Algorithm Documentation - Seamlessly Integrating a Person into a Scene

Objective:
To integrate a person's image into a natural outdoor scene (park) so that the final composition appears photorealistic. The process ensures correct alignment of shadows, lighting, and colors between the person and the background.

Steps Taken:
Task 1: Capturing and Preparing the Person's Image:

1. Captured a high-quality, front-facing image of the person against a plain, well-lit wall to simplify background removal.
2. Removed the background: Used the remove.bg online tool to automatically separate the person from the background and generate a transparent PNG image for compositing.

Task 2: Analyzing Shadows and Lighting of the Background Image

1. Selected a background scene of a sunlit park with strong side lighting (sun from the upper right).
2. Programmatically analyzed shadows:
    a. Converted background to grayscale.
    b. Applied histogram equalization and thresholding using OpenCV to create a shadow mask.
    c. Used cv2.findContours and cv2.fitEllipse on large shadow regions to estimate shadow orientation.
    d. Drew light (red) and shadow (blue) vectors using arrowed lines to visualize direction.

Task 3: Determining Light Direction

1. Determined that light source was coming from the upper right (around 45 degrees) based on shadow vectors.
2. This informed positioning of the person and the shadow in the composite image.

Task 4: Coloring and Blending (Missing Steps Identified)

1. Color harmonization: Adjusting brightness, contrast, and warmth of the person to match the warm, bright background.
2. Edge blending: Softening the cut-out edges of the person to avoid hard lines.
3. Approach:
    a. Used Match Color (Photoshop) to align a person's tone to the background.
    b. Added Curves adjustment (clipped to person) to brighten and warm highlights on the sun-facing side.
    c. Applied a layer mask + soft brush to manually blend edges.

Task 5: Generating the Final Output

1. Combined person's layer, shadow layer, and background.
2. Ensured alignment of lighting (sunlit side brighter), added color grading, and refined mask for clean integration.
3. Exported high-resolution composite image.

Tools Used & Their Reasons:

1. Photoshop (for compositing, color adjustment, masking, shadow painting): As it offered precise control over color, shadows, and edge blending.
2. OpenCV + Python (for shadow detection and light direction estimation): As it allowed programmatic shadow analysis for objective light direction estimation.

3. Matplotlib (for visualizing analysis results): As it offers flexible, high-quality plotting that integrates easily with OpenCV and Python, making it simple to generate clear, labeled visuals for analysis and documentation.
4. Remove.bg (for removing the background of the image): As it is fast, accurate, requires no manual masking effort.

Challenges + How I Solved Them:

1. Original person image lighting didn't match scene: Adjusted using match color + warming filter
2. Person looked pasted initially: Added layer mask
3. Shadows detection had noise: Refined mask with morphological operations + area filtering

Possible Enhancements:

1. Could further improve shadow realism by using 3D shadow projection tools.
2. Could try AI relighting tools to auto-match light and shadow more accurately.
3. Could automate blending pipeline via scripting or AI-based compositors.