SinCUT Model for Single Image Translation in Microscopy Applications: A Complementary Tool for Digital Twin Frameworks

Fiza Khan[1], Baidong Wu[1], Zengbo Wang[1]
School of Computer Science and Engineering, Bangor University, LL57 1UT, UK

ABSTRACT

Introduction

Digital twins, as virtual representations of physical systems, are transforming research and development by enabling predictive modeling and real-time simulation across diverse fields. These frameworks often require high-quality, cross-modal data to model system behaviors accurately, particularly in fields like microscopy, where small-scale systems such as single cells, micro-electro-mechanical systems (MEMS), or on-chip photonics devices play a central role. However, generating comprehensive datasets across imaging modes is challenging due to constraints in time, cost, and sample availability. Addressing these limitations, deep learning-based image translation methods offer new opportunities for efficiently generating synthetic datasets.

Methods:

SinCUT, a novel deep learning single-image translation approach, builds on the Contrastive Unpaired Translation (CUT) framework to generate high-quality cross-modal data using limited input [1]. This capability makes SinCUT an ideal tool for enhancing digital twin frameworks in microscopy by enabling efficient, high-resolution virtual imaging while reducing reliance on extensive datasets.The SinCUT model adapts the CUT framework, leveraging contrastive learning to align sub-patches of a single image in a shared feature space. By encouraging closer alignment of positive patches while maximizing the distance of negative patches, SinCUT generates accurate translations across optical imaging modes. This approach significantly reduces the need for paired datasets, allowing effective single-image translation for microscopy applications. In our experiments, SinCUT was applied to microscopy images to translate between brightfield (BF) and darkfield (DF) modes, as well as brightfield (BF) and differential interference contrast (DIC) modes, as shown in Fig.1 These translations demonstrated high fidelity in preserving content while accurately adapting to the target imaging mode. The model's capability to perform well in both paired and unpaired scenarios highlights its versatility and potential for integration into digital twin frameworks.

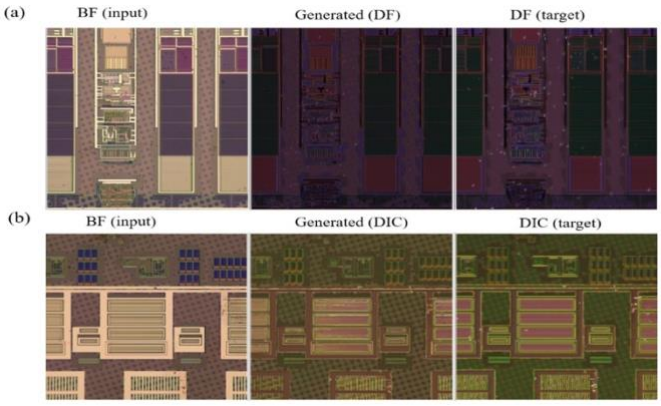

Figure 1: SinCUT model for microscopy image translation for digital twin modellig. (a) Translation from brightfield to darkfield mode, and (b) from brightfield to DIC mode.

References

[1] CUT (Contrastive Unpaired Translation) GitHub Repository. Available at: https://github.com/cryu854/CUT