
"From the wisdom of the ages
to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA
Organised by:
CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors:
Trimble
esri


"From the wisdom of the ages
to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA
Generation of Spatial Information by Digital Photogrammetry Technique Using Objects' Constraints
Author: Borislav D. Marinov
UACEG – Sofia
BULGARIA
CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors:
Trimble
esri

ABSTRACT (1)

The aim of the research is to analyse the possibilities for creation of Digital Object Model using set of multiple images. The problems of image matching and model creation in situation of invisibility of part of the object or terrain in vicinity of artificial objects in urban scenes are formulated and overcame. The influence of shadows is taken into account too.

A complex model of buildings and surrounding terrain is suggested that is suitable for mapping, orthorectification and 3D modelling. The created model consists of DEM of the terrain and Spatial Digital Models of artificial objects on the territory. The suggested model has hierarchical structure and describes main part of buildings as walls, roofs and subparts like balconies, staircases and others.

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

ABSTRACT (2)

The constraints defined by the features of terrain surface and man-made objects are defined and used for proper forming and verification of the complex spatial model. They are applied to separate the images into sub-parts, corresponding to terrain and artificial objects like buildings and civil engineering constructions.

The image analyses technique is applied for image understanding based on currently defined complex model. Image matching and correlation technique are used for automatic extraction the model of terrain and artificial objects taking into account objects' constraints.

The suggested method enlarges the possibilities for DSM generation and orthorectification with systems for digital photogrammetry for urban areas. The suggested method could be used in procedures for archiving and dynamic visualization of architectural objects too.

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

INTRODUCTION (1)

- **Main approaches for model creation**
  - Laser scanning
  - Digital image matching and correlation techniques
- **Constraints for digital image description**
  - Epipolar geometry constraints
  - Geometrical constraints
  - Semantic constraints
  - Line constraints
  - Constraints for Robust matching

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

INTRODUCTION (2)

- **Fields of application**
  - DEM/DSM generation
  - Roofs reconstruction
  - Buildings outlines
  - Road reconstruction
  - Surface reconstruction
  - Facades reconstruction

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

STRUCTURE OF OBJECT MODEL

Image description

•Different topological type of arcs by usage of different subscript index

k - main external arc of leading contour of last cluster
m - main external arc of leading contour of non-last isolated cluster
c - main arc of external contour of non-leading contour
b - non-main outside contour arc of isolated cluster
i - internal arc between two different contour from equal level
s - non-main arc of contours from different levels
d - main arc of internal contour, oriented in direction to point the contour of upper level
o - single or last isolated contour
q non-last isolated contour from set of isolated contours or area clusters

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Topological or height types of arcs

1. Non connected elements:
   se - empty initial area;
2. First order connected elements:
   sq-initial outside area, containing sub areas (isolated areas or area clusters)
2. Second order connected elements (one pointer to inside cluster list and one implied connection to own contour):
   ao - separate (or last) isolated area ;
3. Third order connected elements containing two pointers to the next arcs of the own and adjacent contour and one pointer to main arc of the own contour, or to the main arc the upper level contour for element of type d

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

Formulation of Picture grammar for Image description based on Object model

❖Special activation state of the arc

ρ - generation of isolated contour state

Ω - generation state of the external contour arc

μ - new external arc with moving tail end

Σ - last arc isolated by the moving external arc (with arc state μ)

Ψ - new external arc in scanning state the isolated from it arcs

Φ - scanning the arcs belonging to the contour, isolated from the last generated external arc (state type ψ)

χ - generation of hidden contours

Θ - scanning for generation of the terminal symbols

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Producing rules (1)

$S_0(\,) \to s_E(\,)$ $\quad S_0(\,) \to S_Q A_O(11)(02)$

$A_O(1,2) \to R_O(1,2)$

$A_O(1,2) \to A_{O\rho}(1,2)$ $\quad R_O(1,2) \to R_{O\rho}(1,2)$

$A_O(1,2) \to A_Q A_O(21)(10,30,02)$

$A_Q(1,2,3) \to A_{Q\rho}(1,2,3)$

$A_Q(1,2,3) \to R_{Q\rho}(1,2,3)$

Initial arcs

$Y_{O\rho}(1,2) \to Y_O A_O(21)(10,02)$

$Y_{Q\rho}(1,2,3) \to Y_Q A_O(3,1)(10,20,02)$

$W_{K\rho}(1,2,3,4) \to W_{KA} A_O(41;30)(10,20,02)$

$W_{D\rho}(1,2,3,4) \to W_{DA} A_O(41;30)(10,20,02)$

$W_{M\rho}(1,2,3,4,5) \to W_{MA} A_O(51;30)(10,20,30,40,02)$

Internal contour arcs

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

Producing rules (2)

$A_0(1,2) \rightarrow Y_I A_K Y_C(011,102,220;330,003)(040,004)$

$A_Q(1,2,3) \rightarrow Y_I A_M Y_C(011,102,220;330,003)(040,004,050)$

Generation of adjacent loops

$R_0(1,2) \rightarrow R_I R_K Y_C(011,102,220;330,003)(040,004)$

$R_Q(1,2,3) \rightarrow R_I R_M Y_C(011,102,220;330,003)(040,004,050)$

$A_O(1,2) \rightarrow A_K Y_C(12,21;30,03)(40,04)$

$A_Q(1,2) \rightarrow A_M Y_C(12,21;30,03)(40,04,50)$

External attached loops

$R_O(1,2) \rightarrow R_K Y_C(12,21;30,03)(40,04)$

$R_Q(1,2) \rightarrow R_M Y_C(12,21;30,03)(40,04,50)$

$A_O(1,2) \rightarrow A_D Y_K(11,22;30,03)(40,04)$

$A_Q(1,2) \rightarrow A_D Y_M(11,22;30,03)(40,04,50)$

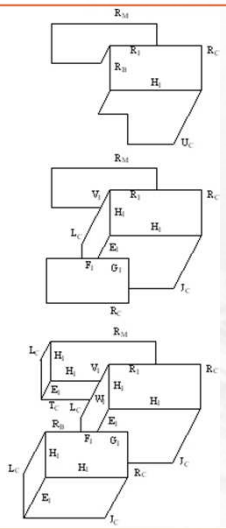
Internal self-closed loops

$R_O(1,2) \rightarrow R_D Y_C(11,22;30,03)(40,04)$

$R_Q(1,2) \rightarrow R_D Y_M(11,22;30,03)(40,04,50)$

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Producing the image of simple set of buildings



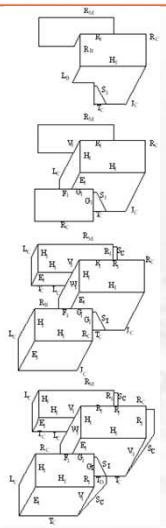
Initial steps of process of forming of image start from isolated area RQ after applying the following rules:
- generation of attached roof;
- generation of wall from roof.

Second image is produced after applying the following rules:
- generation of roof covering the wall;
- generation of wall, staring from covering roof.

The third image is generating after applying the following rules:
-generation of enclosing wall, staring from roof:
- generation of adjacent wall;
- generation of enclosing walls;
- generation of adjacent wall.

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

Generation of image parts in situation of hiding buildings and presence of shadows



Initial steps of image model creation:
- generating of attached roofs, wall from roof, shadow over the wall.

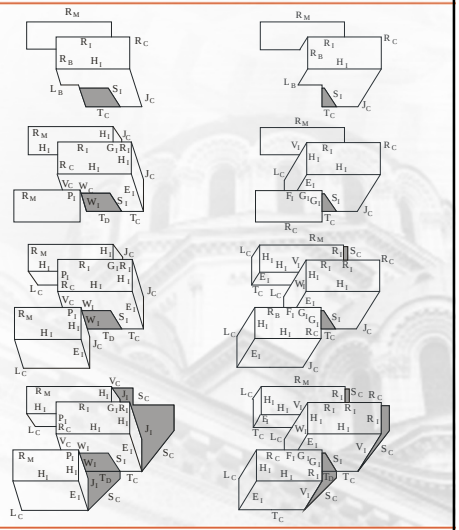
Second step of image generation:
- generating the roof, covering the wall; the wall, starting from covering roof.

Third step of image generation:
- generating the enclosed wall, starting from wall; the adjacent wall; the wall, starting from roof; the shadow, starting from roof.

Fourth step of image generation:
- generating the shadow ,starting from roof; the shadow, starting from wall;
- sliding and converting the arcs of wall; the arcs of roof.

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Producing the images of set of buildings in stereo pair



CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

USAGE OF GEOMETRIC CONSTRAINTS FOR ANALYSES OF VISIBILITY

Semantic approach for analyses the object visibility

$N(...)$	- non terminal symbol
$a,b,c,d...$	- lower case symbols denote faces
$A,B,C,D,...$	- upper case symbols denote edges
$\leftrightarrow$	- means concatenation of stereo pair
A^L, C^R	- mark modification for left and right image
abc^V	- surfaces of convex object
abc^C	- surfaces of concave object

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

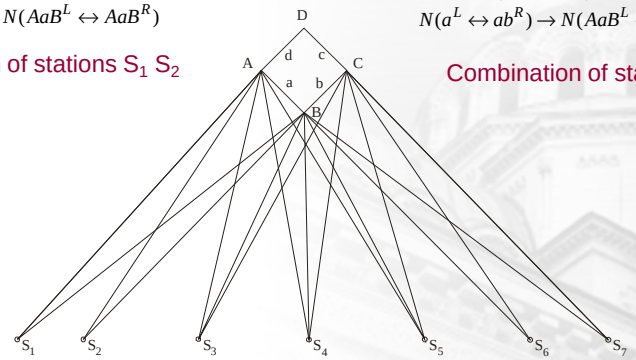
Visibility of objects faces depending on horizontal position

$ab^V \rightarrow N(a^L \leftrightarrow a^R)$
$N(a^L \leftrightarrow a^R) \rightarrow N(AaB^L \leftrightarrow AaB^R)$

Combination of stations S_1 S_2

$ab^V \rightarrow N(a^L \leftrightarrow ab^R)$
$N(a^L \leftrightarrow ab^R) \rightarrow N(AaB^L \leftrightarrow AaBbC^R)$

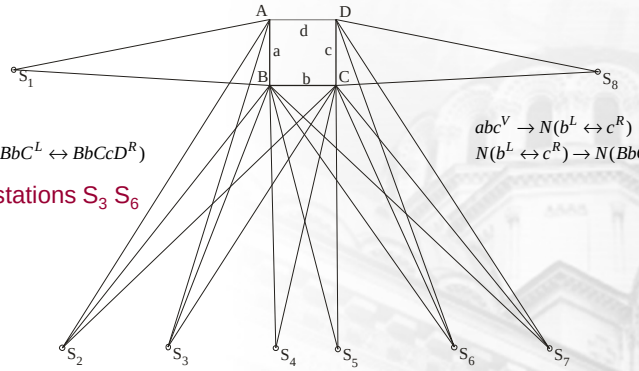
Combination of stations S_2 S_4



Rectangular object with rotated surrounding faces

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

Normally oriented object in front of central camera station



$abc^V \rightarrow N(ab^L \leftrightarrow bc^R)$
$N(ab^L \leftrightarrow bc^R) \rightarrow N(AaBbC^L \leftrightarrow BbCcD^R)$

Combination of stations S_3 S_6

$abc^V \rightarrow N(b^L \leftrightarrow c^R)$
$N(b^L \leftrightarrow c^R) \rightarrow N(BbC^L \leftrightarrow CcD^R)$

$N(b^L \leftrightarrow bc^R) \rightarrow N(BbC^L \leftrightarrow BbCcD^R)$
$N(bc^L \leftrightarrow bc^R) \rightarrow N(BbCcD^L \leftrightarrow BbCcD^R)$
$N(bc^L \leftrightarrow c^R) \rightarrow N(BbCcD^L \leftrightarrow CcD^R)$

Combination of stations S_5 S_6 S_8

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

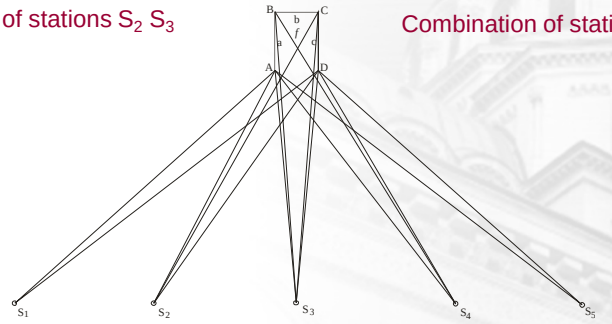
Concave rectangular object

$abc^C \rightarrow N(\tilde{a}bc^L \leftrightarrow abc^R)$
$N(\tilde{a}bc^L \leftrightarrow abc^R) \rightarrow N(AbCcD^L \leftrightarrow AaBbCcD^R)$

Combination of stations S_2 S_3

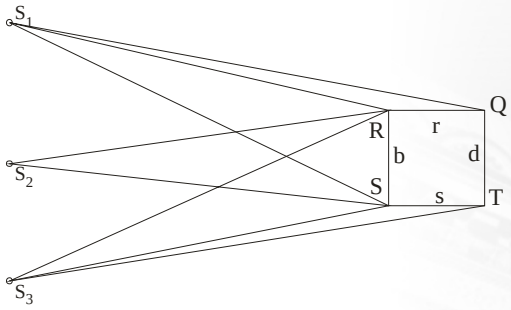
$abc^C \rightarrow N(abc^L \leftrightarrow ab\tilde{c}^R)$
$N(abc^L \leftrightarrow ab\tilde{c}^R) \rightarrow N(AaBbCcD^L \leftrightarrow AaBbD^R)$

Combination of stations S_3 S_4



CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

Visibility of objects faces depending on vertical position



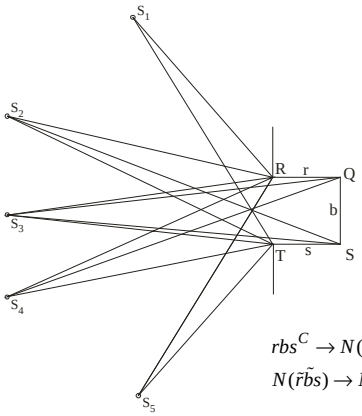
$rbs^V \rightarrow N(rb)$
$N(rb) \rightarrow N(QrRbS)$ Station S_1

$rbs^V \rightarrow N(b)$
$N(b) \rightarrow N(RbS)$ Station S_2

$rbs^V \rightarrow N(bs)$
$N(bs) \rightarrow N(RbSsT)$ Station S_3

Vertical disposition that is treated to convex object

Vertical disposition that is treated to concave object



$rbs^C \rightarrow N(rbs)$
$N(rbs) \rightarrow N(RrQbSsT)$ Station S_3

$rbs^C \rightarrow N(\tilde{r}bs)$
$N(\tilde{r}bs) \rightarrow N(RbSsT)$ Station S_2

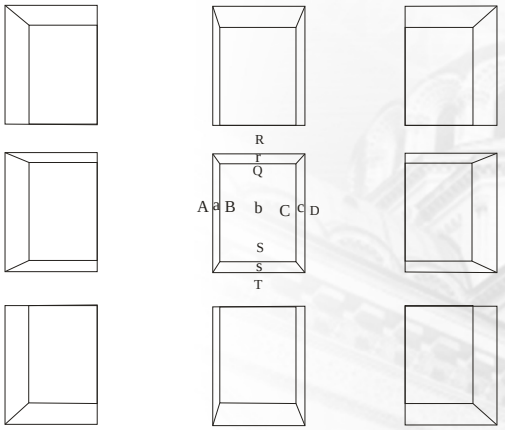
$rbs^C \rightarrow N(rb\tilde{s})$
$N(rb\tilde{s}) \rightarrow N(RrQbT)$ Station S_4

$rbs^C \rightarrow N(\tilde{r}b\tilde{s})$
$N(\tilde{r}b\tilde{s}) \rightarrow N(RsT)$ highest

$rbs^C \rightarrow N(\tilde{r}b\tilde{s})$
$N(\tilde{r}b\tilde{s}) \rightarrow N(RrT)$ lowest

Stations S_1 or S_5

Visibility of the edges in the frontal facade



"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

APPLICATION OF VISIBILITY ANALYSES TO DIGITAL ORTHO RECTIFICATION

- **Generation of complex vector model containing the sub-parts**
  - analyses of hidden parts of buildings' facades
  - analyses or the hidden parts of terrain from set of buildings
- **Creation of mosaic from orthoimages**
  - corresponding visible parts of object from set of close-range images
  - mosaic of visible parts of objects and terrain from set of aerial images

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

Orthorectification of facades

The advantage of suggested complex model is the possibility to produce the correct model in cases of hiding the part of the object by other sub-objects

Frontal oblique image of the entrance of Popular theatre "Ivan Vazov"

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Producing the orthorectified images without front objects

Rectified left image with excluded front objects

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Rectified right image with excluded front objects

CHAMBER OF GRADUATED SURVEYORS

Platinum Sponsors: Trimble. esri

"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Mosaicing the visible parts from different images

Rectified mosaic of front entrance facade without front columns

CHAMBER OF GRADUATED SURVEYORS

Platinum Sponsors: Trimble. esri

Application to Orthophoto mosaic of Urban area

Generation of 3D Object model

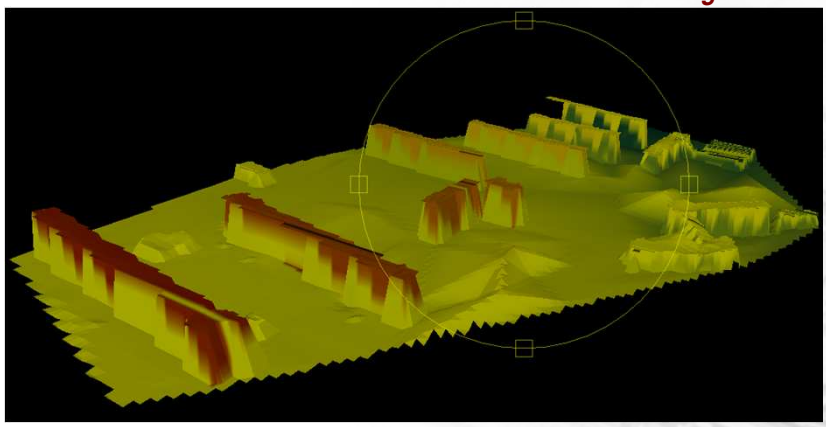
The 3D object model of terrain consists of horizontal and vertical surfaces. The Digital Elevation Model (DEM) for orthophoto generation contains the planar or curved surfaces with different elevation. They could be formulated as terrain, shelters, balconies, roofs.

Parameters for generation of surfaces are defined as type of interpolation surface. The terrain type is formulated as lowland, hilly, low mountain, high mountain.

In fully automated system it is possible to estimate the type of surface as result of analyses of surface curvature or to be defined from operator. The vertical disposition of every surface is based on the calculation the average height of corresponding surface. The attribute characteristic of every surface is height index of surface. As final results the surfaces are disposed in staircase manner.

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

3D visualization of DSM of terrain with roofs of buildings



Model of buildings' roofs created separately on the base of structural roofs' model
Data fusion of DEM of terrain and models of roofs is presented

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Continuous DEM of terrain with roofs of buildings presented by smoothed contours

CHAMBER OF GRADUATED SURVEYORS

Platinum Sponsors: Trimble. esri

"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Outlines of buildings' foundations

CHAMBER OF GRADUATED SURVEYORS

Platinum Sponsors: Trimble. esri

"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Orthorectified image of terrain with holes of building foundations

CHAMBER OF GRADUATED SURVEYORS

Platinum Sponsors: Trimble. esri

"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Outlines of buildings' roofs

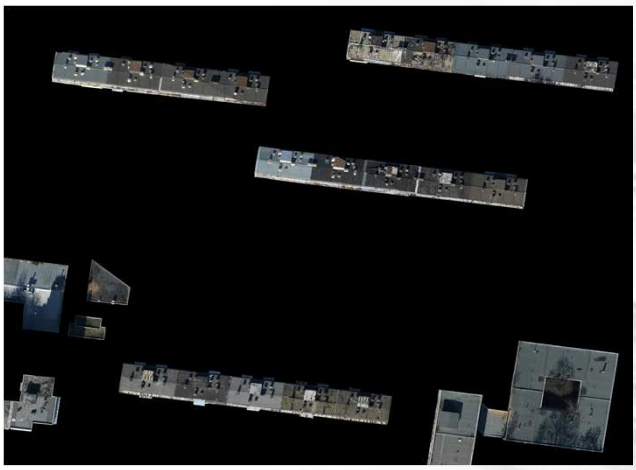
CHAMBER OF GRADUATED SURVEYORS

Platinum Sponsors: Trimble. esri

"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Orthorectified image of set of building roofs



CHAMBER OF GRADUATED SURVEYORS

Platinum Sponsors: Trimble. esri

"From the wisdom of the ages to the challenges of modern world"

FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

Mosaic of orthoimages produced from suitable parts of adjacent images

CHAMBER OF GRADUATED SURVEYORS

Platinum Sponsors: Trimble. esri

DISCUSSIONS AND CONCLUSIONS (1)

Introduced picture grammar is suitable for processing of stereo images of complicated buildings in urban areas in cases when buildings are too close to hide each other

The substantial advantage of proposed model is the possibility for simultaneous analysis of two images of stereo pair, taking into account the projections of building in two images

Improving the reliability and accuracy of obtained information.

Development of picture grammars for generation of stereo images has importance for solving the 3D model generation and for automatic recognition of objects in stereo images in process of image analysis, where usage of semantic analysis of their description is applied

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

DISCUSSIONS AND CONCLUSIONS (2)

On the basis of node analyses the complex lines are excluded.

The subset of parallel line is used for matching the more reliable edges

The problems of invisible faces is solved on the basis of formal grammar rules

Projective relations are introduced for combinations of faces where it is no possible to solve matching task

If some object could not be reconstructed the projective equatons are used to find more reliable matching

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri

DISCUSSIONS AND CONCLUSIONS (3)

The suggested method for description of 3-D spatial data information is suitable for solving the task for visibility analyses in GIS and for orthophoto production in Digital Photogrammetry. The main problems are level of complexity of the model, the structural extension of model for invisible surfaces and lines for which the virtual lines are produced to ensure the concordance of model. The computing efficiency for generation of orthoimage depends on additional information for consisting parts of objects

The multi level approach for mosaicing of sub-parts of images is introduced to improve the quality of orthorectification

The suggested method enlarges the possibilities for DEM generation and orthorectification in systems for digital photogrammetry for urban areas. The produced orthophoto is more accurate and adequate of the objects that are presented on it. The suggested method could be used in procedures for archiving and dynamic visualization of architectural objects

"From the wisdom of the ages to the challenges of modern world"
FIG WORKING WEEK 2015
17–21 MAY SOFIA BULGARIA

THANKS FOR YOUR ATTENTION !

БЛАГОДАРЯ ВИ ЗА ВНИМАНИЕТО !

CHAMBER OF GRADUATED SURVEYORS
Platinum Sponsors: Trimble. esri