

Camera Registration and Image Correspondences

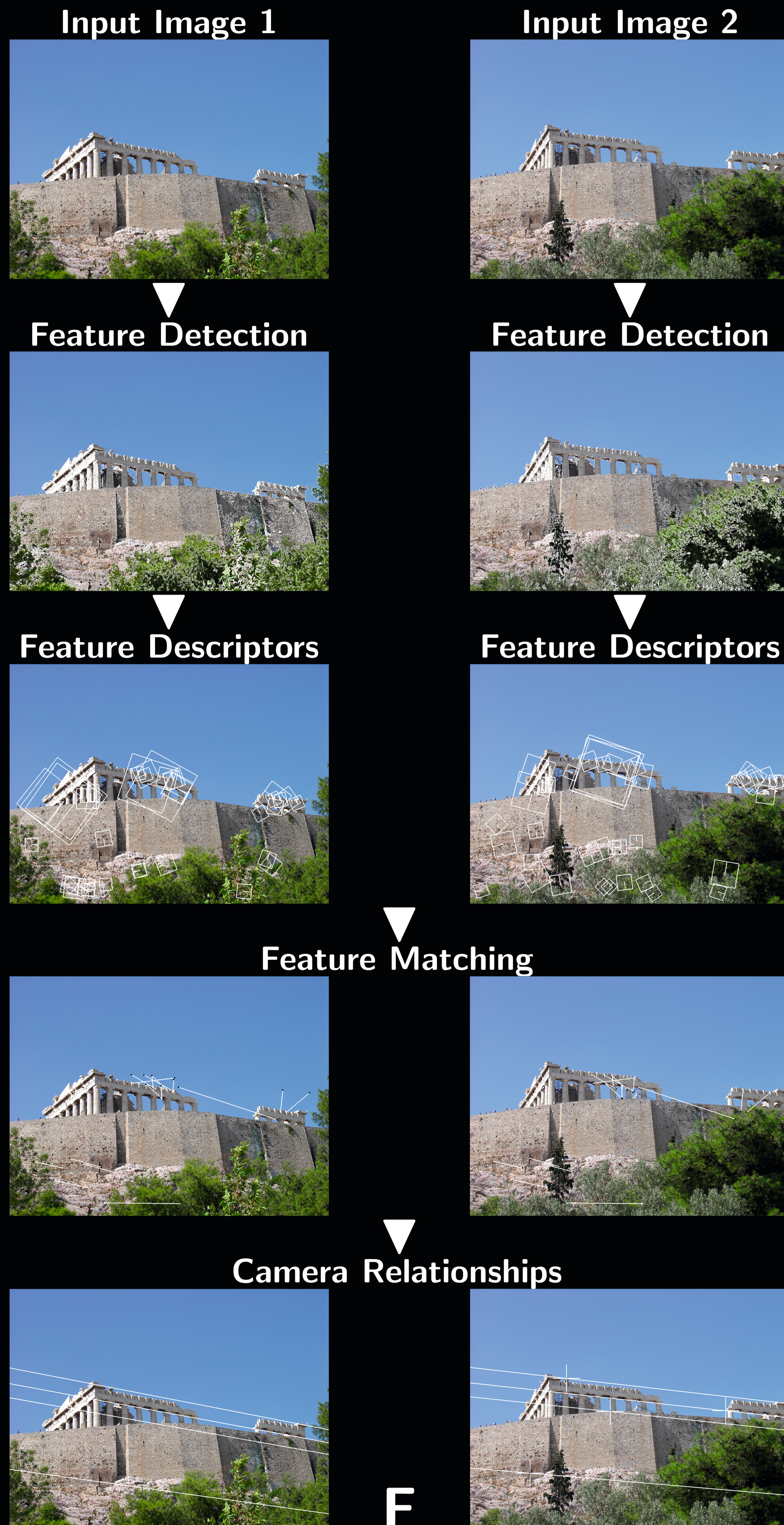
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Abstract

The goal is to reconstruct 3D models **automatically** from **two or more** input images, taken with a **hand-held camera** where **no a priori calibration** is necessary for the camera. It is work in progress. Automatic and fairly robust determination of individual camera poses between two images has been achieved, which is a crucial part. Two reports have been written, the first one [Anoq09a] focusing on determining **feature correspondences** between images and the second one [Anoq09b] focusing on using these to robustly establish the **relationship** between the **camera poses** in each image, expressed as a **fundamental matrix**. The technology from this project will be turned into a commercial application: **CeX3D Inverse**.

Pipeline

Below is an overview of the pipeline, where the last step contains a lot, the entire second report [Anoq09b]:



Feature (a.k.a. Interest Point) Detection

Image features are detected, ideally such that they are *affinely covariant* between images. Methods for this include **Harris points**, **scale-adapted Harris-Laplace** features, **affine-adapted Harris-Affine** features, **Adaptive Non-Maximum Suppression** (enhancement method), **Hessian-Laplace**, **Hessian-Affine**, **Fast Hessian**, **Differences of Gaussians (DoG)**, **Laplacian of Gaussians (LoG)**, **Fast Level Set Transform (FLST)**, **Intensity Based Regions (IBR)**, **Edge Based Regions (EBR)**, or **Maximally Stable Extremal Regions (MSER)** [Mata02], where this last option is currently used in this project, but may be combined with the other methods. The article [Miko06] makes a good comparison between many of these methods.

Feature Descriptors

Feature descriptors are computed for all detected features, to enable efficient matching. Methods for this include **Scale Invariant Feature Transform (SIFT)**, **Multi-Scale Oriented Patches (MOPS)**, **second order generalized moments** (possibly with taking colour into account), **complex moments**, **Gaussian derivatives** (up to 4th order), **Gradient Location and Orientation Histogram (GLOH)**, **Principal Component Analysis (PCA)** (enhancement method), or **Speeded Up Robust Features (SURF)** [BayH06]. The last option is used in this project. The article [Miko05] has a good comparison between many of these methods.

The otherwise excellent and authoritative book [Hart03] does not describe or compare the advanced methods listed here, nor the feature detectors above, so it is an important contribution of the report [Anoq09a] to thoroughly present and compare them.

Feature Matching

Feature matching may be done using *fast approximate methods* or by brute force. Even brute force can be done by **one-way matching**, **two-way conservative**, **two-way cross-correlated** or **two-way aggressive matching**, as argued in [Anoq09a]. The first report [Anoq09a] used two-way *conservative* matching, but **two lines of code** were changed for the second report [Anoq09b] to use two-way *cross-correlated* matching, giving *significantly improved results*.

Camera Relationships

Camera relationships are derived as a **fundamental matrix** F from the set of matched correspondences $x_i \leftrightarrow x'_i$ by a combination of several methods: the **7-point algorithm**, the **geometric reprojection error measure**, **projective reconstruction** by triangulation, **RANdom SAMpling Consensus (RANSAC)** [Fisc81]

and **non-linear Levenberg-Marquardt optimization**. $F = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}$ should be found such that

as many correspondences $x_i \leftrightarrow x'_i$ as possible come as close as possible to satisfying the equation:

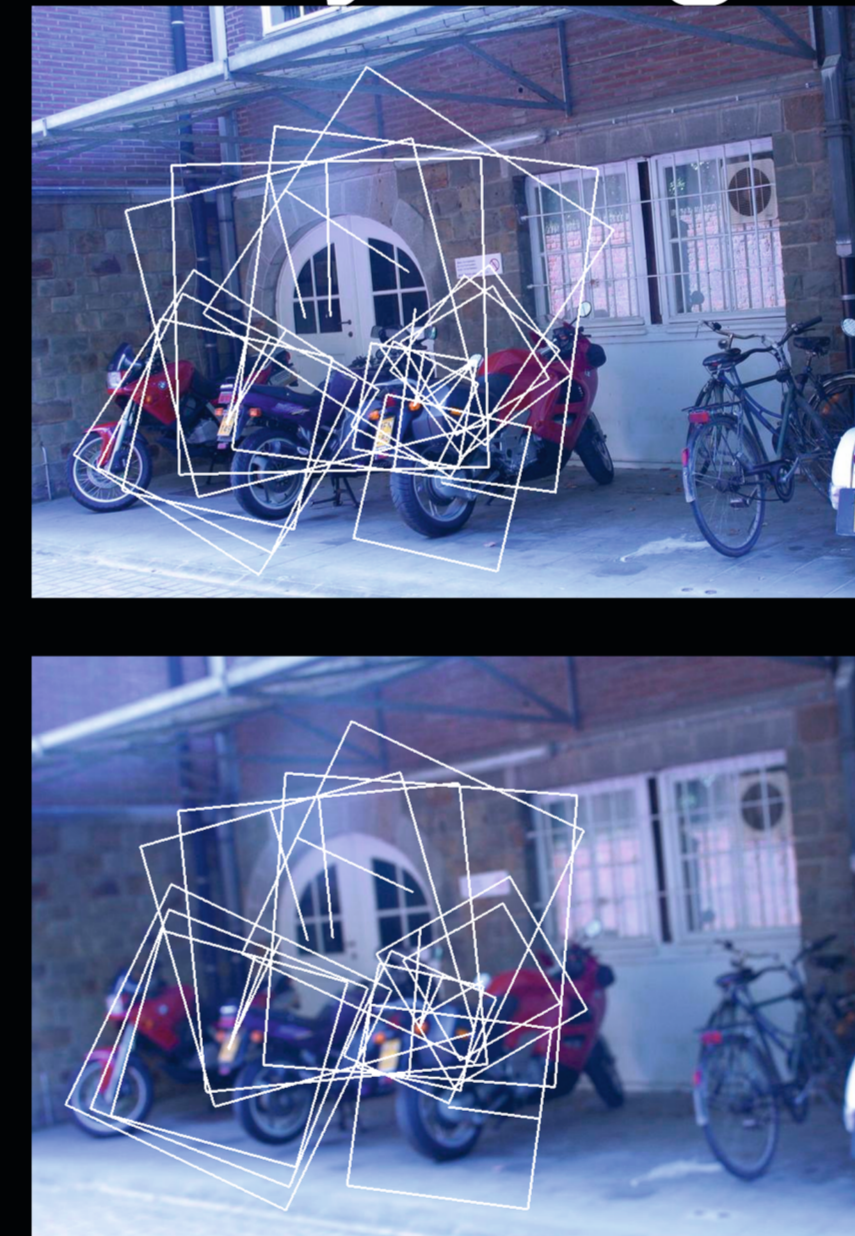
$$x_i'^T F x_i = 0$$

This is the topic of [Anoq09b] and an important contribution is a concise collection of many key formulas.

Examples of Challenges

Challenges: **image blur**, **occlusions**, **rotation**, **scale**, **camera viewing angle** and **degenerate camera motion**.

Blurry Images



Occlusions



Rotation



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