# 摘要

动态视觉传感器通过模拟神经元脉冲发放与视网膜自适应采样机制，相对传统基于帧的传感器，具有低数据冗余、高时间分辨率、高动态范围以及低功耗等优势，在智能安防、自动驾驶以及机器人视觉导航定位等领域具有巨大的应用潜力。面向动态视觉传感器采集的脉冲阵列信号，立足于对其传输、存储需求的编码必要性，及其自身数据冗余带来的编码可行性，需要研究高效的脉冲阵列编码方法。

本文致力于研究面向动态视觉传感器的脉冲阵列失真度量和编码算法，主要创新点包括：

第一，在生物脉冲信息表达与编码机制的启发下，本文提出了面向动态视觉传感器的脉冲阵列失真度量模型，实现了对脉冲信号的高效信息表达与失真度量。将脉冲序列抽象为其内蕴的随机过程，用点过程的条件强度函数作为信息表示的等价刻画。在此基础上，将脉冲序列空间映射到特征空间，借助特征空间丰富的代数结构建立了脉冲序列的表示方法。根据对动态视觉传感器的先验假设不同，引入了基于极性干涉的和基于极性独立的脉冲序列失真度量模型，并进一步将其扩展到脉冲阵列的失真度量模型。初步实验结果验证了本文所提失真度量模型的有效性和鲁棒性。

第二，在面向脉冲阵列的失真度量模型基础上，根据动态视觉传感器的脉冲发放机制，本文统计分析了脉冲阵列的数据特性，为脉冲阵列压缩提供了理论和实证证据。脉冲发放模型的建立论证了动态视觉传感器的自适应采样机制可以有效降低时间冗余。空域相邻脉冲序列的相似性分析证明了空间冗余的存在。对时域相邻脉冲极性的条件熵的统计结果揭示了由于运动连续性产生的相邻光子脉冲极性的相关性的存在。

第三，以失真度量模型为评价指标，以数据冗余分析为指导，本文构建了面向动态视觉传感器的脉冲阵列编解码平台。将脉冲阵列划分为若干不同的脉冲立方体，并做时空域八叉树划分。大小可变的编码立方体单元使编码过程可以根据场景动态变化进行自适应，为脉冲编码带来了极大的灵活性。提出了时间优先预测和地址优先预测模式，能够有效去除脉冲阵列的时空冗余。在本文提出的 PKU-DVS 数据集上的实验结果表明，该脉冲阵列编码平台能够在保持较低失真的情况下达到较好的压缩性能。

综上所述，本文面向动态视觉传感器建立了脉冲阵列失真度量模型，统计分析了脉冲阵列数据特性，在此基础上设计并实现了基本的脉冲阵列编解码平台，为进一步研究脉冲阵列编解码打下了基础。

关键词：动态视觉传感器，脉冲阵列编码，脉冲阵列失真度量

# Quality Assessment and Spike Coding for Dynamic Vision Sensors

Zhichao Bi (Computer Application Technology)
Directed by Yonghong Tian

## ABSTRACT

Dynamic vision sensors (DVS) emulate the neuron spike firing and adaptive retinal sampling mechanisms, which have taken advantages of low redundancy, high temporal resolution, wide dynamic range and low power consumption in contrast to conventional frame-based vision sensors. DVS has shown great potential in applications such as video surveillance, autonomous driving, and mobile robot navigation. However, considering the requirements for transmission and storage, there is a big challenge to develop effective coding methods for the output spike data of DVS.

Inspired by the study of biological neural coding and conventional video compression, this thesis focuses on developing the quality assessment and coding methods of DVS spikes. The innovations of this thesis can be concluded as follows:

1. A novel quality assessment algorithm of spike array of DVS is proposed which can effectively measure the distortion induced by compression. By analyzing the stochastic process of the spike train, and mapping the spike train into a feature domain, it is in a position to calculate the distance of different spike trains, which can be further extended to measure the distortion of the whole spike array. Experimental result verifies the effectiveness of the proposed quality assessment algorithm.

2. As a new kind of data, the characteristics of DVS spikes have been deeply investigated, containing the temporal and spatial redundancies. In temporal, by modeling the spike firing process, it proves that the dynamic sampling mechanism of DVS has removed much of temporal redundancies. In spatial, there are still lots of correlations among the spike trains in adjacent positions. Moreover, the statistics of the polarities in consecutive spikes reveal their temporal correlations which can be compressed.

3. A spike coding framework is built for DVS. A spike array is divided into multiple cubes based on the octree structure in spatiotemporal. Variable-sized cubes adaptively fit the changes of the scene, which provides great flexibility in spike coding. For different spike statistics, two prediction modes, the time-prior and address-prior modes are introduced. And a context-

adaptive polynary arithmetic coding can further reduce the redundancy of prediction residuals. To evaluate the coding performance, a new dataset, the PKU-DVS dataset is constructed which contains multiple spike sequences in various luminance conditions. The experiments on PKU-DVS dataset show that the proposed coding framework achieves impressive compression ratios at rather low distortions.

In summary, the thesis has proposed a quality assessment algorithm, then investigated the characteristics of DVS spike data, and finally designed a spike coding framework to evaluate the effectiveness of the quality assessment on the spike array.

KEY WORDS: Dynamic vision sensors, Spike coding, Quality assessment