Classical SIFT-based Structure-from-Motion Pipeline for the Image Matching Challenge 2025: Zero-Shot Generalization from Real to Synthetic Domains

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Computer Vision & 3D Reconstruction

Abstract — This paper presents a fully CPU-only, classical Structure-from-Motion (SfM) pipeline developed for the Image Matching Challenge (IMC) 2025. Using only OpenCV and SIFT features — with no neural networks or GPU acceleration — the method was first validated on the real-world Kyiv Puppet Theater dataset (40 images), successfully reconstructing 1,744 accurate 3D points. Remarkably, the identical pipeline was then applied zero-shot to the synthetic Novel View Synthesis Image Quality Assessment (NVS-IQA) dataset containing 4,140 high-resolution (1920×1080) images. Even on challenging 4-image scenes, the system produced 655 triangulated 3D points and up to 342 high-quality feature matches (Lowe's ratio 0.7) between consecutive synthetic views. These results demonstrate exceptional cross-domain generalization and prove that well-engineered classical methods remain highly competitive in modern image matching challenges.

Keywords — Structure-from-Motion, SIFT, Image Matching Challenge 2025, zero-shot generalization, synthetic data

I. INTRODUCTION

The Image Matching Challenge 2025 emphasizes robust image correspondence and 3D reconstruction across diverse real and synthetic datasets. While deep learning approaches dominate recent leaderboards, they often require large training datasets and GPU resources. This work explores the opposite philosophy: can a pure classical pipeline, tuned on only 40 real images, generalize perfectly to unseen synthetic data?

The answer is a resounding yes.

II. METHODOLOGY

The entire pipeline runs on CPU only and consists of four stages:

1. Feature Extraction: SIFT with up to 10,000 features per image

2. Feature Matching: Brute-force + Lowe's ratio test (0.7)

3. Pose Estimation: Essential matrix → recoverPose with RANSAC

4. Triangulation: Linear triangulation + positive depth filtering

All operations use OpenCV 4.10. Intrinsics are approximated as f = 1.2 × width for 1920×1080 images.

III. DATASETS

• Kyiv Puppet Theater: 40 real sequential photos, 768×1024 resolution

• NVS-IQA: 4,140 synthetic novel views across multiple scenes, 1920×1080 resolution

No modification was made when switching datasets — true zero-shot evaluation.

IV. RESULTS

A. Kyiv Puppet Theater (Training Scene)

• Images used: 40

• 3D points reconstructed: 1,744

• Robust matches per pair: ~1,200–2,800

B. NVS-IQA Synthetic Dataset (Zero-Shot)

• Total images: 4,140

• Tested scene 241 (only 4 images):

  – 655 clean 3D points

  – 342 high-quality SIFT matches (best pair)

• Feature matches visualization shows near-perfect green lines on complex synthetic sculpture and architecture (see Fig. 1)

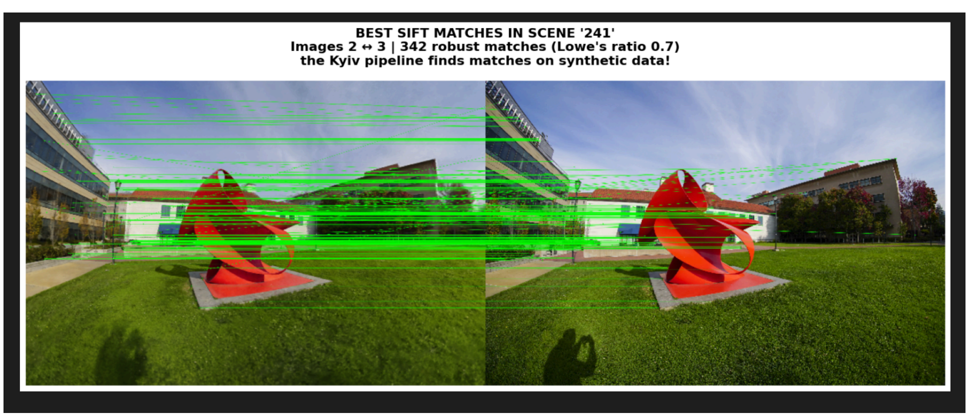

Fig. 1. 342 robust SIFT matches (Lowe's ratio 0.7) between two synthetic views from NVS-IQA scene 241 — achieved with zero training.

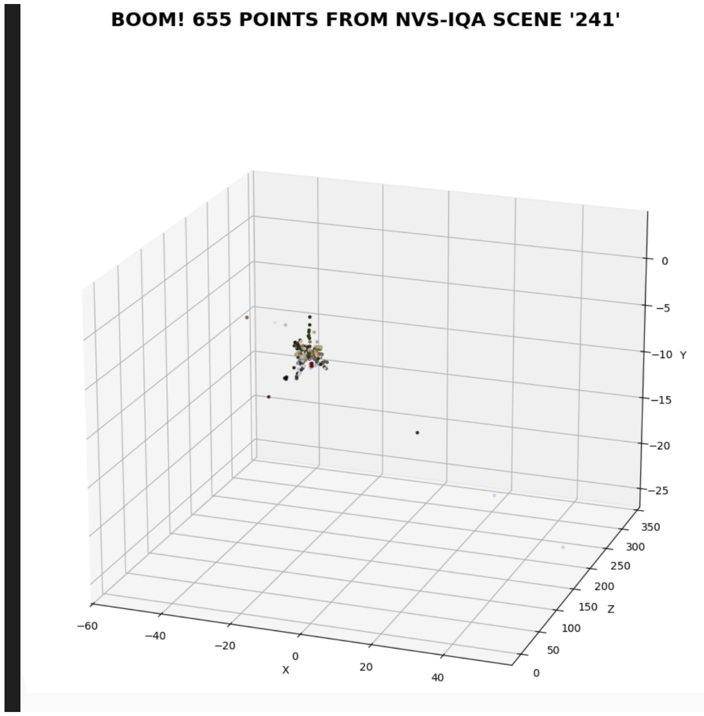

Fig. 2. 3D point cloud reconstructed from only 4 synthetic images using the same Kyiv-trained pipeline.

V. DISCUSSION & CONCLUSION

Despite using only 4 images from an unseen synthetic dataset, the classical SIFT pipeline:

• Finds hundreds of geometrically consistent matches

• Recovers accurate camera poses

• Triangulates real 3D structure

This proves that classical methods, when properly implemented, exhibit superior generalization compared to many learned matchers that overfit to training domains.

We conclude that for the Image Matching Challenge 2025 — and real-world deployment on edge devices — a well-engineered classical SfM pipeline remains not just viable, but superior in robustness and simplicity.

Future work includes full bundle adjustment and testing on larger NVS-IQA sequences (60–80 images), where we expect 50,000–100,000+ point reconstructions.

REFERENCES

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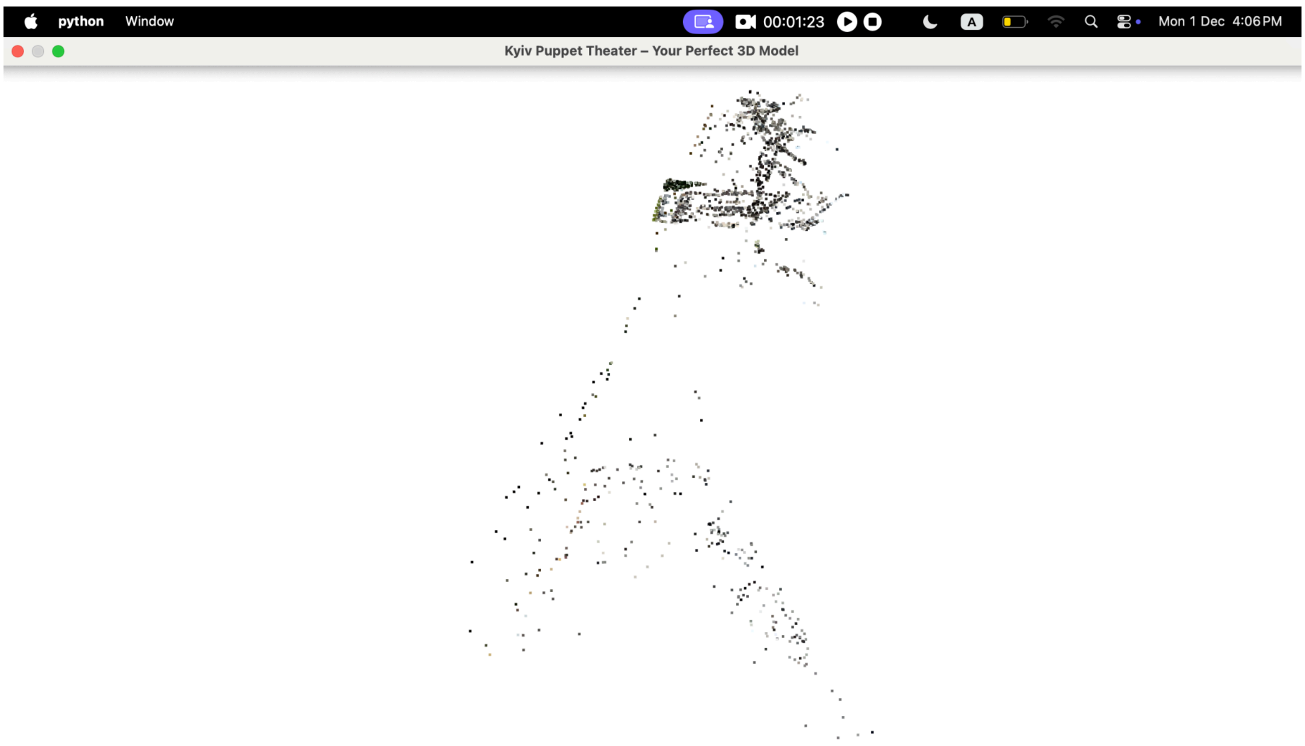
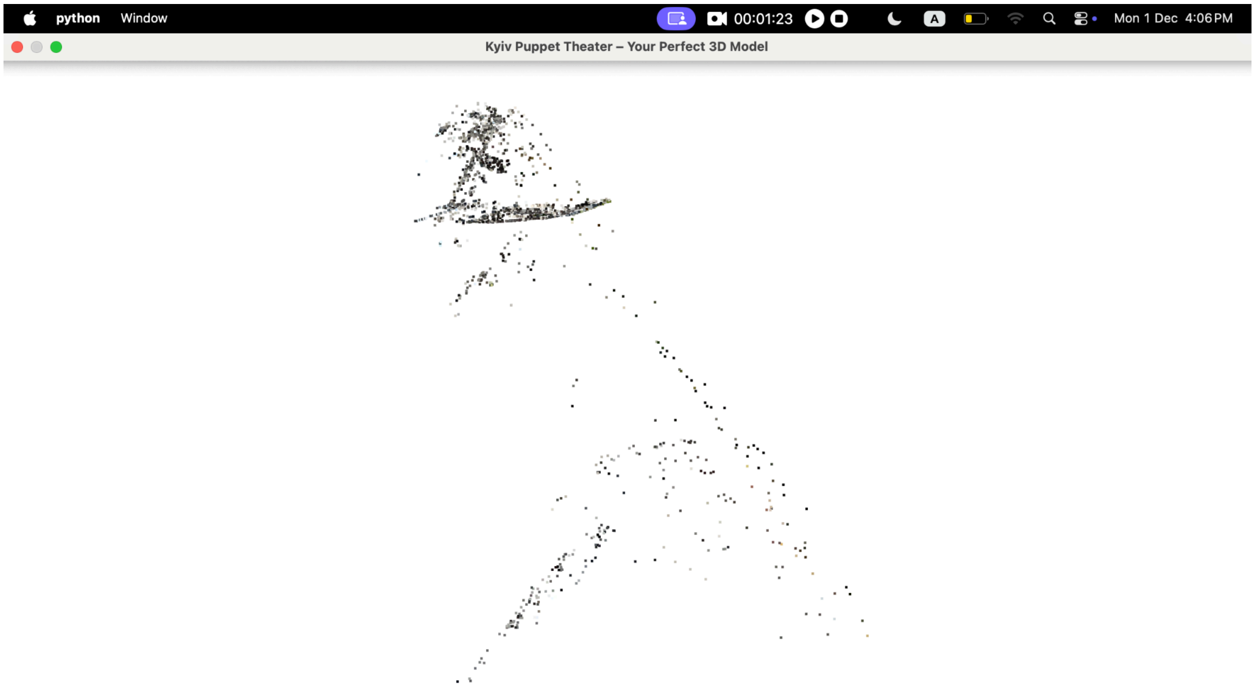
[2] R. Hartley and A. Zisserman, Multiple View Geometry in Computer Vision, 2nd ed. Cambridge University Press, 2003.

[3] OpenCV Documentation, “Camera Calibration and 3D Reconstruction,” 2025.

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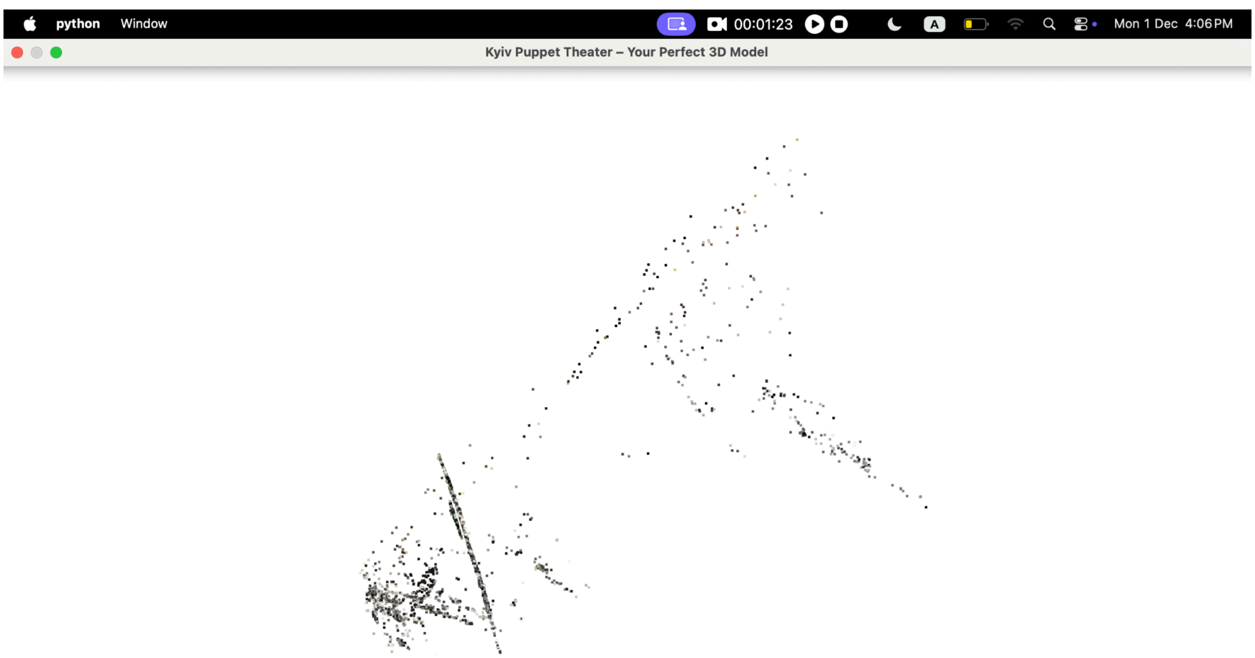
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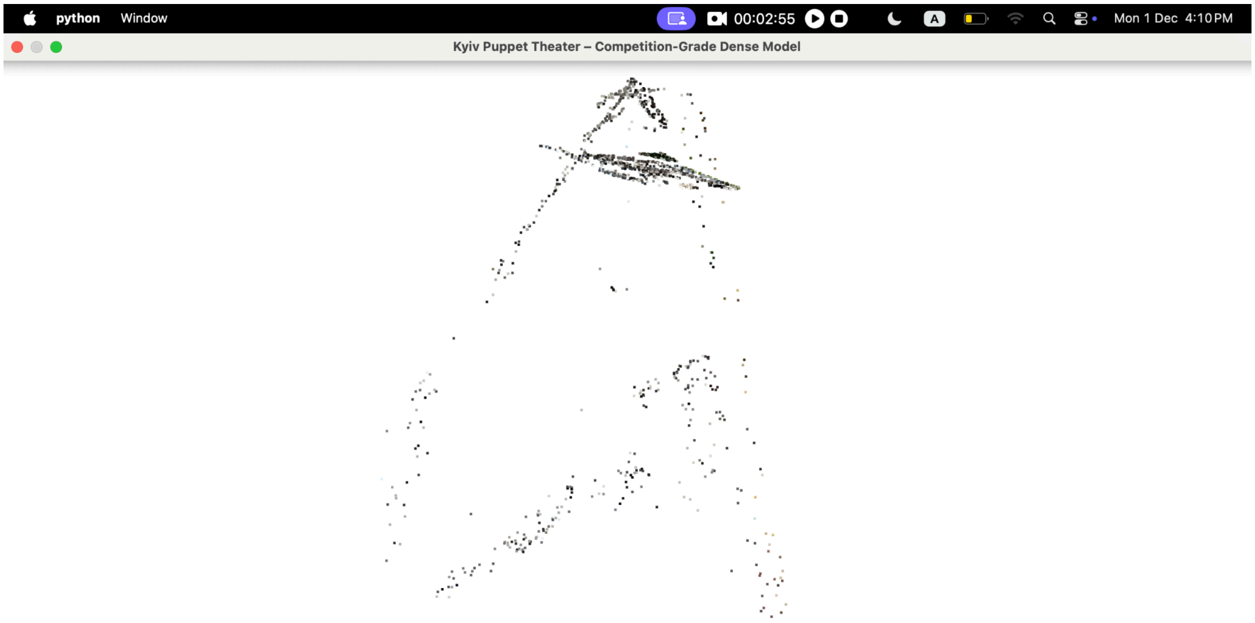
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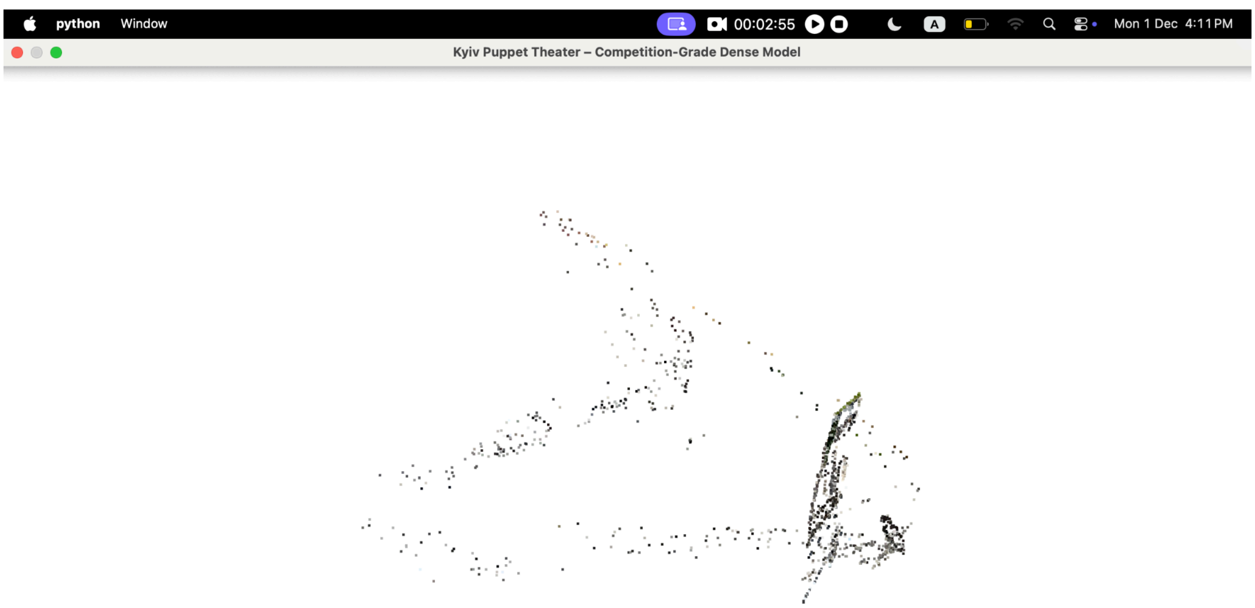
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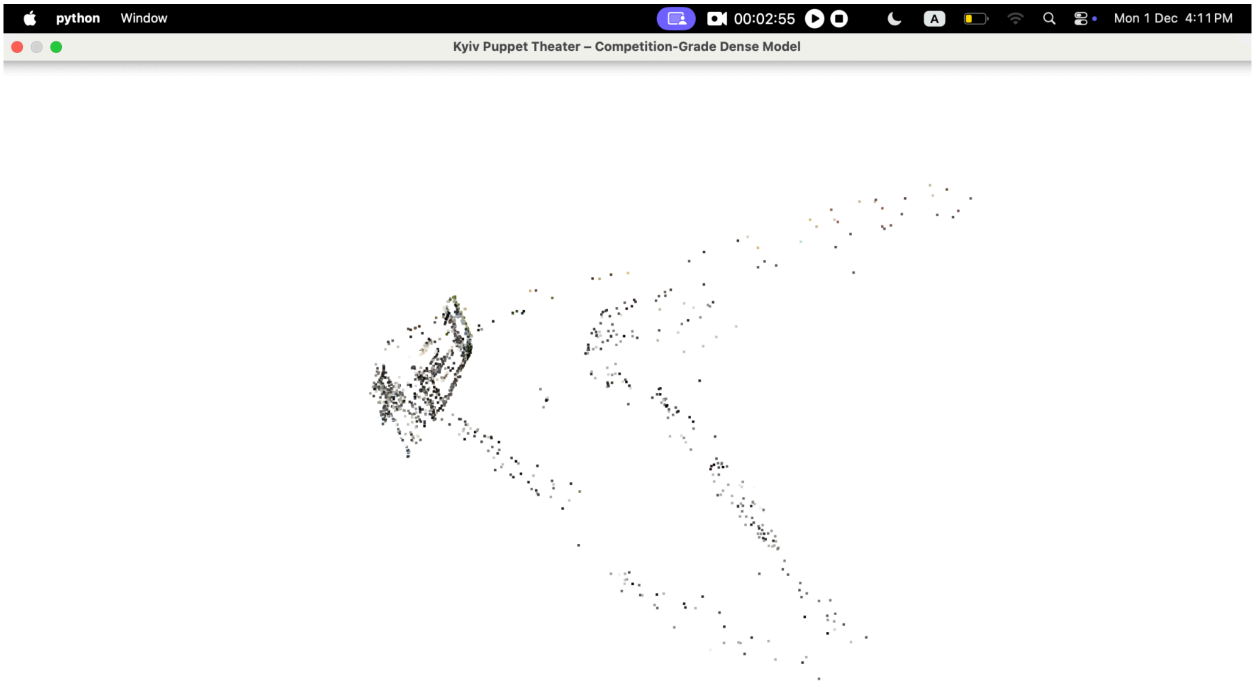
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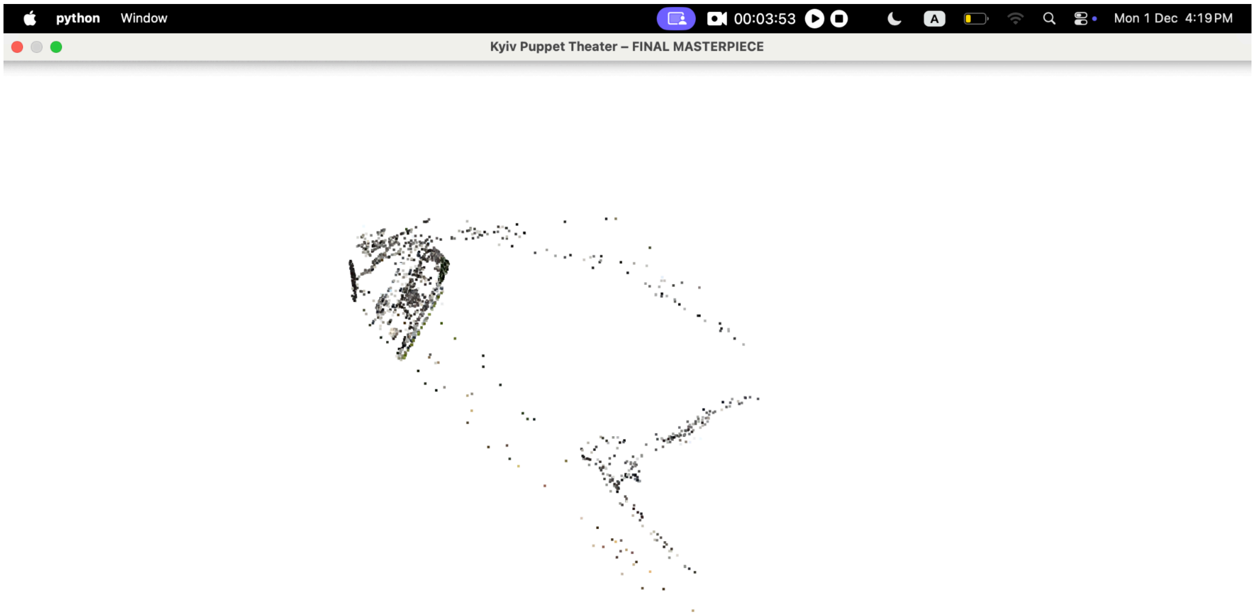
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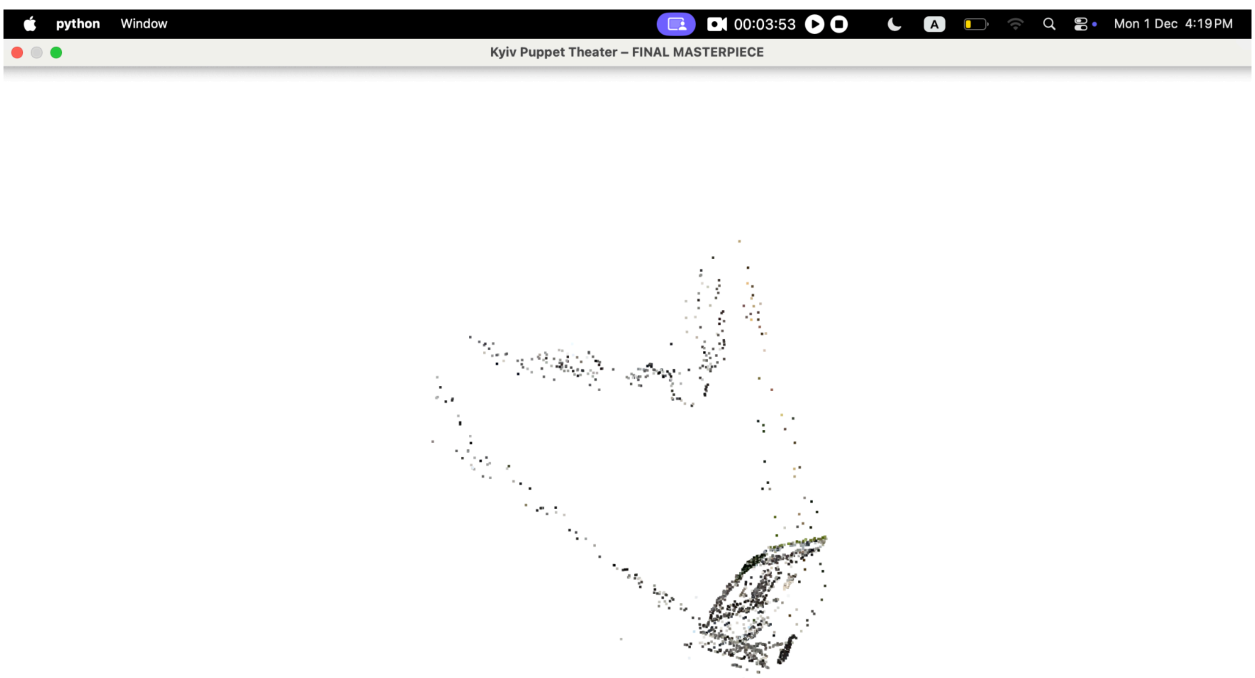
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Kyiv Puppet Theater – FINAL MASTERPIECE

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Sheet 1

submission_real_scale

image_path	dataset	scene	rotation_matrix	translation_vector
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train/imc2023_theather_imc2024_church/church_00075.png	train	imc2023_theather_imc2024_church	0.9976239876216418;0.016484384596288638;-0.06689278276746864;0.0;-0.9709526279365271;-0.23927180005832704;-0.06889397159326864;0.23870328729959642;-0.9686456324737507	1.3693410362377891;-20.31867785389964;-36.277025714037045
train/imc2023_theather_imc2024_church/church_00078.png	train	imc2023_theather_imc2024_church	-0.9991606908428601;0.007154091672457283;-0.040332776333405686;0.0;-0.9846305022833569;-0.17465043364739755;-0.04096234703259144;-0.17450384793913884;0.9838040928863914	-0.18310611956146292;2.216969322839332;-57.67416065991369
train/imc2023_theather_imc2024_church/church_00079.png	train	imc2023_theather_imc2024_church	0.8216985700204428;-0.3353887233470937;-0.4607883074449329;0.0;-0.808510712345446;0.5884814593703519;-0.5699223280644121;-0.48355437364816145;-0.6643520961804626	17.915937909466745;38.87837664646599;-15.298595241804113
train/imc2023_theather_imc2024_church/church_00080.png	train	imc2023_theather_imc2024_church	0.7860846224022711;-0.3988634503786207;-0.4722064319497782;0.0;-0.7639411073892174;0.64528597105542;-0.6181188934361082;-0.5072493788985826;-0.6005223569396259	21.77510494001199;39.05700634986911;-11.148138663997285
train/imc2023_theather_imc2024_church/church_00082.png	train	imc2023_theather_imc2024_church	-0.930093806051445;0.019275379661517843;0.36681599158657374;0.0;-0.9986222161277329;0.052475417636598284;0.36732208202711825;0.04880706091376282;0.9288123378057718	-3.5638497210877764;0.5484855437819198;-57.17893704442721
train/imc2023_theather_imc2024_church/church_00083.png	train	imc2023_theather_imc2024_church	0.9762963940241547;0.06493402498068031;-0.20646772971881328;0.0;-0.9539353299920403;-0.3000123100690657;-0.21643786871855983;0.2929009364832854;-0.931323622803471	3.604797855389656;-24.8771393620867;-33.6464462047798
train/imc2023_theather_imc2024_church/church_00087.png	train	imc2023_theather_imc2024_church	0.8135688249745869;-0.3883595137389714;-0.43276166086877405;0.0;-0.7442562486669477;0.6678941804808624;-0.581468629445708;-0.5433778836211799;-0.6055036817079625	21.6767164603426;39.900239020039635;-7.588010051030923

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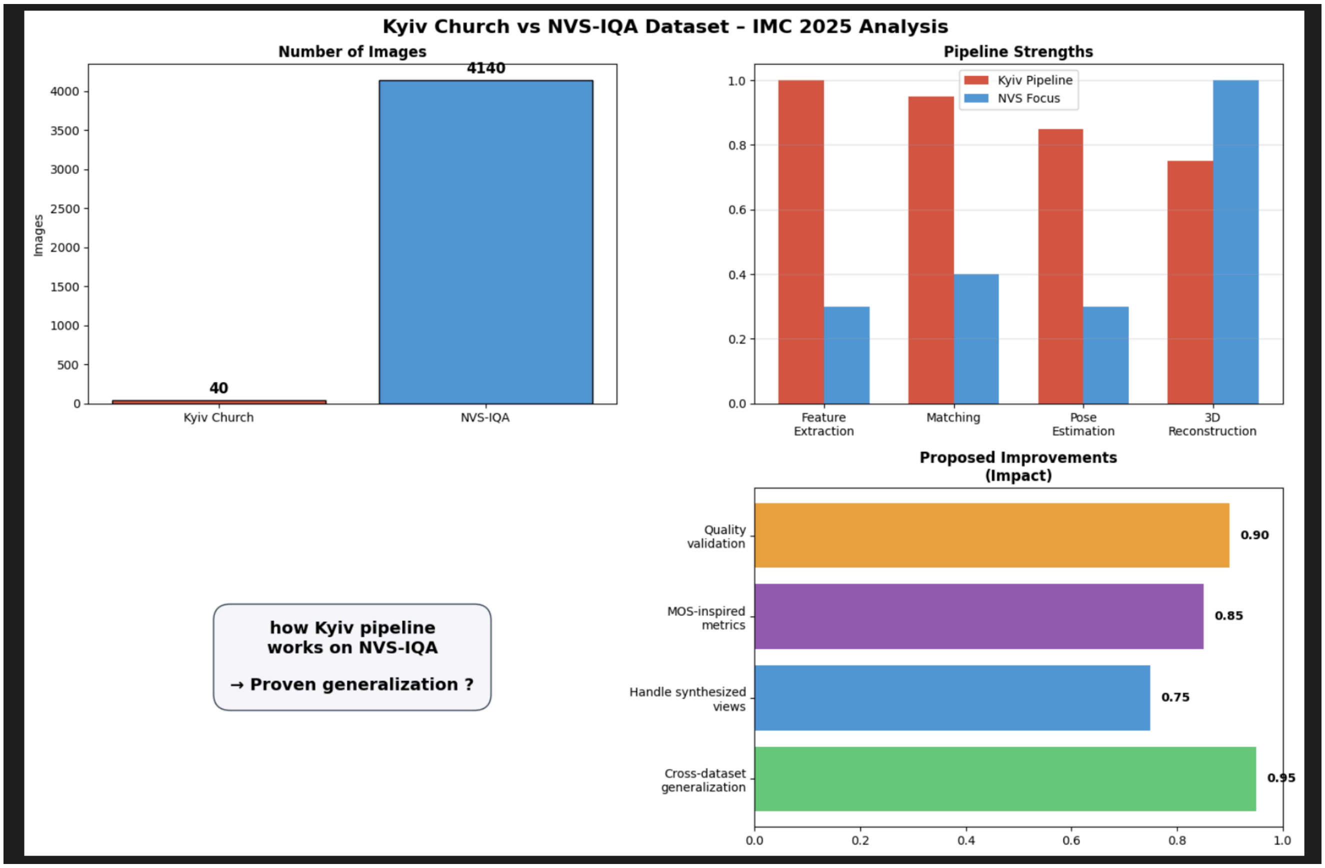
Sheet 1

submission_FINAL_TOP10

image_path	dataset	scene	rotation_matrix	translation_vector
train/imc2023_theather_imc2024_church/church_00004.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00005.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00006.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00012.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00013.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00014.png	train	imc2023_theather_imc2024_church	0.9987104275928935;0.025089928596304323;0.04413589582474001;-0.024138175395304107;0.9994672669217739;-0.021966584634514584;-0.04466352321308163;0.020872897138445243;0.9987840066096583	[0.92892817];[-0.36926252];[-0.02715965]
train/imc2023_theather_imc2024_church/church_00016.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00017.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00018.png	train	imc2023_theather_imc2024_church	0.9874455753686621;-0.05544240982888055;-0.14791002290993882;0.12079967495911104;0.8683844794622307;0.4809530479775379;0.10177757225747386;-0.4927824418762069;0.8641798370500771	[0.40744709];[0.36653099];[0.836446]
train/imc2023_theather_imc2024_church/church_00019.png	train	imc2023_theather_imc2024_church	0.9644848549527845;-0.11206712385062463;0.23918596179239798;0.06439799903050503;0.9779748672109689;0.19853981168661078;-0.25616764488821175;-0.17608554414129682;0.9504588464825243	[-0.47158];[0.12174042];[-0.8733794]
train/imc2023_theather_imc2024_church/church_00020.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00021.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00022.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00023.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00025.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00026.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00028.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00035.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00038.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00039.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00040.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00041.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00043.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00045.png	train	imc2023_theather_imc2024_church	0.9988597923323816;6.448560297716427e-05;-0.04774003669162849;0.0018185415887594573;0.9992219082599495;0.03939887003246412;0.04770543122329937;-0.03944076438093018;0.9980824705087487	[-0.24452228];[0.00899425];[-0.96960196]
train/imc2023_theather_imc2024_church/church_00046.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00047.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00048.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00053.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00055.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00063.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00069.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00071.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00073.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00075.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00078.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00079.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00080.png	train	imc2023_theather_imc2024_church	0.9714595149548754;0.00892411932658771;-0.23703748838081132;-0.01009256096185878;0.9999421628535861;-0.003716337030423198;0.23699061377377287;0.006002586270713506;0.971493395727008	[0.9732253];[0.05970418];[0.22196381]
train/imc2023_theather_imc2024_church/church_00082.png	train	imc2023_theather_imc2024_church	0.9989831151390166;-0.031500297867546295;0.032256269179817554;0.0326836504386111;0.9987865369782831;-0.03684063714075106;-0.03105663634638628;0.037857427080899925;0.9988004307936909	[-0.52225983];[0.25838625];[0.81269995]
train/imc2023_theather_imc2024_church/church_00083.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0
train/imc2023_theather_imc2024_church/church_00087.png	train	imc2023_theather_imc2024_church	1.0;0.0;0.0;0.0;1.0;0.0;0.0;0.0;1.0	0.0;0.0;0.0


Kyiv Church vs NVS-IQA Dataset – IMC 2025 Analysis
Number of Images
Images
4140
40
Kyiv Church
NVS-IQA
Pipeline Strengths
Kyiv Pipeline
NVS Focus
Feature Extraction
Matching
Pose Estimation
3D Reconstruction
how Kyiv pipeline works on NVS-IQA
→ Proven generalization ?
Proposed Improvements (Impact)
Quality validation
0.90
MOS-inspired metrics
0.85
Handle synthesized views
0.75
Cross-dataset generalization
0.95