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Video-based Indoor Exploration with Autonomous and Mobile Robots

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Dedicated to my parents

Contents

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Symbols and Abbreviations

A	Region
AO	Association operators
AW	Window
B	Blue channel
BC_j	Plane image contour j
BE	Base elements
C	CCD array
CE	Complex elements
CO	Contour
D	Projection matrix
E	Essential matrix
$\mathrm{E}[x]$	Expected value for random vector x
$\mathrm{E}(A)$	Erosion of a pixel set A
F	Focal point
$\mathrm{F}\{\mathrm{f}(\mathrm{x})\}$	Fourier transform for function $\mathrm{f}(\mathrm{x})$
G	Green channel
$\mathrm{G}(f_x)$	Fourier transform for Gabor filter
H	The horizontal direction vector of the $Fz_{\mathrm{C}}HL$ projection equation
$H(t)$	Observation matrix
I	Image
J	Jacobi matrix
K	Matrix
L_i	The Jacobi matrix of the observation equation at point in time i
L	Left-hand side
L	The vertical direction vector of the $Fz_{\mathrm{C}}HL$ projection equation
M	Rotation matrix
N	Unit matrix
O	Origin
P	Covariance matrix
P_k^+, P_{k+1}^-	The update and prediction of the covariance matrix, respectively
Q	Index set
Q_i	The covariance matrix of process noise at point in time i

R	Red channel
R	Right-hand side
S	Structuring element
SE	Set
T	Rotation
$\mathrm{Tf}(\mathrm{x})$	Vectorial transformation function
U	Disparity
U	Color channel
V	Color channel
W	Skew symmetric matrix
$\mathrm{W}(A)$	Function that calculates the width of a region A
X	Point in three-dimensional space
Y	Brightness
Z	Diagonal matrix
Z_i	Motion matrix at point in time i
a	Length
ao	Association operator
b	Focal length
c	Constant
d	Distance
d_i	The binormal vector of a polygon with index i
dr_{max}	Maximal recursion depth by the cluster search
$e_x^{\mathrm{C}}, e_y^{\mathrm{C}}, e_z^{\mathrm{C}}$	The column vectors of transformation matrix $\mathrm{H}_{\mathrm{BC}_j,\mathrm{C}}$ in camera coordinates
e	Epipole
f	Result
f_x	Frequency measured at X-axis
$f_{x_{\mathrm{m}}}$	Middle frequency measured at X-axis
g	Epipolar line
g_x	The size of a pixel in X direction
g_y	The size of a pixel in Y direction
$\mathrm{g}(\mathrm{x})$	One-dimensional Gabor filter
h_i	The number of bisections per axis i in the transformation space
h	Principal point offset
i	Imaginary number
ip	Vectorial input parameter
l	Location
lc	Contour length
lg	The local goodness of single element i in the transformation space
m	Node
n	Normal
nf	Norm factor
o	Octave
of	Offset
p	Pixel

$q(t)$	State vector
$\tilde{q}(t)$	Linear state valuer
$r(t)$	Random vector
r	Edge
s	Spectrum factor
se	Element in set SE
t	Time in general
u	Projection
v	Variable
$(x, y)_{\mathrm{A}}$	Two-dimensional image affine coordinates
$(x, y)_{\mathrm{I}}$	Two-dimensional image Euclidean coordinates
$(x, y)_{\mathrm{S}}$	Two-dimensional sensor coordinates
$(x, y, z)_{\mathrm{W}}$	Three-dimensional world coordinates
$(x, y, z)^{-}_{\hat{\mathrm{W}}_{k+1}}$	The update of three-dimensional world coordinates at point in time $k+1$
$(x, y, z)^{+}_{\hat{\mathrm{W}}_{k}}$	The prediction of three-dimensional world coordinates at point in time k
A	The camera's line of sight
B	Fundamental matrix
$\mathrm{B}(A)$	Function that calculates the area of a region A
$\mathbf{X}_{\mathrm{A}}$	Image affine coordinate system with axes X_{A}, Y_{A}, and Z_{A}
$\mathbf{X}_{\mathrm{BC}_j}$	Contour-centered coordinate system
$\mathbf{X}_{\mathrm{C}}$	Camera Euclidian coordinate system with axes X_{C}, Y_{C}, and Z_{C}
$\mathbf{X}_{\mathrm{I}}$	Image Euclidean coordinate system with axes X_{I}, Y_{I}, and Z_{I}
$\mathbf{X}_{\mathrm{M}}$	Robot coordinate system
$\mathbf{X}_{\mathrm{S}}$	Sensor coordinate system with axes X_{S}, Y_{S}, and Z_{S}
$\mathbf{X}_{\mathrm{T}}$	Transformation space with axes X_{T}, Y_{T}, and Z_{T}
$\mathbf{X}_{\mathrm{W}}$	World Euclidean coordinate system with axes X_{W}, Y_{W}, and Z_{W}
$\varDelta$	Difference
H	Homogeneous matrix
$\mathrm{H}(A)$	Function that calculates the height of a region A
I	Matrix
K	Resolution power
$\varPhi(t+1; t)$	Transition matrix
$\varPhi(t+1; t)^{*}$	Estimated transition matrix
$\mathbf{\Gamma}$	Disparity gradient
M	Matrix
N	Matrix
O	The vectorial output variable of a transformation
P	Segment
T	Threshold
$\varUpsilon$	Ξ/K Quality
$\varOmega$	Tensor
$\varXi$	Field of vision
$\varPsi$	Calibration matrix

Z	Matrix
α	Rotation applied to X-axis
β	Rotation applied to Y-axis
δ	Dilation
ε	Error value
ϕ	Activation profile
$\varphi(x)$	The local phase of a Gabor filter
γ	Rotation applied to Z-axis
η	Surface normal
ι	Intensity
κ	Quality factor
λ	Gabor wavelength
μ	Solution
$\mathrm{\mu}$	Learning rate
ν	Vector
$o(t)$	Observation vector
ϖ	Probability
θ	Angle of rotation
ϑ	Object size
ρ	Scale factor
σ	Standard deviation
τ	Translation
υ	Neuron
ω	The element of a vector
$\omega(t)$	Random vector
ξ	Angle that is surrounded from two polygon areas
ψ	Distortion coefficient
ζ	Balance

1 Introduction

The video-based exploration of interiors with autonomous and mobile service robots is a task that requires much programming effort. Additionally, the programming tasks differ in the necessary modules. Commands, which control the technical basis equipment, must consider the reality of the robot. These commands activate the breaks and the actuation. The parts are basically included in the delivery. Often a mobile robot additionally possesses sonar, ultrasonic, and cameras, which constitute the perception function of the robot. The programming of such a mobile robot is a very difficult task if no control software comes with the robot. First, the programmer must develop the necessary drivers. As a rule the manufacturer includes a software library into the scope of the supply. This enables programs in a high-level language like C++ to be created very comfortably to control most or all parts of the robot's basic equipment. Typically operators are available. The user can transfer values to the arguments whose domain depends on the device that is to be controlled, and the admitted measurement. Operators, which enable rotary motions, may take values in degrees or radians. The velocity can be adjusted with values, which are specified in meters per second or yards per second. Video cameras are sometimes also part of a mobile robot's basic equipment, but further software and/or hardware must be acquired generally. A frame grabber is required. This board digitizes the analog signal of the camera. The gained digital image can then be processed with an image-processing library. Such a library provides operators for the image processing that can also be included into a high-level program. If the camera comes with the robot, the manufacturer provides two radio sets if the computer that controls the robot is not physically compounded with the robot. One radio set is necessary to control the robot's basic equipment from a static computer. The second radio set transmits the analog camera signals to the frame grabber. Nowadays, robots are often equipped with a computer. In this case radio sets are not necessary, because data transfer between a robot's equipment and a computer can be directly conducted by the use of cables. Additionally, a camera head can be used that connects a camera with a robot and enables software-steered panning and tilting of the camera. Mobile service robots use often a laser that is, as a rule, not part of a robot. They are relatively expensive, but sometimes the robot-control software provided involves drivers for commercial lasers.