3D Object Recognition Considering Light Conditions

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Motivation

There is a demand to solve object recognition under complex conditions such as noise, geometric distortions and changes of visualization caused by an incident light source. Recognition systems must process a lot amount of data, and make decisions in real time to accomplish their tasks.

Basic Idea

This work presents a GPU implementation of statistical correlation filters for a 3D object recognition system providing a solution on real-time visualization. Parallel computation is used to accelerate the filter bank processing based on FFT correlation between the input frame and a filter generated by each target reference in frequency domain.

Visualization of Light and Matter Interactions

The appearance of an object within a scene involves light and matter interactions. Image fidelity is achieved with accurate light interreflection calculation. Fig. 1 shows the input signal model layout.

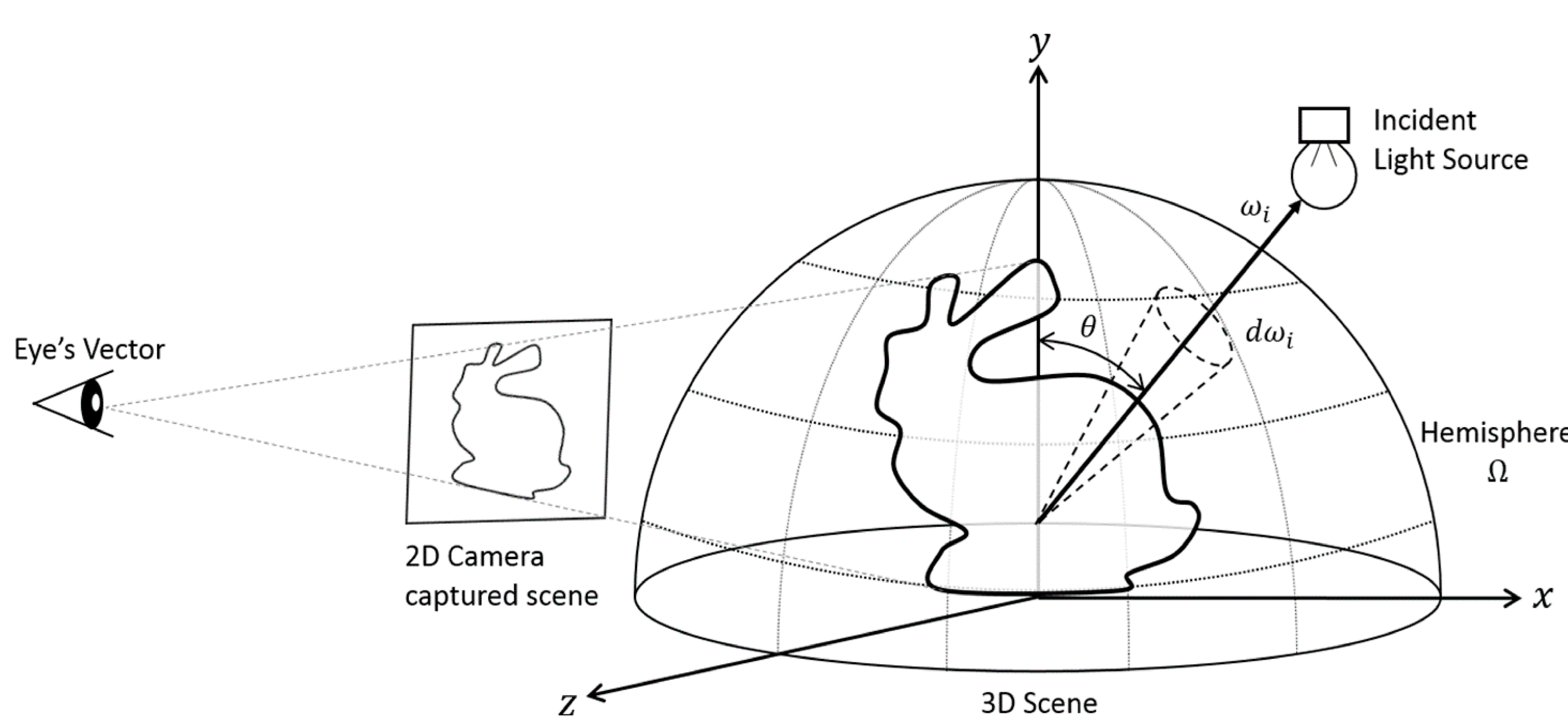

Fig. 1. Input signal representation.

Adaptive filtering for 3D recognition

The system employs an adaptive filter bank of space variant correlation filters adapted to local statistical parameters of the observed object's pose in each frame. We build a filter per each target reference per video frame. As shown in Fig. 2, an input frame is correlated by each filter in frequency domain. Generalized match filter is based on maximize the SNR criterion, which is given by (Eq. 1). The best match is determined by the max value of DC (discrimination capability) obtained from the correlation planes (Eq. 2).

$$H_{GMF}^{*}(\mu,v) = \frac{2\pi\left(T(\mu,v) + m_b W_1(\mu,v) + m_t W_t(\mu,v) \right)}{|W_1(\mu,v)|^2 * N_b(\mu,v) + |W_t(\mu,v)|^2 * N_t(\mu,v)} \quad \text{Eq. (1)}$$

$$DC = 1 - \frac{|c^b|^2}{|c^t|^2} \quad \text{Eq. (2)}$$

Results

In our experiments, the object changes its appearance depending of the light source and the surface material. The algorithm implementation was done in CUDA C/C++, ArrayFire for FFT evaluation, and NVIDIA OptiX Ray Tracing Engine for customizing rendering visualization. We use a CPU/GPU architecture on Linux OS, multi-core host processor (Intel i7) and NVIDIA GeForce GTX780 with 3.5 computation capability. Fig. 2 shows the best match between an object's pose from an input frame and the 3D reference model. The visualization of the 3D object is rendered in NVIDIA Optix, depending of the estimated pose (x,y,z-axis rotation) and the incident light. The table below shows the obtained time from different stages of implementation.

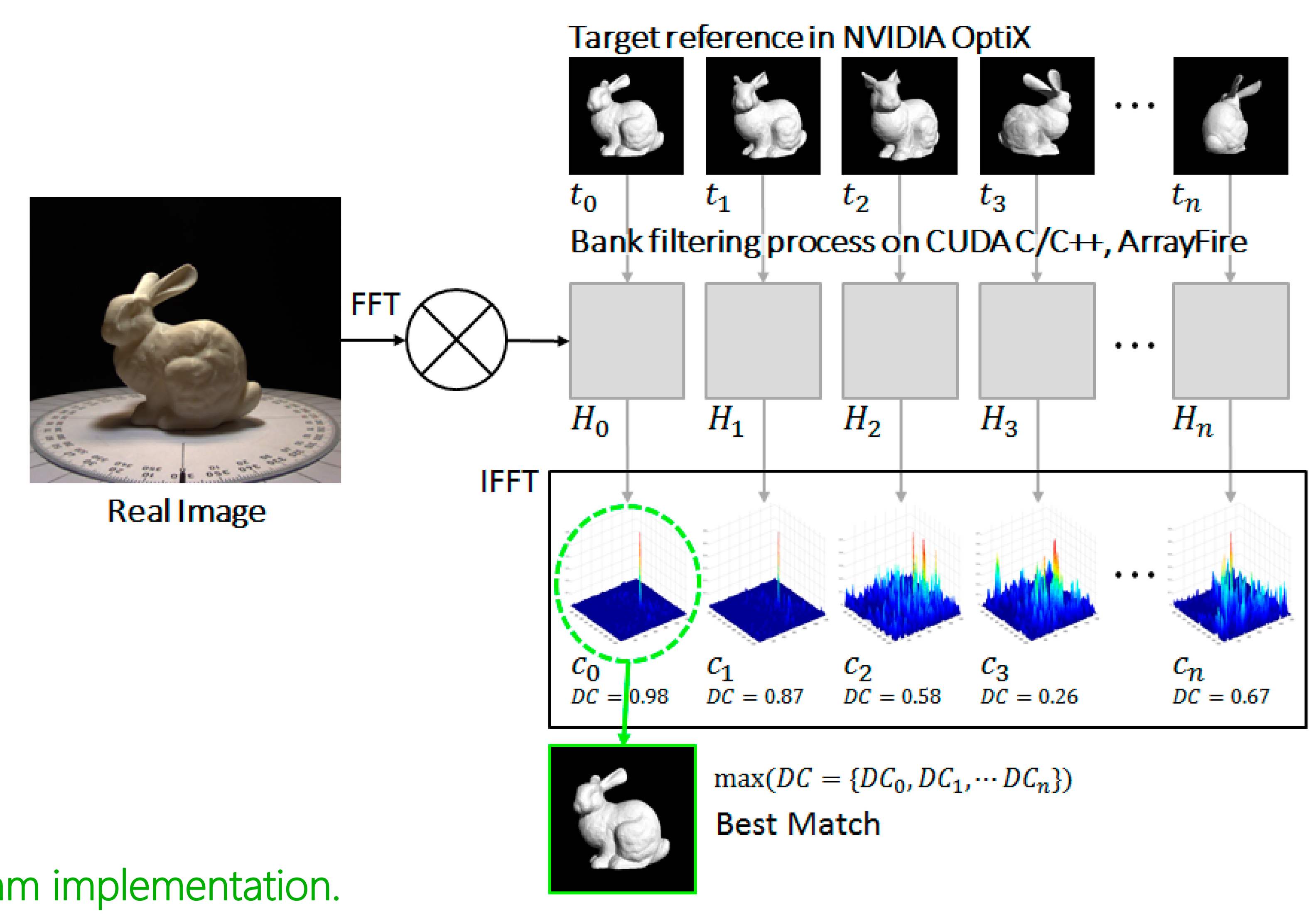

Fig. 2. Algorithm implementation.

Sequential Evaluation 1024x1024 pixels RGB	Parallel Evaluation CUDA, ArrayFire 1024x1024 pixels x 3 channels RGB x 631 templates in frequency domain per frame	Graphics Evaluation NVIDIA OptiX Buffer Size: 1920x1080
3.24 s	1.61 ms	52.87 fps

Conclusions

This work presents a proposal for object recognition under light conditions. A GPU-based implementation using CUDA/ArrayFire interop and NVIDIA OptiX that achieves real-time visualization performance is presented. A correlation filtering method for object recognition was tested under lighting conditions and noise in terms of DC. The implementation achieves good performance in reflective materials, making the implementation suitable for real life applications. Our future work will focus to optimize the performance of multi-pose object recognition invariant to lighting conditions for complex materials.