

IMIGRASP: Zero-shot 6-DOF pose estimation via generative AI imagination and cross-image geometric transfer

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Abstract—Robotic grasping in unstructured environments remains a fundamental challenge, particularly for novel objects not encountered during training. Traditional approaches rely on large scale annotated datasets, extensive training, and hand crafted features. This work introduces IMIGRASP (Imagine to Grasp), a zero-shot framework for 6-DOF pose estimation that leverages generative artificial intelligence for imagination guided pose estimation. The key insight is that modern generative models, trained on vast internet scale visual data, implicitly encode rich knowledge about human grasping behavior and object affordances. Given a single RGB image of a target object, the proposed pipeline employs GPT-5.6 Luna to generate a corresponding image with a realistic hand grasping the object, complete with colored landmarks at the thumb tip, index fingertip, and wrist. A state-of-the-art segmentation model, SAM3, is utilized for precise segmentation of objects and hands, while a bounding box transfer method is introduced for cross-image geometric transfer between generated and real images. The complete 3D grasp frame is reconstructed using RGB-D data and robot kinematics, and executed on a Franka Panda robot. The approach is validated on 130 diverse household objects, achieving a success rate of 86.9% without any prior training or object specific tuning. The results demonstrate that generative AI models can serve as powerful zero-shot priors for robotic manipulation, opening new directions for imagination guided robotics.

Index Terms—Generative AI for pose estimation, zero-shot robotic grasping, 6-DOF grasp generation, foundation models for manipulation, robotic affordance learning.

I. INTRODUCTION

ROBOTIC grasping is a cornerstone capability for autonomous manipulation systems, enabling robots to interact with and manipulate objects in unstructured environments [1, 2]. Despite significant advances in recent years, robust and generalizable grasping remains challenging, particularly for novel objects and poses not seen during training [3]. Recent approaches have explored zero-shot grasping using generative examples and semantic guidance [4]. In this work, IMIGRASP (Imagine to Grasp) is introduced, a zero-shot framework that leverages generative AI for 6-DOF grasp generation. The core insight is that GPT-5.6 Luna’s ability to produce realistic hand object interactions from a single RGB image can be harnessed to infer optimal grasp configurations without any prior training [5, 6]. Modern generative models demonstrate remarkable capabilities in generating realistic images and understanding visual concepts from text, and these models, trained on vast

internet scale data, implicitly encode rich knowledge about human behavior, object affordances, and physical interactions. Specifically, GPT-5.6 Luna [7] exhibits particularly strong capabilities in generating realistic human object interactions from visual inputs, making it well suited for synthesizing grasping configurations [8, 9]. The complete pipeline consists of generative image synthesis with colored landmarks, segmentation using SAM3, color based landmark detection, 2D geometric construction for grasp point identification, scale-invariant bounding box transfer, RGB-D based 3D reconstruction, and grasp frame computation and execution [10, 11, 12]. Recent zero-shot and task-oriented grasping approaches have also been investigated [13, 14, 15]. Traditional approaches rely on large scale annotated datasets and extensive training, which limits their applicability to new domains and objects [16, 17, 18]. Affordance learning and language grounding have been explored for robotic manipulation [19, 20, 21]. The concept of imagination has also been investigated in robotics for planning and reasoning [22, 23, 24]. In contrast to these approaches, this work is unique in using generative AI capabilities for zero-shot grasp generation, requiring no training or fine-tuning [25, 26, 27]. The main contributions include: a zero-shot framework for 6-DOF grasp generation using generative AI without any training data; a pipeline combining GPT-5.6 Luna, SAM3, and geometric construction for grasp pose estimation; a scale-invariant bounding box transfer method for correspondence mapping between generated and real images; and comprehensive experimental validation on 130 diverse household objects with a Franka Panda robot [28, 29, 30].

II. RELATED WORK

A. GenAI for Grasping

Recent works have explored generative AI for robotic grasping. GRIM [1] retrieves and re-aligns grasps from generative examples in a training-free memory-based pipeline. SegGrasp [2] employs semantic and geometric guided segmentation for zero-shot task-oriented grasping. Imagine2Act [3] leverages object-action motion consistency from imagined goals within a trained imitation-learning policy. Affordance diffusion [4] synthesizes hand-object interactions using diffusion models trained on large-scale data. GraspGen-X [11] performs cross-embodiment diffusion-based grasping trained on billions of simulated grasps. GraspLDP [12] proposes a latent diffusion approach for generalizable grasping. GraspFoM [13] utilizes

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3D foundation priors for joint reconstruction and grasp generation. DCGrasp [14] enables controllable, diffusion-based hand-object grasp generation. Dexter [15] employs autoregressive, language-driven dexterous grasp generation with embodied contact reasoning. Cross-view fusion [16] fuses multiple camera views via a trained network for robust 6-DoF pose estimation, while Contact-GraspNet [10] serves as a purely discriminative, non-generative baseline trained on synthetic point clouds.

B. Imagination and Affordance Learning

The concept of imagination and affordance learning has been explored for robotic manipulation. Luo et al. [26] learn affordance grounding from exocentric images via a trained cross-view transfer framework. Part-SLIP [27] lifts 2D detections from a pretrained image-language model for low-shot 3D part segmentation. SATR [28] performs zero-shot 3D shape segmentation using off-the-shelf 2D detectors, requiring no training. CLIP-based models [29] enable open-vocabulary understanding through large-scale contrastive pretraining. Visual foresight [30] learns physical dynamics through video prediction, requiring extensive training data. One-shot affordance learning [18] trains on a single example per category yet generalizes reasonably to unseen objects and affordances. ShapeGrasp [19] uses large language models over a geometric decomposition for zero-shot, training-free grasp reasoning. Language-guided dexterous grasp generation [20] guides grasp selection via a dataset-trained model, while AnyGrasp [17] offers a purely discriminative grasp-perception baseline with no affordance or imagination component.

III. METHODOLOGY

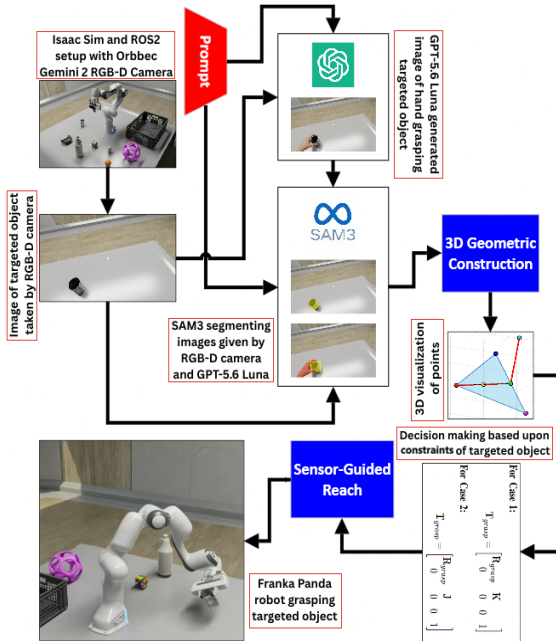


Fig. 1: Block diagram illustrating the complete IMIGRAS pipeline for zero-shot 6-DOF grasp generation.

A. GPT-5.6 Luna Image Generation

Given the original RGB image $\mathbf{I}_{orig} \in \mathbb{R}^{1080 \times 1920 \times 3}$, GPT-5.6 Luna generates a corresponding image $\mathbf{I}_{gpt}$ with a realistic hand grasping the object, preserving object position, orientation, and scale. The prompt requires red, blue, and green circles at thumb tip (A), index fingertip (B), and wrist (C), respectively. This step leverages the generative model's understanding of human grasping behavior to produce physically plausible hand configurations without any training data.

B. Segmentation and Landmark Detection

SAM3 [9] segments object masks $\mathcal{M}_{gpt}$ and $\mathcal{M}_{real}$, and hand mask $\mathcal{M}_{hand}$. Colored landmarks are detected using a color LUT approach. For each target color, a LUT is built and the point is found by minimizing within the hand mask:

$$\text{LUT}_{color}(r, g, b) = (r - r_{target})^2 + (g - g_{target})^2 + (b - b_{target})^2 \quad (1)$$

$$P = \arg \min_{\mathbf{p} \in \mathcal{M}_{hand}} \text{LUT}_{color}(\mathbf{I}_{gpt}(\mathbf{p})) \quad (2)$$

This yields $A = (u_A, v_A)$ for thumb tip, $B = (u_B, v_B)$ for index fingertip, and $C = (u_C, v_C)$ for wrist.

C. Mask Validation and Correction

Points A and B are validated to lie within $\mathcal{M}_{gpt}$. If not, the closest mask pixel is found via expanding circle search:

$$A' = \arg \min_{\mathbf{p} \in \mathcal{M}_{gpt}} \|\mathbf{p} - A\|_2, \quad B' = \arg \min_{\mathbf{p} \in \mathcal{M}_{gpt}} \|\mathbf{p} - B\|_2 \quad (3)$$

This validation step ensures robustness against minor inaccuracies in GPT-generated landmark placement, preventing downstream errors in grasp computation.

D. 2D Geometric Construction

Line ℓ_C is constructed through C parallel to AB, and perpendicular bisector ℓ_D of AB is constructed. Their intersection E is computed. Walking along $\overline{ED}$ from E to D, the first pixel inside $\mathcal{M}_{gpt}$ is identified as the grasp point T. This geometric construction leverages the relationship between finger positions and object geometry to determine the optimal grasp point on the object surface.

E. Bounding-Box Transfer

Direct pixel transfer between images is not possible due to minor scale and translation differences. For each mask $\mathcal{M}$, the bounding box center V and diagonal length L are computed. The scale ratio $r = L(\mathcal{M}_{gpt})/L(\mathcal{M}_{real})$ captures the relative scaling. For each point P in $\{A, B, T\}$, it is transferred to the real image using polar coordinates centered at the bounding box center:

$$P'' = \text{Project}_{\mathcal{M}_{real}} \left(V_{real} + r \cdot \|P - V_{gpt}\|_2 \cdot \frac{P - V_{gpt}}{\|P - V_{gpt}\|_2} \right) \quad (4)$$

This approach ensures translation and scale invariance, enabling accurate correspondence mapping between generated and real images.

F. 3D Reconstruction and Grasp Frame Computation

Using the RGB-D camera intrinsic matrix $\mathbf{K}$:

$$\mathbf{K} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \quad (5)$$

The back-projection to camera coordinates is:

$$\mathbf{P}_{camera} = \begin{bmatrix} (u - c_x) \cdot d / f_x \\ (v - c_y) \cdot d / f_y \\ d \end{bmatrix} \quad (6)$$

With camera extrinsics from Franka Panda kinematics:

$$\mathbf{P}_{base} = \mathbf{R}_{camera}^{base} \mathbf{P}_{camera} + \mathbf{t}_{camera}^{base} \quad (7)$$

The 3D points $\mathbf{A}_{3D}$, $\mathbf{B}_{3D}$, and $\mathbf{T}_{3D}$ are obtained in the robot base frame. $\mathbf{K}$ is the midpoint of $\mathbf{A}$ and $\mathbf{B}$. Points $\mathbf{L}$ and $\mathbf{M}$ are obtained by rotating $\mathbf{AB}$ to be perpendicular to $\mathbf{TK}$ in 3D space. The normal to the plane containing $\mathbf{L}$, $\mathbf{M}$, $\mathbf{T}$ is computed:

$$\mathbf{n} = (\mathbf{M} - \mathbf{L}) \times (\mathbf{T} - \mathbf{L}) \quad (8)$$

And point $\mathbf{X}$ is defined as:

$$\mathbf{X} = \mathbf{K} + \hat{\mathbf{n}} \cdot \delta \quad (9)$$

completing the grasp frame.

G. Rule-Based Grasp Alignment

The Franka Panda's physical constraints inform the rule base. Point $\mathbf{Y}$ is the 3D projection of the midpoint of $\mathbf{A}$ and $\mathbf{B}$ from the camera stream.

Case 1: $Y_z - K_z \geq -0.03$ ($\mathbf{Y}$ is above $\mathbf{K}$ by any amount or below $\mathbf{K}$ by up to 3 cm)

The Z-axis (joint axis) is aligned parallel to $\mathbf{KX}$. The Y-axis (arm length direction) depends on $\mathbf{LM}$ magnitude:

Subcase 1a: $\|\mathbf{LM}\|_2 \geq 0.07$ ($\mathbf{LM}$ is 7 cm or more)

Y-axis is parallel to $\mathbf{TK}$, reach target is $\mathbf{X}$. Sensor feedback stops the arm if a surface is encountered during approach.

Subcase 1b: $\|\mathbf{LM}\|_2 < 0.07$ ($\mathbf{LM}$ is less than 7 cm)

Y-axis is parallel to $\mathbf{LM}$, reach target is $\mathbf{X}$. Sensor feedback stops the arm if a surface is encountered during approach.

Case 2: $Y_z - K_z < -0.03$ ($\mathbf{Y}$ is below $\mathbf{K}$ by more than 3 cm)

Z-axis is parallel to $\mathbf{KX}$. Y-axis is parallel to $\mathbf{TK}$. Reach target is $\mathbf{J}$, the midpoint of $\mathbf{TK}$. Sensor feedback stops the arm if a surface is encountered during approach.

For all cases, the X-axis is the cross product of $\mathbf{Y}$ and $\mathbf{Z}$ axes, completing the orthonormal frame. The rotation matrix is constructed from the three axes:

$$\mathbf{R}_{grasp} = [\hat{\mathbf{x}} \quad \hat{\mathbf{y}} \quad \hat{\mathbf{z}}] \quad (10)$$

The final homogeneous transformation matrix is:

For Case 1:

$$\mathbf{T}_{grasp} = \begin{bmatrix} \mathbf{R}_{grasp} & \mathbf{K} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (11)$$

For Case 2:

$$\mathbf{T}_{grasp} = \begin{bmatrix} \mathbf{R}_{grasp} & \mathbf{J} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (12)$$

The 3 cm and 7 cm thresholds were empirically determined through extensive experimentation on diverse household objects, considering the gripper's physical constraints, and can be adjusted for environment-specific requirements.

IV. EXPERIMENTS AND RESULTS

A. Experimental Setup

Franka Panda robot and Orbbec Gemini 2 RGB-D camera were used in Isaac Sim along with ROS2 integration, in a cluttered environment with groups of 6-9 objects Fig. 2. The proposed method was validated on 130 diverse household objects including storage objects, decoration objects, toys, etc.

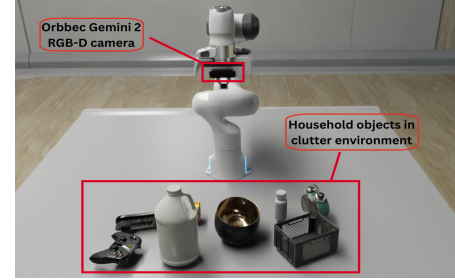


Fig. 2: Isaac Sim and ROS2 setup for experimental verification

B. Results and Analysis

The complete experimental results across all 130 objects show that IMIGRASP achieves a success rate of 86.9% (113 successful grasps out of 130 attempts) with only a single attempt per object. Cylindrical and cuboid objects achieved approximately 93% success rate, the big reason was that GPT was itself very clear that from where to grasp this object. Table I presents the success rate comparison with state-of-the-art methods.

TABLE I: Success rate comparison with state-of-the-art methods.

Method	Success Rate (%)
Contact-GraspNet	90.2
Cross-View Fusion	96.0
IMIGRASP	86.9

Fig. 3 shows complete pipeline demonstration for 7 objects i.e., from object segmentation in actual image taken to successful grasp. While the two methods listed above report higher success rates, it is important to note that IMIGRASP operates with a single attempt per object across 130 diverse household objects and requires no prior training or fine tuning for the cluttered environment or specific object.



Fig. 3: IMIGRASP: Zero-shot 6-DOF grasp generation using generative AI for imagination guided pose estimation. Each row shows results for one of 7 objects i.e., PS Controller, Shoe Brush, Brass Bowl, Utility Jug, Plastic Container, Packer Bottle, and Alarm Clock. Columns show object mask in actual image, hand grasping image by GPT-5.6 Luna, object and hand masks in genAI image, genAI image with geometric construction lines, object in actual image with final mapped points A, B, T and successful grasp execution attempt by Franka Panda robot respectively.

TABLE II: Grasp performance and failure analysis across 130 objects.

Outcome	Occurrences	Percentage
Grasps touching others	81	62.3%
Minor movement of others	59	45.4%
Major movement of others	22	16.9%
Surrounding objects that fell	13	10.0%
GPT-5.6 Luna failure	11	8.5%
SAM3 wrong bounding box	6	4.6%

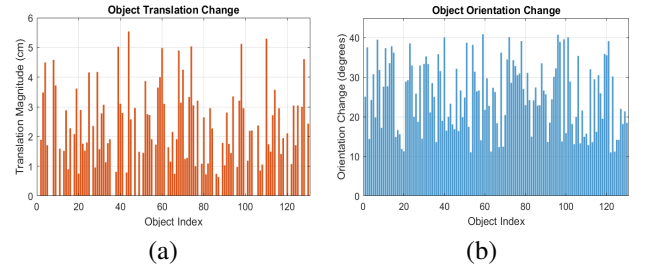


Fig. 4: Displacement and orientation error in all objects (a) Translation of objects from their original positions. (b) Orientation change of objects from their original orientations.

Fig. 4 presents the displacement analysis during grasping approach. Maximum translation observed was 5.6 cm, while maximum orientation change was 41 degrees. Table II summarizes success and failure categories and their frequencies. Fig. 3 presents the complete pipeline that how 7 objects were dealt with to Franka Arm grasping them.



Fig. 5: Rubik's Cube failure case (a) GPT-5.6 Luna generated a grasp from the corner instead of the side. (b) The cube slipped under Franka Panda's finger force, resulting in an unsuccessful grasp.



Fig. 6: Failure case examples. (a) Bowl: SAM3 bounding box exceeds object limits causing misplacement of mapped points. (b) Oil Tin: GPT-5.6 Luna incorrectly generated a grasping configuration for a plastic container instead of the oil tin.

Of the 17 unsuccessful attempts, 11 were attributed to GPT-5.6 Luna failure, where the generated hand configuration was inappropriate for the object geometry or it grasped wrong object. For example, generating a corner grasp for the Rubik's Cube (Fig. 5a) instead of a side grasp, causing the cube to slip due to finger force (Fig. 5b) and the oil tin case (Fig. 6b) illustrates a unique failure where GPT-5.6 Luna generated a grasping configuration for a plastic storage container instead of the actual oil tin, demonstrating the importance of prompt clarity and the model's ability to distinguish between visually similar objects [5, 6]. The remaining 6 failures were due to SAM3 wrong bounding box (Fig. 6a), where the bounding box exceeded the object limits causing misplacement of mapped points. In cluttered environments with groups of 6-9 objects, 81 successful grasps occurred with the object touching other objects. Among these, 59 resulted in minor movement of surrounding objects, 22 caused major movement, and 13 objects fell during the process. This indicates that while reaching and gripping the target object inevitably disturbs neighboring objects, the methodology remains robust in most cluttered scenarios. The 3D geometric construction using points L, M, T, K, X, and the associated vectors (LM, TK, KX) provides a general

and flexible grasp pose that does not require perfect adherence minor deviations, slips, and movements during approach still frequently lead to successful grasps, as evidenced by the overall success rate. Thin and horizontally oriented objects were not tested due to gripper and methodology limitations, as these geometries present challenges for the two-finger parallel gripper configuration and gripper will not be able to grasp that unless the object is thick enough that contact with gripper's fingers is enough to hold and lift it.

C. Computational Complexity Analysis

A key advantage of the proposed zero-shot approach is its favorable time and space complexity compared to training based and retrieval based methods. Training based methods like Contact-GraspNet [10] require 40 hours of GPU training on 17 million simulated grasps, while Cross-View Fusion [16] requires training on the large-scale GraspNet-1B dataset. Retrieval based methods like GRIM [1] require memory reconstruction (7 minutes per item) and online semantic alignment (10 seconds per grasp) during inference. In contrast, IMIGRASP operates with no training phase, reducing both the time and energy costs associated with model training. IMIGRASP achieves near constant time complexity $\mathcal{O}(1)$ with respect to the number of objects or training examples, as the pipeline consists of a single generative inference call followed by basic matrix and pixel wise operations. The space complexity is equally minimal $\mathcal{O}(1)$, requiring only the input image and intermediate masks during execution, with no datasets, memory banks, or precomputed features to store. While the success rate of IMIGRASP (86.9%) is lower than Contact-GraspNet (90.2%) and Cross-View Fusion (96.0%), its significantly lower computational requirements make it particularly suitable for resource-constrained robotic systems, edge computing, and real-time deployment in cluttered environments where computational efficiency is critical.

V. CONCLUSION

IMIGRASP presents a practical zero-shot solution for 6-DOF grasp generation by leveraging generative AI to imagine plausible hand-object interactions. The framework eliminates the need for training data, hand pose estimation networks, or object-specific tuning, making it suitable for applications where data collection is impractical. Its low computational footprint and near-constant time complexity enable real-time deployment on resource-constrained robotic systems in warehouses, assistive robotics, and household manipulation tasks. The results validate that generative AI models, trained on internet-scale visual data, can serve as effective imagination priors for robotic grasping, reducing reliance on expensive training pipelines and enabling rapid deployment in unstructured environments.

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