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厦门大学

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基于蚊子检测和位置跟踪的图像处理与识别算法研究

Based on Arithmetic Study of Image Processing and Recognition for Mosquito Detecting and Position Tracking

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Based on Arithmetic Study of Image Processing and Recognition for Mosquito Detecting and Position Tracking

A Dissertation Submitted for the Degree of Doctor of Philosophy (PhD)

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摘要

蚊子的系统性检测与杀灭在控制与防治疟疾方面十分重要，因而其过程极具研究价值和创新。本课题基于识别技术分析了蚊子的物理特征、区域性及行为模式，所采用的图像处理方法可满足研究人员直接检测出蚊子及其位置的功能要求。研究表明，利用上述研究方法分析蚊子的物理特征、区域性及行为模式能够将蚊子检测并区分出来。本文同时对蚊子的模式和区分特征进行了研究。图像处理检测过程中考虑蚊子的尺寸、数量、喙、体型、颜色、触须、后肢和形状参数等因素，所获取的全部信息将用于形成蚊子的检测算法。本研究以三只蚊子为实验对象，进行了蚊子的特征描述和有关数据的统计分析。作为蚊子检测的关键技术，蚊子图像处理中所涉及的数字图像处理的数字化被认为是对基础理论的回顾。直方图分析直接影响蚊子的检测、位置追踪，本文在图像分析方面也作了简要分析。蚊子信息处于本研究所规定的矩阵坐标系和向量空间内，并运用各种图像处理算法，完成蚊子的图像分析及模式识别。本文所涉及的研究方法都被认为是提出了一种机器人视觉对蚊子图像接受能力的挑战。目前只有极少有效算法被提出，以满足基于现有机器人视觉来有效识别蚊子模式过程的处理要求和计算估计。存在如卷积、相关性、傅里叶分析及基于活动窗口的数据处理技术等方法可用于识别蚊子，本研究中主要考虑了模式识别来实现图像分割。

杀灭蚊子的首要前提是检测出蚊子的位置的精确定位，可采用帧差别法从摄像机中检测到蚊子。在以蚊子为确定目标进行射击杀灭的过程中，摄影设备可随时调整自身姿态。背景运动也被考虑进图像处理和视觉特性中并应用于进行蚊子的检测方法。本文研究了如何综合运用绝对差估计(ADE) 和图像处理集中对蚊子及其位置进行检测，提出了一种具有时效性的追踪高速飞行蚊子的技术。视觉流中的图像分割主要是依靠时效技术，对利用分割视觉流域对指定兴趣区域(SROI）中蚊子的追踪，进一步用连续图像帧计算视觉流。首先建立视觉流进而获得两帧图像用以计算，利用模糊对立参数表征飞蚊的飞行一致程度。图像帧用于分割视

厦门大学博硕士论文摘要库

觉流场，图像根据兴趣区域（ROI）内不同的一致程度可在视觉流场中被分割。指定兴趣区域（SROI）能在不同的兴趣区域（ROI）被检测出来，因而蚊子可从两幅连续图像中被追踪到。然而被检测到的指定兴趣区域（SROI）仅仅是不同的兴趣区域（ROI）的子域。指定兴趣区域（SROI）小于图像帧能够直接减少对指定兴趣区域（SROI）的运算时间。蚊子的检测与追踪是一个便于杀灭蚊子的实时过程。

蚊子的检测和位置跟踪在智能机器人系统中扮演重要的角色。蚊子的检测算法对其飞行运动十分敏感。为了检测蚊子，一种结合帧间差分法被提出，该方法利用基于蚊子的特征和肌理信息改善背景的去除效率。双阈值用以检测蚊子的移动和飞行并做出多种有意义的判别，而利用卡尔曼滤波和均值漂移法能够有效并迅速的跟踪处于快速飞行中的蚊子。蚊子的飞行时间将有助于在未来的研究中有效地消灭蚊子。本研究的试验工作主要在于采用卡尔曼滤波和均值漂移法对所获取的蚊子图像进行检测和位置追踪。在分析蚊子图像的过程中提出的紧密度概念来直接分析兴趣区域（ROI）内蚊子及其位置，为进一步检测和追踪做好准备。线性回归模型、指数模型、高斯模型、对数模型将在轮中进行研究。蚊子图像的直方图显示了统计建模、脉冲响应和脉冲表示法。直方图中所表达的像素和强度被用于在将来的机器人视觉系统中分析蚊子图像。本文采用了离散余弦变换（DCT）来表达像素与强度水平，使得蚊子图像的检测及追踪便于理解。

本文提出了蚊子的检测方法、动态检测、位置追踪以及位置预测方法。利用本方法能够凭借由空间理论、图论、状态空间理论所定义的图像处理检测出蚊子。所提出的状态空间理论研究了如何设计一个能够有效且精确检测并杀灭蚊子的控制系统。在本研究中,提出了 8RF,5RF,3RF 射频预测方法来预测下一蚊子位置。二进制的处理和表达形式能够保证精确的结果。图集理论采用力学定义空间理论。状态空间理论由线性时不变系统（LTI）表示。在蚊子图像空间中进行分割和设置阈值来检测并追踪蚊子的位置将其杀灭，最终达到消除疟疾的目标。

关键词

蚊子检测和位置追踪；蚊子位置的预测及预测方法；蚊子模式分析和统计模型..

厦门大学博硕士论文摘要库

Abstract

The systematic detection and elimination of mosquitoes are a valuable process, the results of which could be important in the fight against Malaria. In this study, image processing is used, allowing the researchers to detect the mosquitoes and their locations. Mosquitoes' physical characteristics, territorial and behavioral patterns were also analyzed by pattern recognition of the mosquito. It is found that mosquitoes can be detected and differentiated by their physical, territorial and behavioral patterns through these methodologies. In addition to mosquitoes are analyzed for their patterns, as well as their distinguishing features. Size, number of objects, proboscis, body shape, color, antennae, hind legs, and shape parameters were all factors considered for mosquito detection with image processing. All these information were used in the Mosquito Detection Algorithm. This research study provides characteristic descriptions and statistical analysis of the mosquito as well as mosquito’s linear modeling. To detect the mosquito, it is important to process the image for digitization of digital image processing which has been stated as the review of the fundamental theory. The histogram analysis is important for detection, position tracking and the image analysis that are briefly presented in this research. Mosquito is in the matrix coordinates, vector space which are stated in this work. Mosquito’s Image analysis involves the use of image processing algorithms. The pattern recognition also involves the use of image processing methods. There are few methods or algorithms have been proposed to satisfy the processing and estimate computation that is effective to recognize the Mosquito’s pattern for robotic visions. There are some methods to recognize the Mosquito such as convolution, correlation, Fourier analysis and moving window-based data processing etc. The pattern recognition principal has

厦门大学博硕士论文摘要库

been considered with the methods of image segmentation.

The necessary perform to detect the mosquito and its position, from the video by Frame Difference Method (FDM). The camera can be changed its movement during shooting and to exactly target to the Mosquito. The background motion also is considered by the image processing and vision properties which can be applied for this method to detect the Mosquito. The concentrated to detect the Mosquito and its position by using the sum of the Absolute Difference Estimation (ADE) and with the help of image processing are discussed. High speedy Mosquito tracking and a time efficient technique have been proposed in this research. The time efficient technique is basically considered on image segmentation of the optical flow. The optical flow has been computed by image successive frames which followed by the tracking of the Mosquito of a specific region of interest (SROI) on the region of field (ROF) with segmented flow regions or field. Initially, the optical flow has been established for two successive frames to compute by the acquired image. A fuzzy opposition index has been indicated as the degree of the consistency of flying Mosquito in the image frames to segment the optical flow field. The images have been segmented in flow field with in the different consistency of region of interest (ROI). The specific region of interest (SROI) can be detected in the different ROI spaces. Therefore, the Mosquito can be tracked from two subsequent images. However, the detected specific region of interest (SROI) is a sub-region of ROI. The SROI is smaller in the image frames which can reduce the time to compute the SROI. It is the facilitating real-time process of Mosquito to detect and track its position.

Mosquito detection and its position tracking is a significant role in the intelligent robotic system. The Mosquito detection algorithm can be sensitive to its flying motion. To detect the Mosquito, a few methods have been proposed with an approach of combining the inter-frame difference method which can improve background subtraction method that makes use of features and texture information. The dual-threshold has been used to detect moving or flying mosquito that makes

厦门大学博硕士论文摘要库

sense multiple judgments. The Kalman filter and Meanshift algorithm have been considered to track the fast flying mosquito efficiently. The proposed algorithm can be adopted to detect Mosquito and track its position. The time of flight would be helpful for destroying the Mosquito with efficiently and effectively in future research. In this research, the experimental works have been proposed to sketch the whole detection process and position tracking of Mosquito by different methods. The compactness of an image is very important to process the ROI in image processing. The compactness has been proposed to analyze the mosquito image and its ROI to detect the mosquito and track its position. The linear regression model, exponential model, improved Gaussian model, logarithmic model are discussed in this proposal. The statistical modeling, impulse responses and the impulse representation are shown in the histogram of the mosquito's image. The intensity and pixel has been represented in the histogram to analyze the mosquito's image for using in future robotic vision systems. In the intensity and pixel levels also expressed by the discrete cosine transform (DCT) to understand the mosquito's image for detection and tracking the position.

The mosquito detection method, detection dynamics, position tracking and the position forecasting methods are proposed to detect and track the position of mosquito by using image processing. The image processing is defined by space theory, graph theory, and state space theory. The state space theory is discussed for designing a control system to detect mosquito and destroy efficiently and accurately. In this research, it has been proposed of 8RF, 5RF, and 3RF forecasting method to forecast the next position of the mosquito so that it can be tracked the position precisely. The Binary processing and representation can be determined to make sure the precise results. The graph and set theory has been defined the space theory with its dynamics. The linear time invariant (LTI) system can be represented as the state space theory. In the mosquito image space, it has been segmented and thresholds the image in order to track the position and detect the mosquito with image processing.

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Keywords:

Mosquito Detection and Position Tracking; Mosquito's Position Forecasting and Forecasting Methods; Mosquito's Pattern Analysis and Statistical Modeling.

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List of Symbols

$	USD Dollar sign
%	Percentage
2D	Two Dimensional
3D	Three Dimensional
X-Y	X axis-Y axis
f	Function
$\forall$	For All
$\sum$	Summation
$\in$	Member
$\boldsymbol{R^2}$	2D Real Space
$\frac{d}{dt}$	Differential Operator
$d\omega$	Derivative
H^{-1}	Inverse Operator
90^o	o is the degree
Ø	Longitudinal velocity potential
θ	Theta (Angle)
R_θ^Z	Rotation around Z-axis
I	Intensity; Identity matrix
$\times$	Multiplication
D^T	T is the Transpose matrix
ε	Epsilon (Error terms)
CW	Clock Wise
CCW	Counter Clock Wise
$\odot\odot$	2D correlation operator, continuous or discrete
∇^2	Laplacian operator
$\partial/\partial x$	Partial differential operator
∇	Curl (Difference operator)
∇f	Difference of the function
$\otimes$	1D or 3D convolution operator, continuous or discrete
tan^{-1}	Inverse tangent

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$\otimes\otimes$	2D convolution operator, continuous or discrete
$e^{-(x^2+y^2)/\sigma^2}$	Here, e is the exponential
σ^2	Standard deviation (Stdv)
Σ	Summation
σ	Variance
ω_1	Angular frequency
α	Alpha (Phase Angle, Rotational Angle)
β	Beta (Phase Angle, Rotational Angle)
$\hat{T}$	Approximation of the function
$\ominus$	Morphological erosion and dilation operator
π	Pi (180°)
$\Theta(t)$	Instantaneous Phase
ln	Natural logarithm
$\int$	Indefinite integral
$\langle f_{ij} \rangle$	Mean value of f_{ij}
$\int_{-x}^{x}$	Definite integral
x'	x prime
ρ_0	Linear Constant
log	General logarithm
$\emptyset(x)$	Covariance function
$x^{(p)}, x^{(q)}$	Ordered matrix
λ_i	Lambda (Constant coefficient)
cos	Cosine
1: ImOp01	1: characteristics no., Im: Image, Op: Operation, 01: Operation no.
2: Blob01	2: characteristic no., Blob: Operation, 01: Blob no.
$\frac{\partial}{\partial \theta}$	Partial differential operator
ms	Millisecond
deg	Degree
StdDev	Standard Deviation
mm	Millimeter
cm	Centimeter
$M(x,y,z)$	Mosquito's position in Cartesian
$R(X,Y,Z;\theta)$	Mosquito's angular position
Hz	Hertz (Frequency)
inch	Inch

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mg	Milligram
grains	Grains
km	Kilometer
Min	Minimum
Max	Maximum
$\pm$	Positive/Negative
$(\hat{u}, \hat{v})$	u, v vector
ρ	rho (scalar optical distance)
sin	Sine
$\hat{\rho}$	cap rho (Vector distance)
$\hat{b}$	Cluster in the optical flow
$\hat{\beta}$	Cap Beta (Optical flow direction)
$\left\Vert \overline{X_p^{k-1} X_q^k} \right\Vert$	Norm of the continuous function and upper bar is the average
δ	sigma; small difference operator
$\vec{V}$	Velocity; the arrow indicate vector
$\vec{\omega}$	Angular or Rotational velocity
$\vec{\theta}$	Image Velocity
$C^{\perp}(\vec{T})$	Orthogonal basis complement of $C(\vec{T})$
~	Equivalent or near or greater
δt	Small time
$\delta \vec{x_\iota}$	Local displacement in the image
$\vec{v_\iota}$	Velocity vector in the image
$\pi_M(x_i)$	Fuzzy membership function
M	Membership set
0	Binary value '0'
1	Binary value '1'
Avg.	Average
Syspar1	System Parameter 1
StatNum	Start Number
ConfidenceC	Confidence Calculation
TimeC	Time Calculation
S	Space
.	Dot (Scalar multiplication)
$\underset{\Delta t}{Lt}$	Lt: limit, with respect to small time Δt
$\cap$	Intersection

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$\cup$	Union
$+$	Positive sign
$(S_1 \cap S_2)'$	Indicate the set complement
$(S - S_b)$	Difference between two sets
(V, E, s, t)	Definition of graph theory; V: vertices, E: edges, s: source, t: target
$\boldsymbol{R}$	Real space
$\dot{x}_1$	'.' means $\frac{d}{dx}$

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