 0)). \qquad (2)$$

Heir L – certain fixed value. It means a degree of images non-calibration. When it is zerro($L = 0$), the labeling must be such, that set of corresponding points is in some sence a continuous consecution in rows with the same indices. Under positive L corresponding points may be located in different rows of left and right image.

The continuity of labeling means the next. If for some pair of image elements (j,i) (l,k) holding an equality $G(j,i,l,k) = 1$, then must exist a pair of elements (j_1,i_1) (l_1,k_1), that fulfill equality $G(j_1,i_1,l_1,k_1) = 1$, besides elements (j,i), (j_1,i_1), (l,k), (l_1,k_1) must be horizontal neighbors in left and right images accordingly.

Under other restriction – **vertical continuity** we must take into account dependence of labeling at neighbor rows. Additional restriction to the labeling continuity looks like:

$$\forall i, \forall j, \forall k, \forall l (G(j,i,l,k) = 1) \Rightarrow (\exists l_1, \exists l_2, \exists l_3 \mid (|l_1 - l| \le L) \& (|l_2 - l| \le L) \& (|l_3 - l| \le L) \& \\ \& (G(j+1,i,l_1,k-1) + G(j+1,i,l_2,k) + G(j,i+1,l_3,k+1) > 0)). \qquad (3)$$

The number L is degree of images non-calibration so far. Wen it is zerro($L = 0$), the labeling must be such, that set of corresponding points is in some sence a continuous consecution in columns.

When there are both horizontal and vertical continuity restrictions, it is impossible to find a labeling in every row independently. Solving of this problem requires a **two-dimensional optimization algorithm**.

Lets look at the example of corresponding point searching in one dimensional problem formulation for some row of left image. We will assume that all possible corresponding points in right image are located in a same row.

At fig. 2 is given an example for images that hold 8 pixels in a row. Cells in this figure mean 8 pixels of left image row. Points(**labels**) in every cell mean 8 pixels of right image row.

A selection of certain label in some cell means juxtaposition of pixels pair – one in left image and one in right image. For neighbor cells there is a restriction to their labeling. Choosing labels in neighbor cells must be connected by edge.

Every point in every cell holds a quality of pixel corresponding. This is a value that describe a measure of pair of pixel to be resemble.

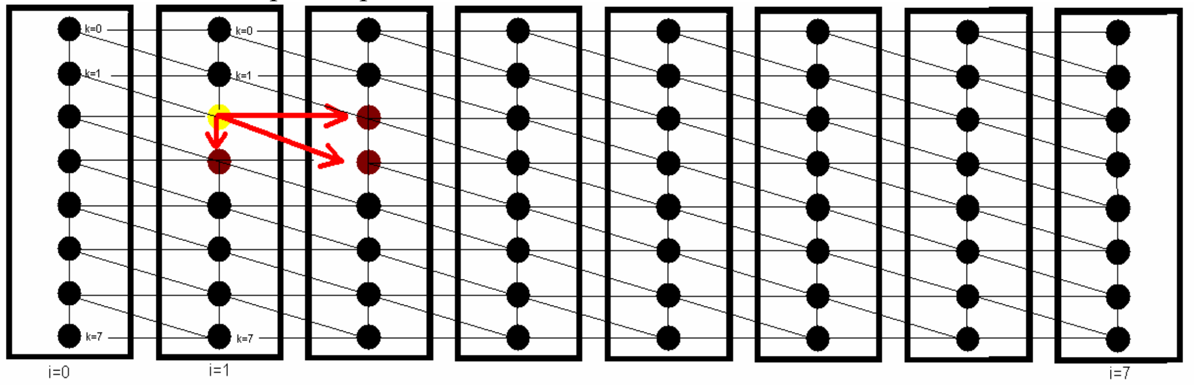

Fig. 2

We need to find such labeling, that maximize sum of correspondence qualities under restriction of horizontal continuity. In example at fig. 2 cell i=1 hold label к=2. Such situation restrict further labeling in cell i=2, where possible labels can be now к=2 or к=3.

A solution of optimization problem (1) is fulfilled by **dynamic programming**.

2. The technology of 3D scenes reconstruction

2.1 Cameras relative position

Relative position of cameras plays important role for creation a good stereoimage of 3D scene for its further spatial reconstruction. A distance between cameras(**a base**) must take into account object properties.

The big base enables to increase the precision of reconstruction, but when the base is too big such situation may occurs, where points of object are observed only in one image. These monoobserved points cannot be correctly reconstructed.

Thus, to locate cameras in optimal position we must install them one from another as far as possible, but their images must not contain monoobserved points.

2.2 Image preparation for processing

Before the stereoprocessing we need to perform some preliminary operation.

First of all, we need to ensure, that all the points of 3D scene are projected into both images. In other case all the monoobserved points must be painted by black color.

The second step – we must delete some points in pictures, that do not belong to the object, becouse most of them are also monoobserved.

And the last third step – make sure, that there are no catchlights in images. Shiny objects cannot be good reconstructed due they hold information not about the object but about some light source.

2.3 Building of 3D model by parallax estimation

After stereoimages are processed, for every element of left image there is a corresponding element in right image. A difference of horizontal coordinates of corresponding pixels (the parallax) gives a distance to the points. When there is no information about cameras relative positions the stereoreconstruction can be done up to some scale transformations. But if the distance between cameras is mush lower than distance between cameras and object, the spatial coordinates can be calculated by following expressions:

Horizontal coordinate	=	index of pixel in the left image
Vertical coordinate	=	index of pixel in the left image
Distance coordinate	=	the parallax if left image pixel

For 3D visualization of the object important are it's relative coordinates, but not absolute. Thus sometimes is reasonable to change scale parameters of a model with a help of operator.

3. Stereoreconstruction results

Fig. 3

Fig. 4

Fig. 5

An example of stereopair is presented at fig.3, this is an image of a temple. At fig. 4 there is a prepared for processing image. At fig. 5 there are reconstructed 3D models that are generated from different points of view.

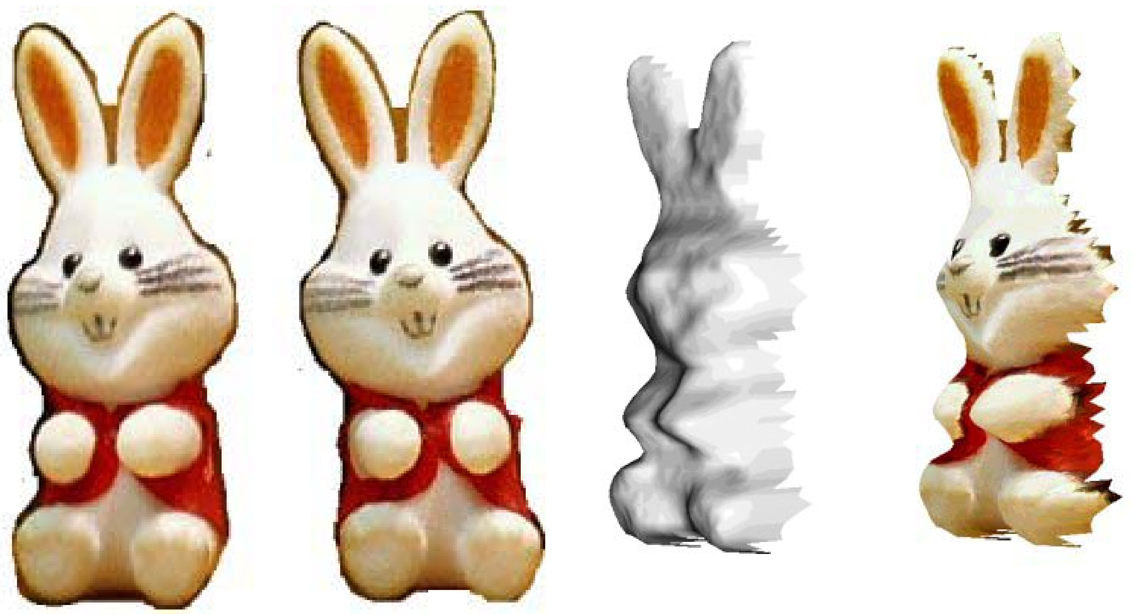

Fig. 6

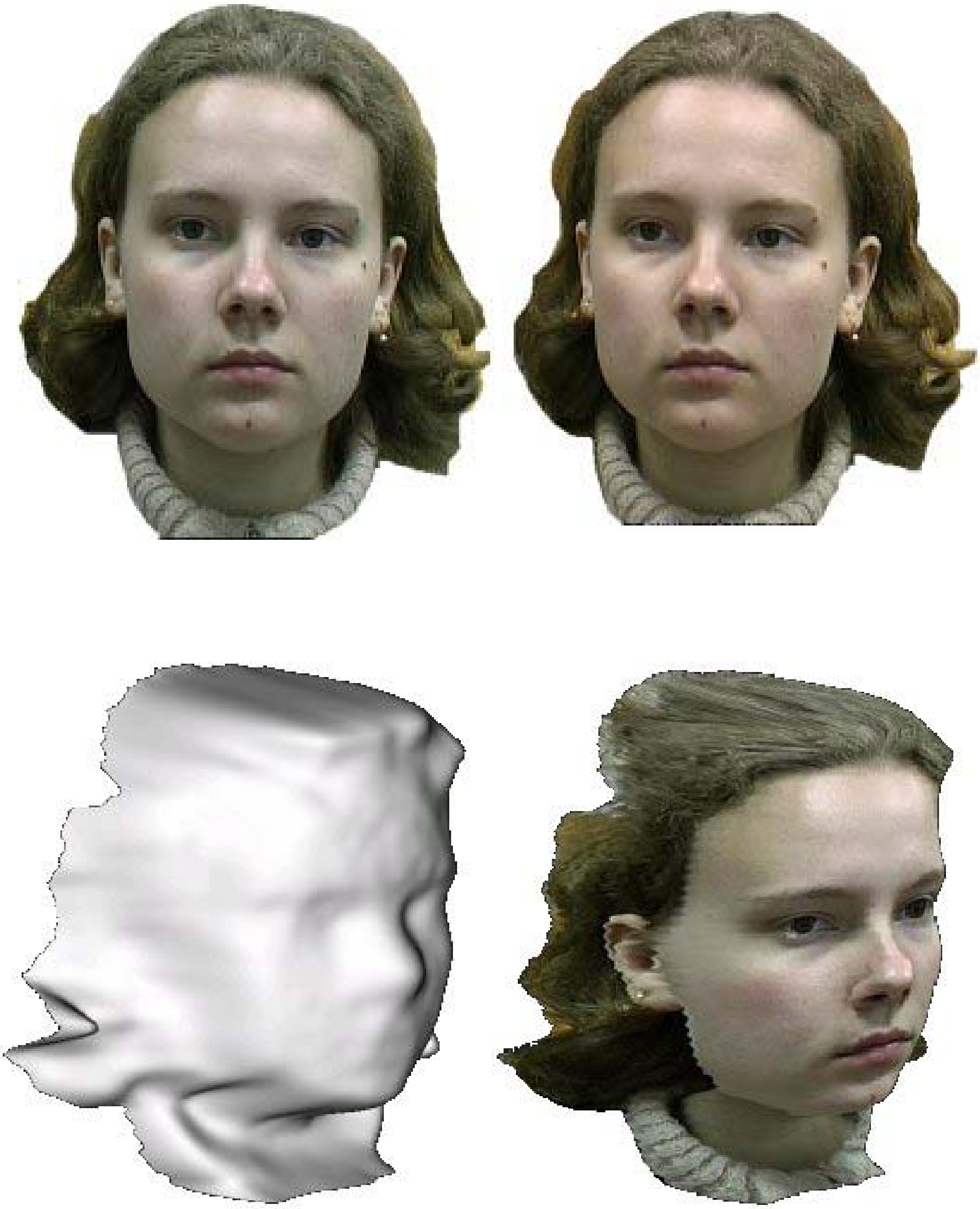

Fig. 7

At fig. 6 a 3D model of child toy is presented. The picture contains input data(stereopair) and reconstruction result(textures and non-textured models).

At fig. 7 an example of reconstructed human face is presented. The result contains textured and non-textured model.

Conclusions

In this work a technology of creation of 3D models by stereoimages is presented. A hardware for realization of presented technology is rather simple. All we need are two videocameras and personal computer. A time of 3D model creation is about 10 minutes. A memory required for data storage is less than 1 Mb.

For visualization of reconstructed models enough to have a personal computer with standard software of 3D graphic support. The presented technology can be used for of virtual museums, where spatial models of sculptures, buildings, other objects are stored.

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References

[1]G. Gimmelfarb. Symmetrical bi- and trinocular vision: connection of theoretical bases and heuristic solutions" Theoretical and applied tasks of pattern recognition. Kiev 1995.(In Russian).

[2] R. Sara. “The Class of Stable Matching for Computation Stereo.”

[3] R. Hartley. “In defence of the 8-point algorithm.” In InternationalConference on Computer Vision, pages 1064–1070, 1995.

[4] T. Werner. “Practice of 3D Reconstruction from Multiple Uncalibrated Unorganized Images. Czech Pattern Recognition Workshop 2000.”

[5] G. Gimmelfarb. "Symmetrical approach to the task of automatic stereoscopic measures in photometry". Kiev, Cybernetics 1979.