lamar.ethz.ch

LaMAR Tutorial
4. Practical guide & conclusion

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ECCV TEL AVIV 2022

Microsoft

Overview

a) Benchmarking Pipeline
b) Customizing the Pipeline
c) Data format
d) Additional tools
e) Conclusion

a) Benchmarking Pipeline

Benchmarking pipeline – Mapping

feature extraction
global features
local features

Many realistic configurations (red)
Swapable with GT quantities (blue) derived from lidar

Benchmarking pipeline – Mapping

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pair selection
retrieval
(& poses)
OR
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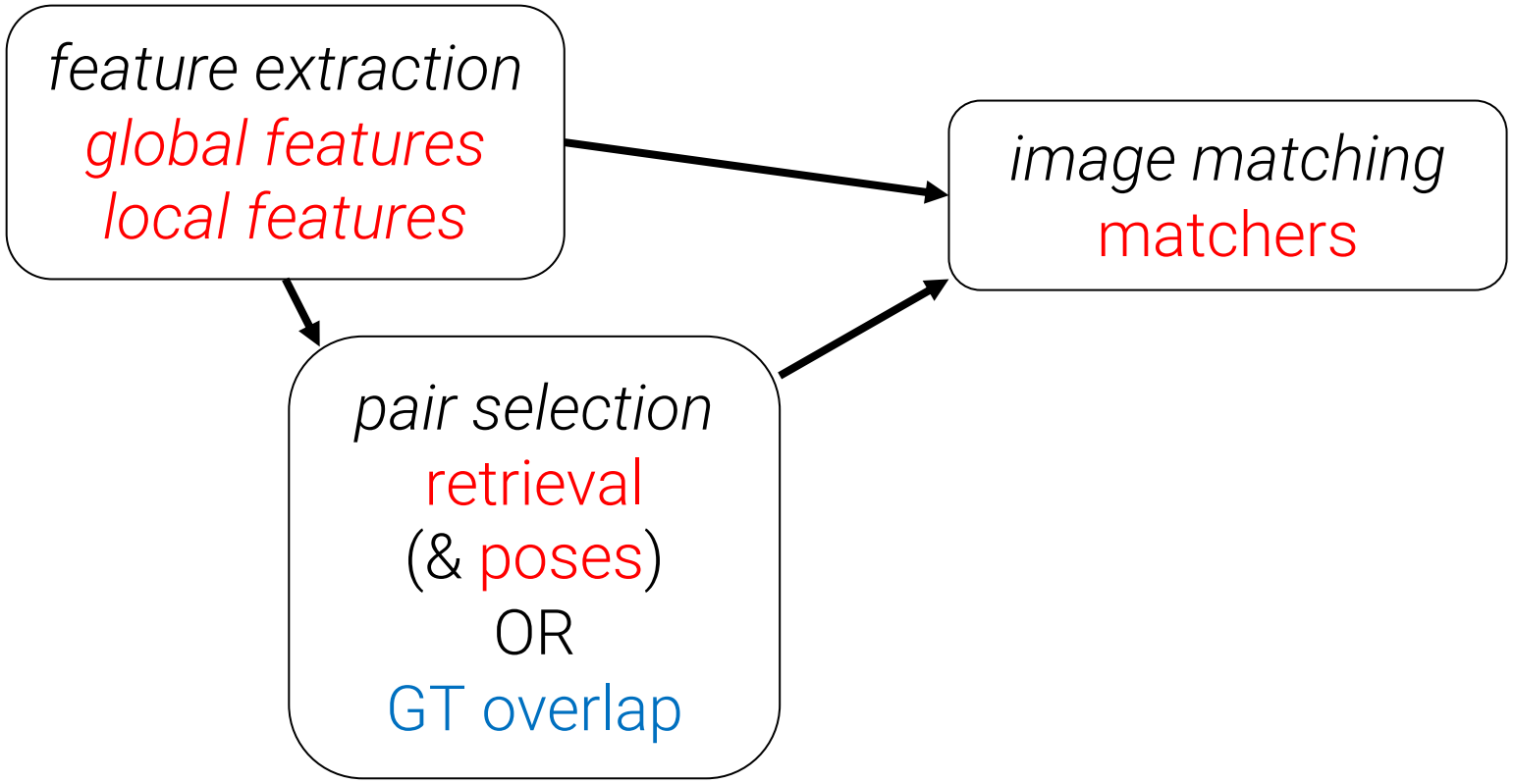

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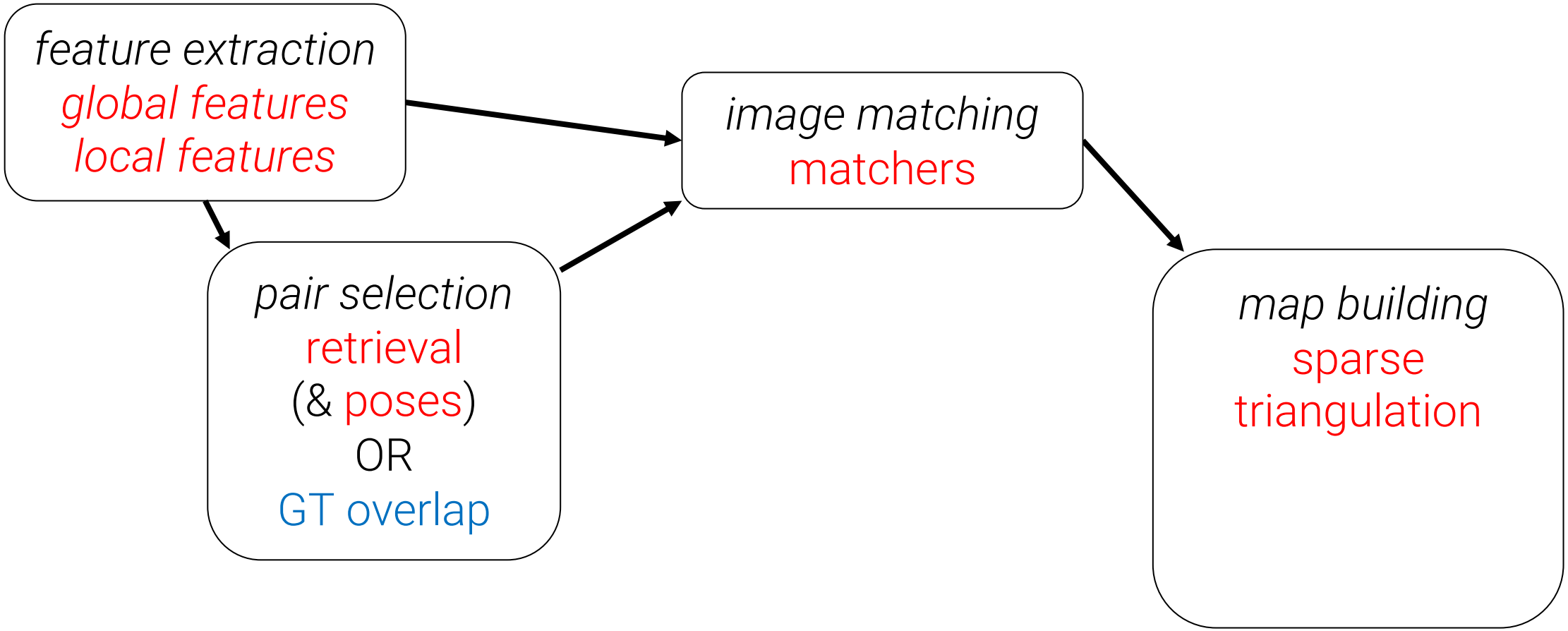

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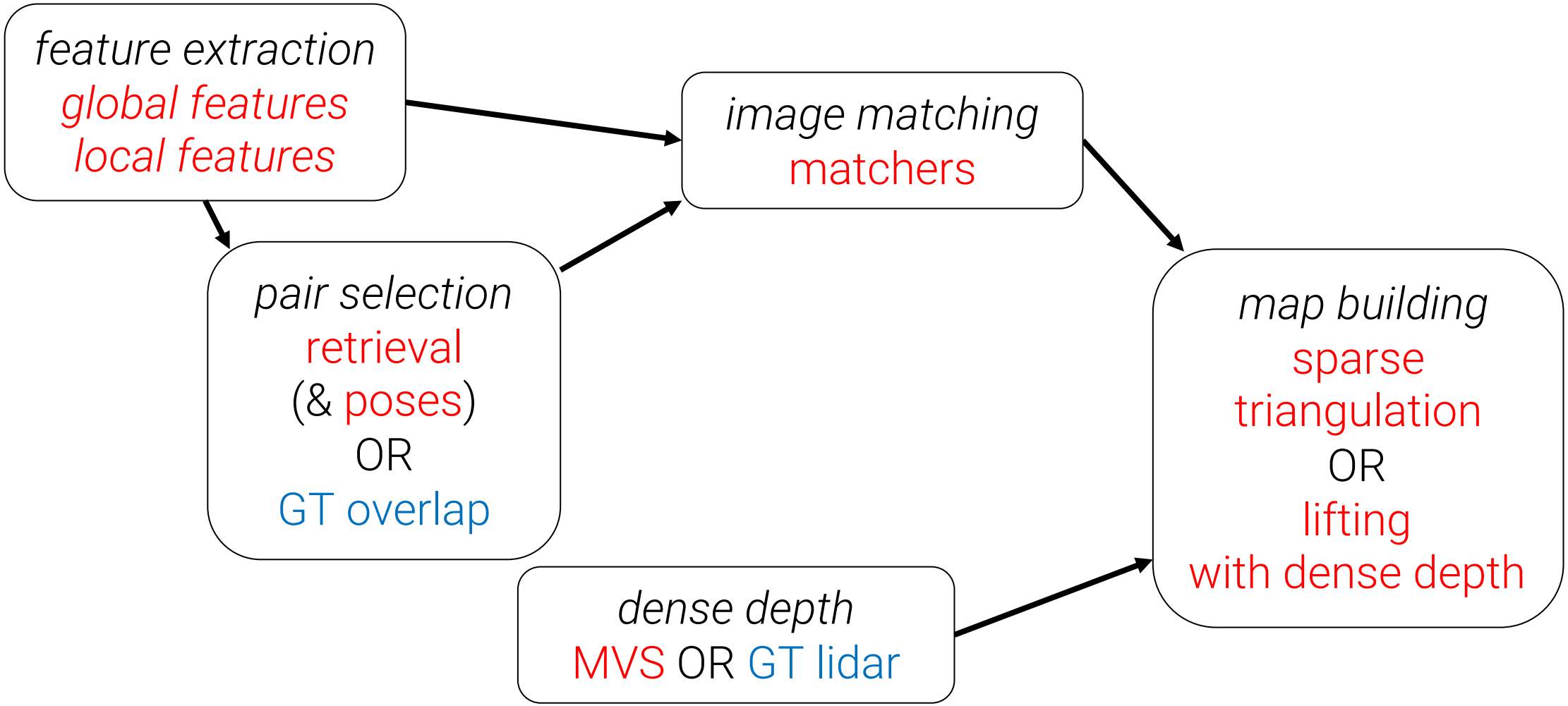

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Benchmarking pipeline – Localization

feature extraction
global features
local features

map building
sparse
triangulation
OR
lifting
with dense depth

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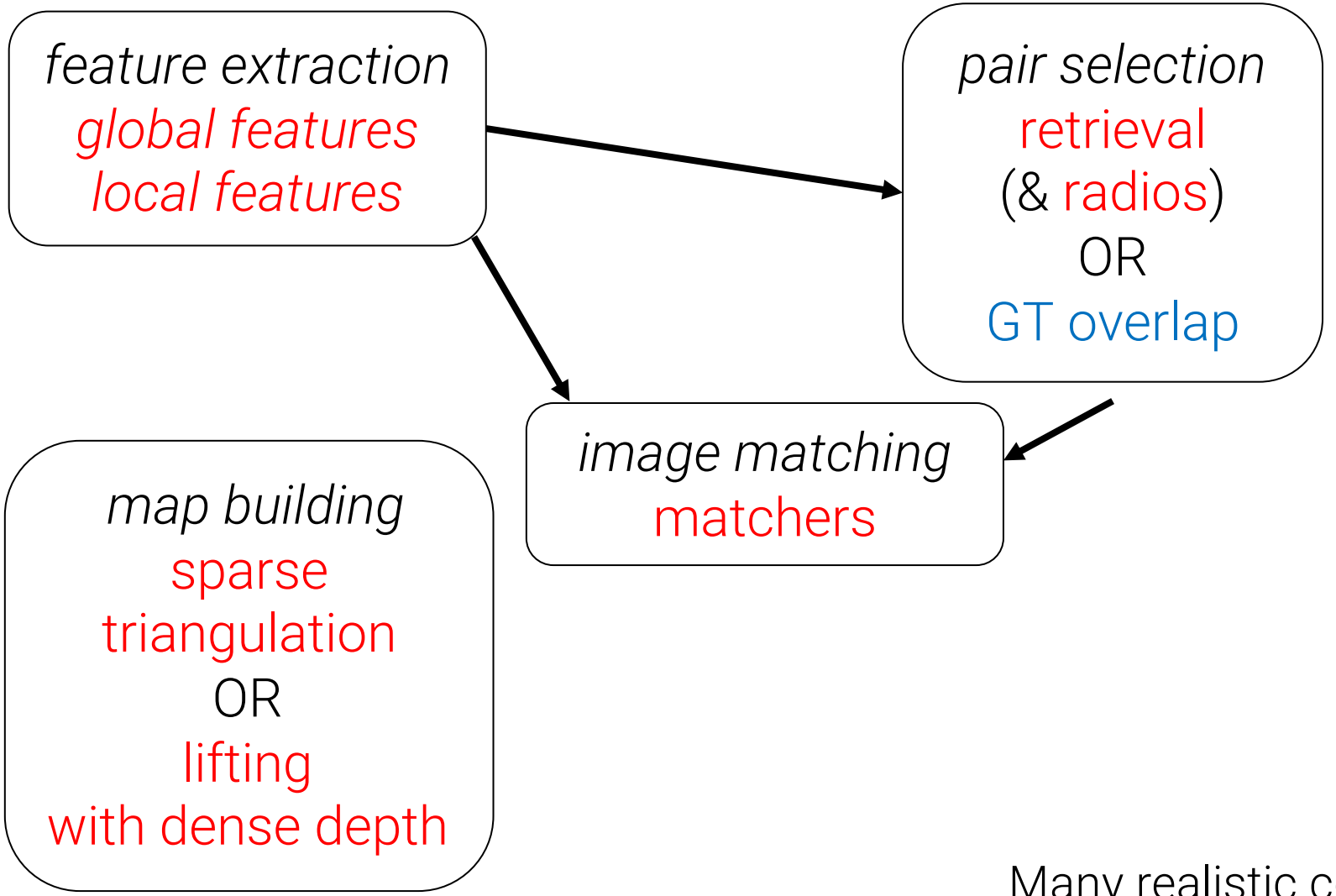

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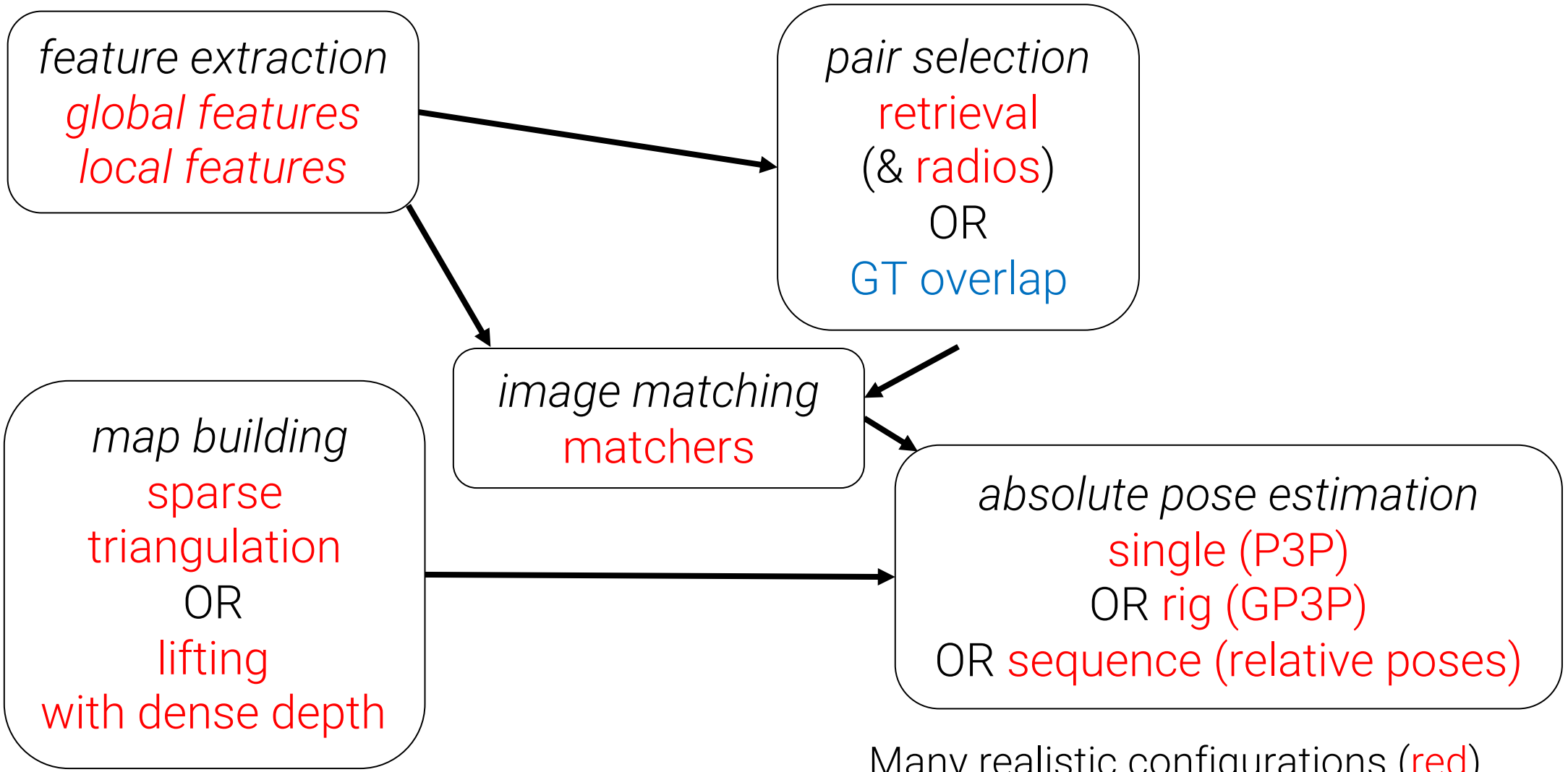

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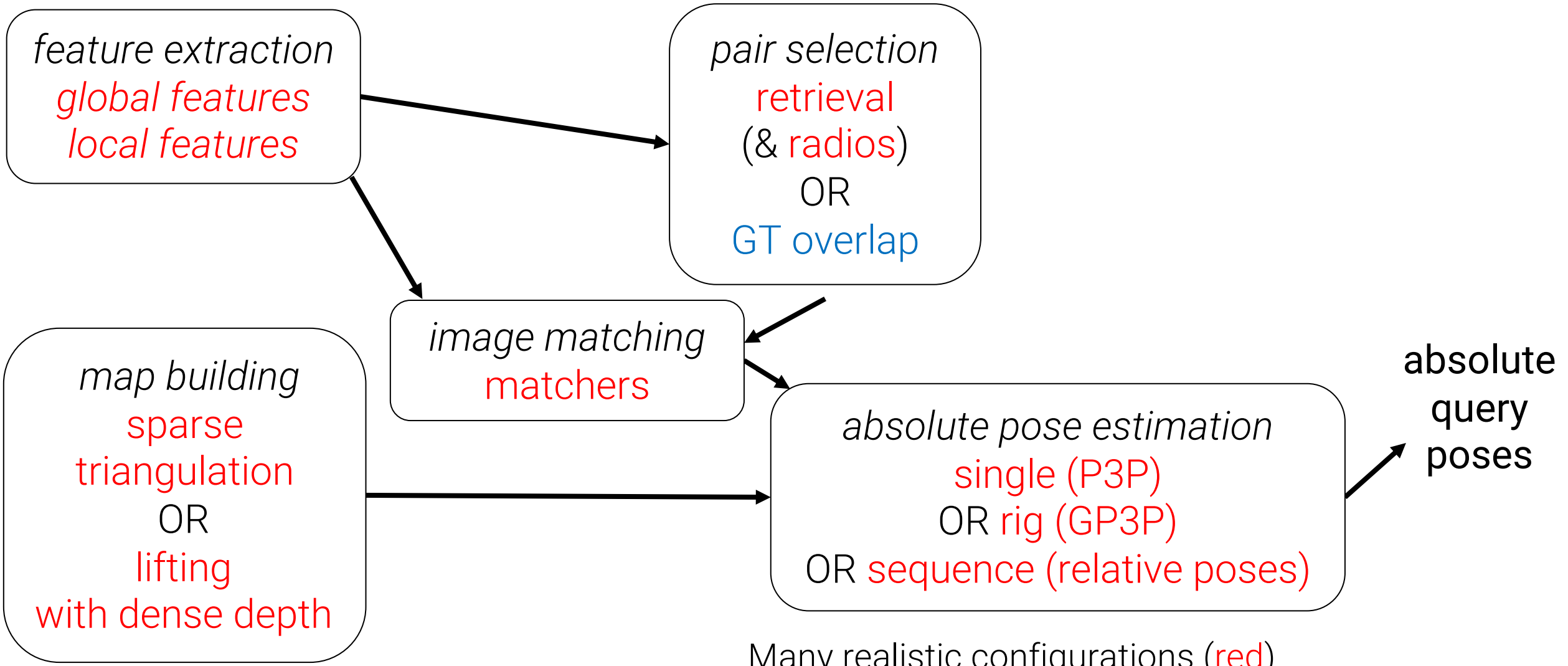

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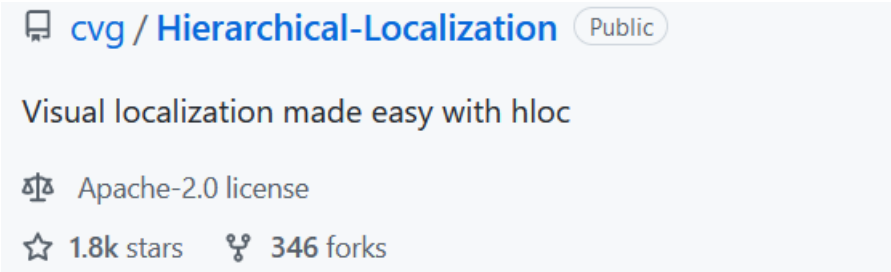
b) Customizing the Pipeline

Feature Extraction / Matching

- Builds upon Hierarchical-Localization (hloc) repository



- Minimal changes required in the benchmarking repository

Adding a new feature extractor

- Add the method to hloc
  - New class: hloc/extractors/my-extractor.py
  - Inputs: image
  - Outputs:
    - Global features: global descriptor
    - Local features: keypoints, descriptors

```python
class MyGlobalFeature(BaseModel):
    default_conf = {
        'model_name': 'MyGlobalFeature',
    }
    required_inputs = ['image']

    def _init(self, conf):
        pass

    def _forward(self, data):
        image = data['image']

        desc = np.zeros(512)

        return {
            'global_descriptor': desc
        }
```

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- New config in the benchmark repo
  - tasks/feature_extraction.py

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        pass

    def _forward(self, data):
        image = data['image']

        desc = np.zeros(512)

        return {
            'global_descriptor': desc
        }
```

```python
class RetrievalFeatureExtraction(FeatureExtraction):
    methods = {
        'netvlad': {
            'name': 'netvlad',
            'hloc': {
                'model': {'name': 'netvlad'},
                'preprocessing': {'resize_max': 640},
            },
        },
        'my-global-feature': {
            'name': 'my-global-feature',
            'hloc': {
                'model': {'name': 'MyGlobalFeature'},
                'preprocessing': {'resize_max': 640},
            },
        },
    }
```

Adding a new feature matcher

- Add the method to hloc
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  - Outputs: matches

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- New config in the benchmark repo
  - tasks/feature_matching.py

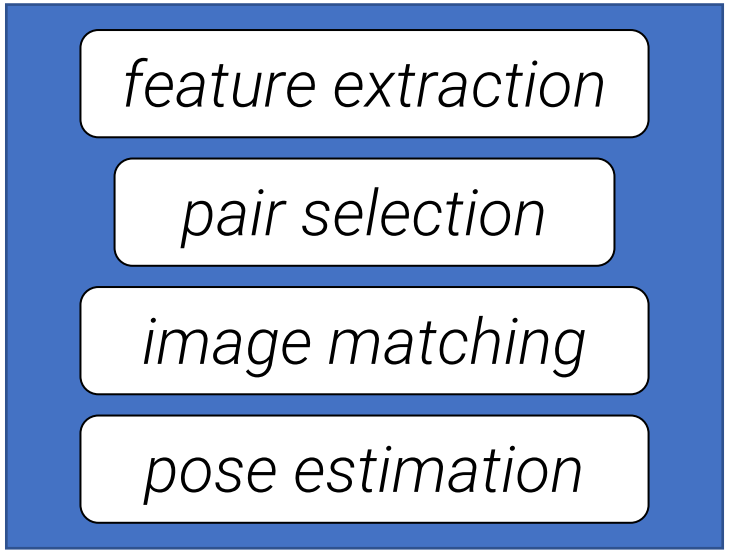
Mapping algorithm

- Create your own mapping class
- “run” method
  - Input: Capture object
  - Runs the reconstruction
- “get_points3D” method
  - Input:
    - image ID (key)
    - keypoint indices
  - Output:
    - valid indices
    - 3D coordinates, 3D point ids

```
class Triangulation(Mapping):
    method = {
        'name': 'triangulation',
        # some COLMAP parameters and thresholds
    }

    def __init__(self, config, outputs, capture, session_id,···

    def run(self, capture):···

    def get_points3D(self, key, point2D_indices):···
```

```
def get_points3D(self, key, point2D_indices):
    image = self.reconstruction.images[self.key2imageid[key]]
    valid = []
    xyz = []
    ids = []
    if len(image.points2D) > 0:
        for idx in point2D_indices:
            p = image.points2D[idx]
            valid.append(p.has_point3D())
            if valid[-1]:
                ids.append(p.point3D_id)
                xyz.append(self.reconstruction.points3D[ids[-1]].xyz)
    return np.array(valid, np.bool), xyz, ids
```

Sequence Baseline Overview



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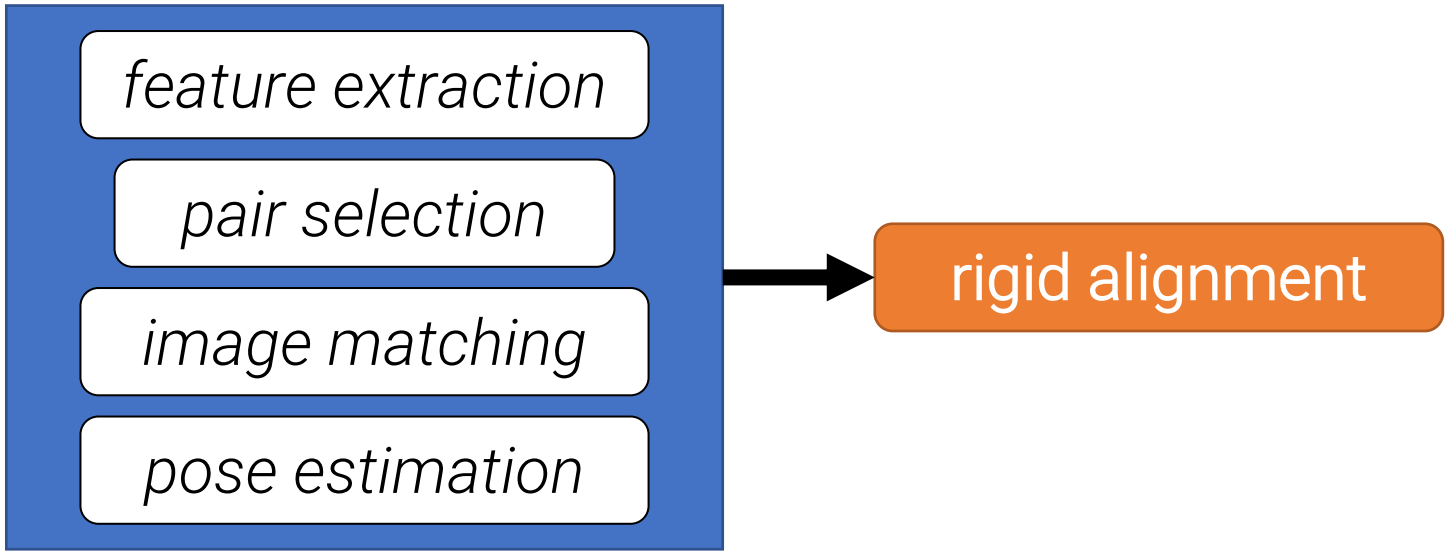

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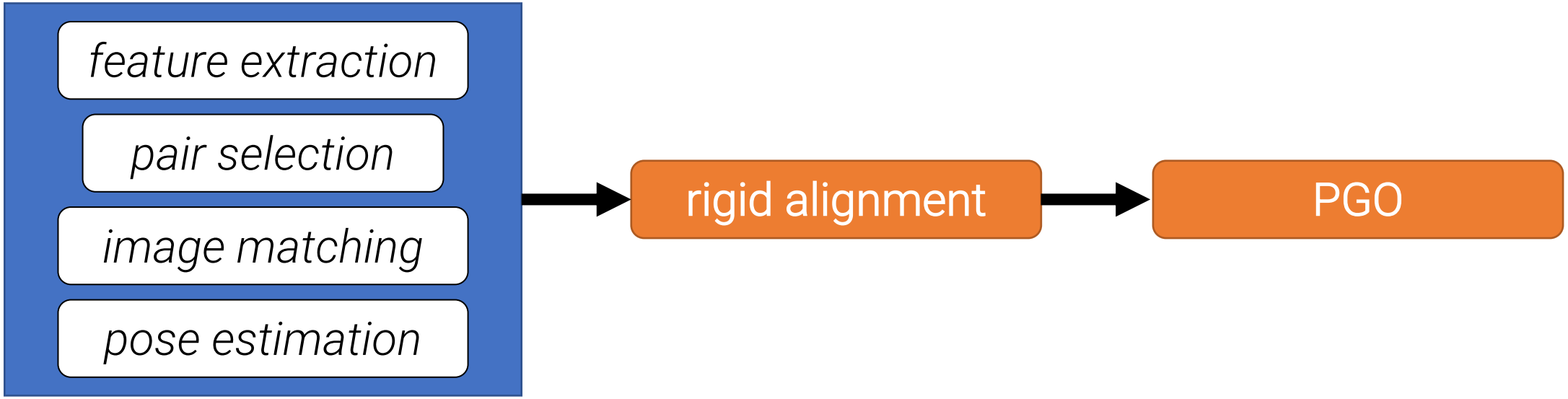

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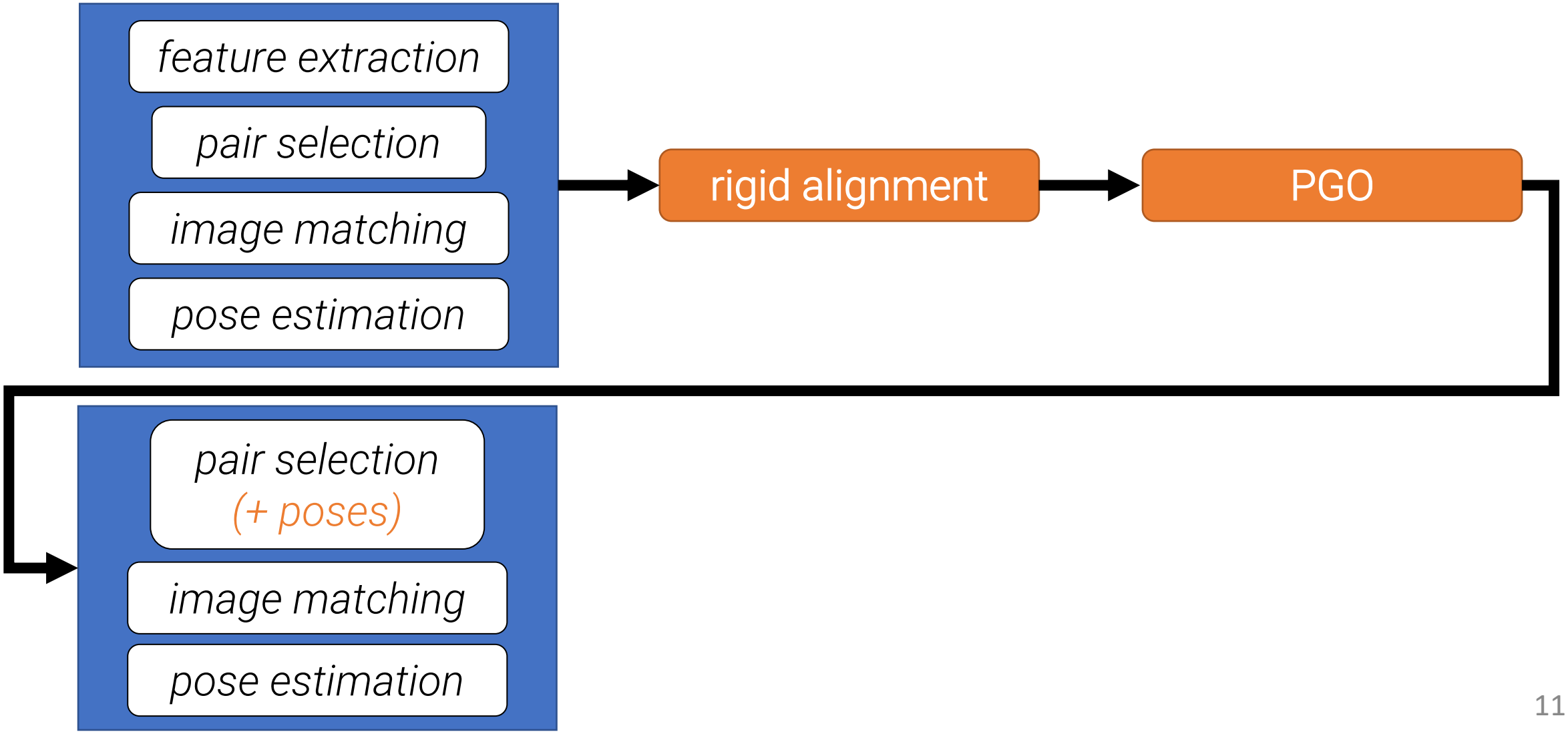

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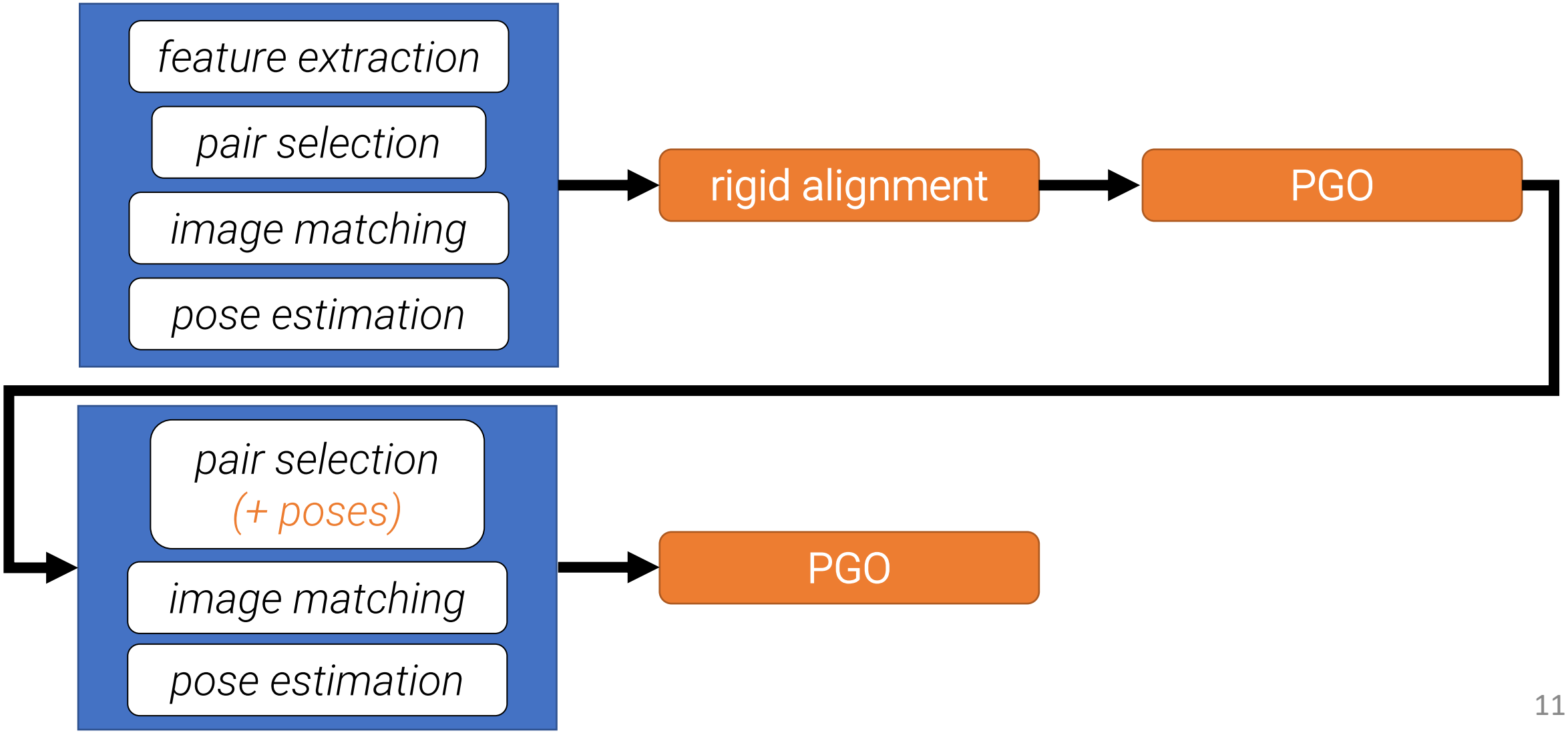

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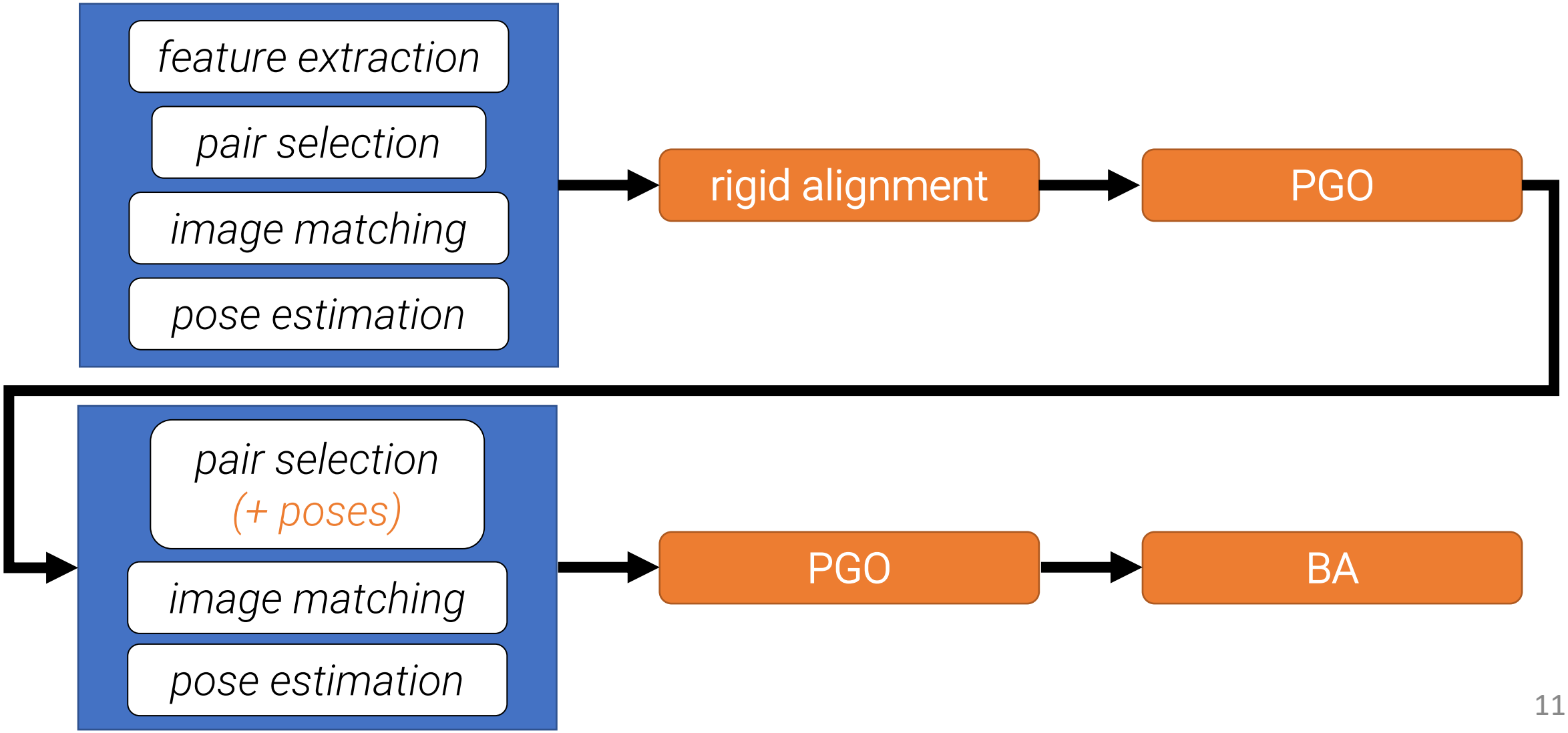

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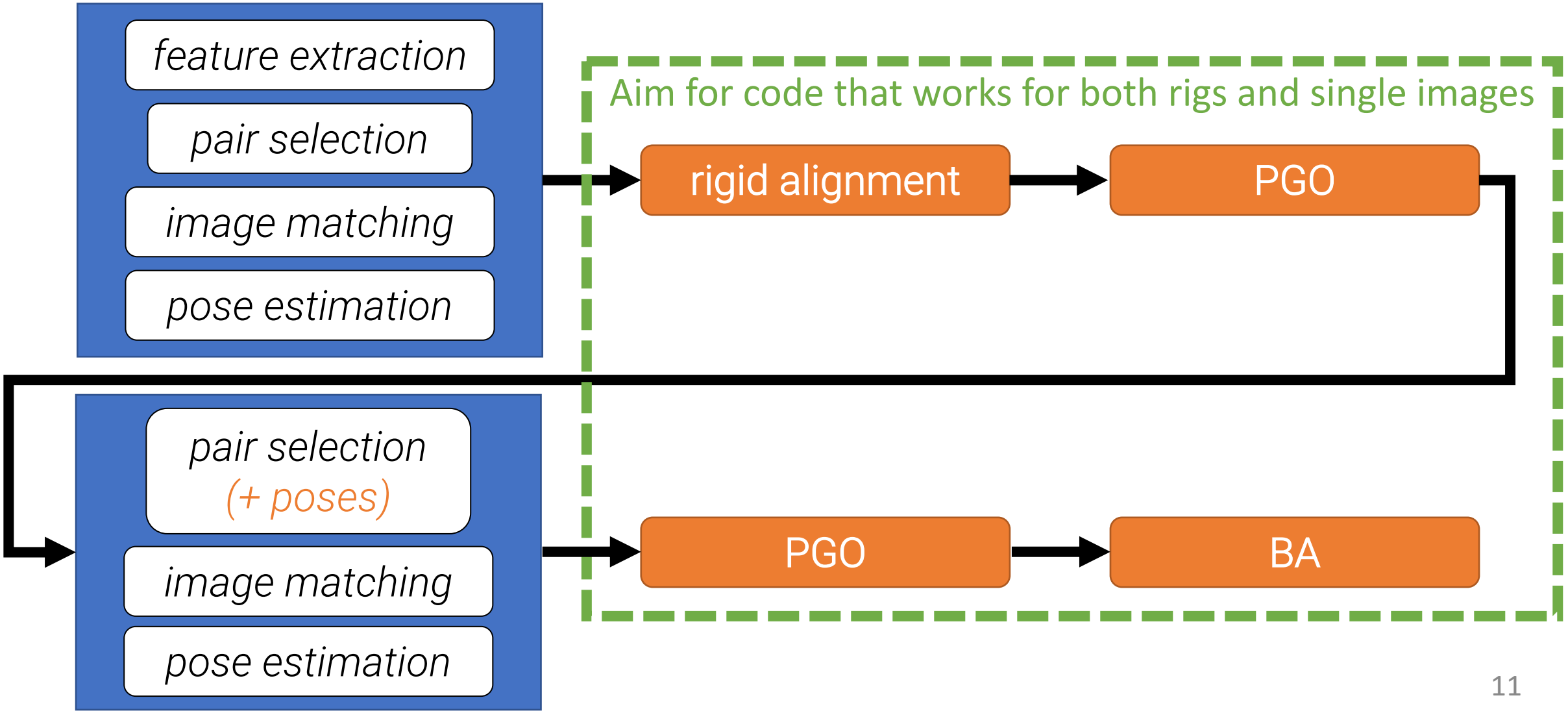
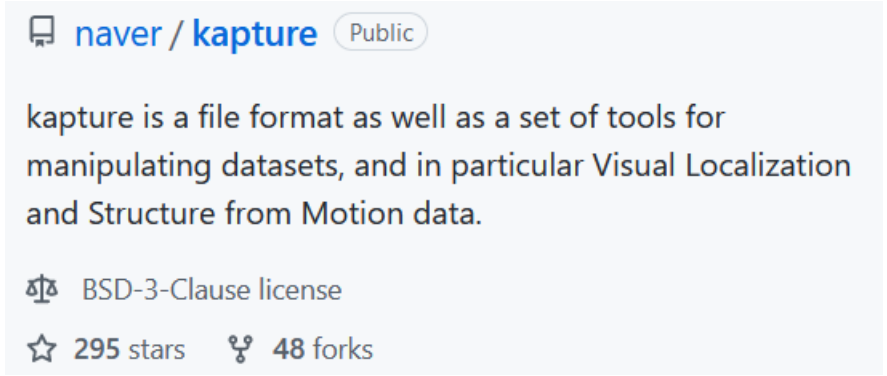


c) Data format

Existing data format

- *Kapture* format
  - Great format for Vis-Loc / SfM
  - Contains most common sensors
  - Support for features
  - Unified format for all datasets – great effort!
- Our requirements → new *Capture* format
  - Native multi-session datasets
  - Support for processed data (meshes, renderings, different trajectories)
  - Separated (raw / processed) data from features / reconstructions
- Very easy conversion between *Capture* and *Kapture*

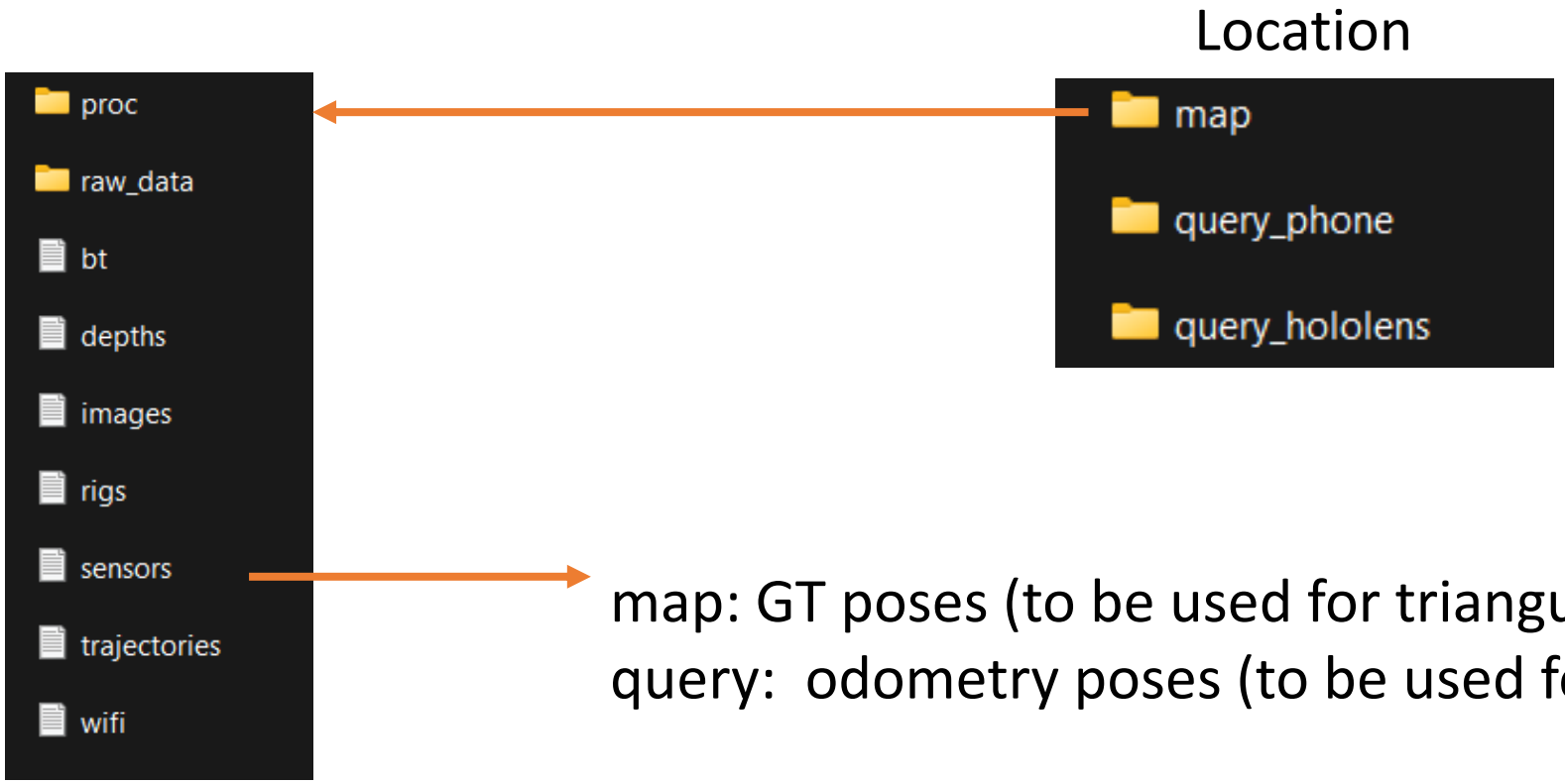


Overview of the capture format

- Images, depth maps, point-clouds
- Camera intrinsics, rigs
- Trajectories (from odometry)
- Radios (WiFi, Bluetooth)
- Coming soon: GPS, IMU, Gravity
- Natively multi-session
- Support for processed data

Benchmarking Data

- Keyframed data (images only)
  - 2.5FPS for database, 1FPS for query

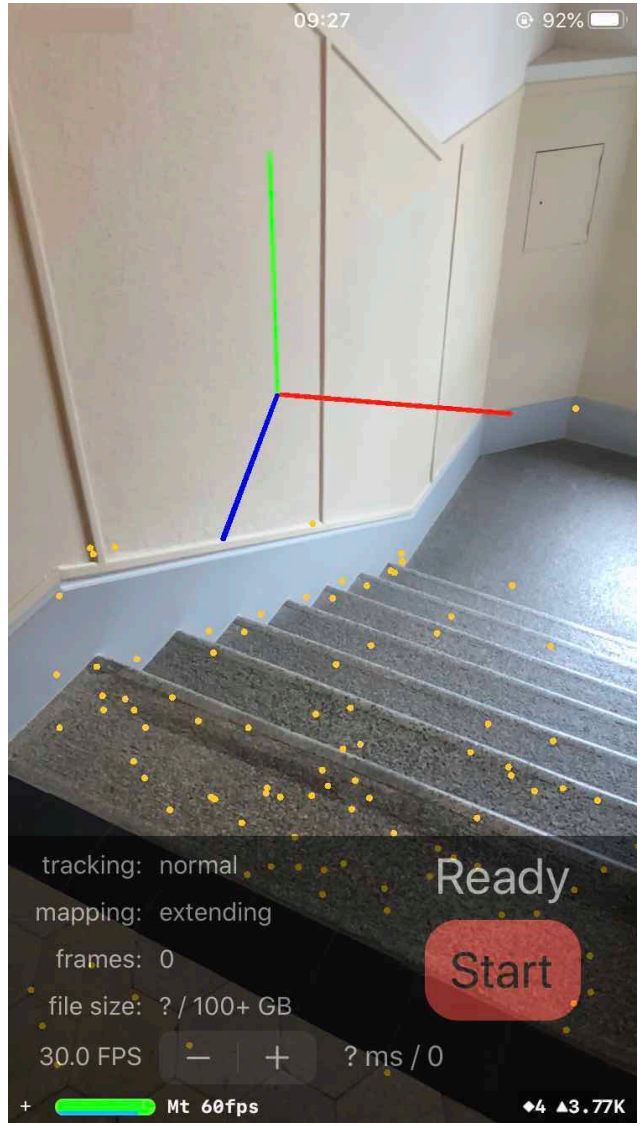


map: GT poses (to be used for triangulation)
query: odometry poses (to be used for seq. evaluation)

d) Additional tools

iOS Capture App

- iPhone / iPad capture app recording
  - Video stream (variable framerate)
  - Depth maps
  - ARKit poses & camera intrinsics
  - IMU (filtered & unfiltered)
  - GPS, Bluetooth (anonymized)



PyCOLMAP

colmap / pycolmap Public

Python bindings for COLMAP

BSD-3-Clause license

417 stars 65 forks

- Python bindings for COLMAP
  - Estimators (P3P, GP3P, Homography, Essential / Fundamental + LO-RANSAC)
  - Reconstruction object (images, cameras, points)
  - SIFT (VLFeat / GPUSIFT) feature extraction
  - Reconstruction, triangulation, MVS pipelines
- Contributions
  - Bindings for parts of COLMAP you're using!
  - Modularize each pipeline to be able to costumize
- Thanks to Philipp Lindenberger 

PyCeres

cvg / pyceres Public

Factor graphs with Ceres in Python

82 stars 11 forks

- Factor graphs backed by Ceres from Python
  - Relative pose constraints
  - Absolute pose constraints
  - Bundle cost
  - Floor-plan alignment cost
- Contributions
  - Gravity constraints
  - IMU with preintegration
  - GPS cost
- Thanks to Philipp Lindenberger 

pcdMeshing

cvg / pcdmeshing Public

Point cloud meshing with CGAL

Apache-2.0 license

12 stars 1 fork

- CGAL meshing for large dense point-clouds
  - Advancing Front algorithm

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- CGAL meshing for large dense point-clouds
  - Advancing Front algorithm
- Contributions
  - Free-space filtering with sensor positions
  - Simplification and UV texturing

RayBender

cvg / raybender Public

Fast CPU rendering in Python using the Intel® Embree backend

BSD-3-Clause license

26 stars 5 forks

- CPU ray tracing with Intel Embree from Python

```
scene = rb.create_scene()
geometry_id = rb.add_triangle_mesh(
    scene, vertices, triangles)

ray_origins, ray_directions = rbutils.compute_rays_for_simple_pinhole_camera(
    R, tvec, intrinsics)
geom_ids, bcoords = rb.ray_scene_intersection(
    scene, ray_origins, ray_directions)

tri_ids, bcoords, valid = rbutils.filter_intersections(
    geom_ids, bcoords)
rgb, depth = rbutils.interpolate_rgbd_from_geometry(
    triangles, vertices, vertex_colors,
    tri_ids, bcoords, valid,
    R, tvec, w, h)
```

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cvg / raybender Public

Fast CPU rendering in Python using the Intel® Embree backend

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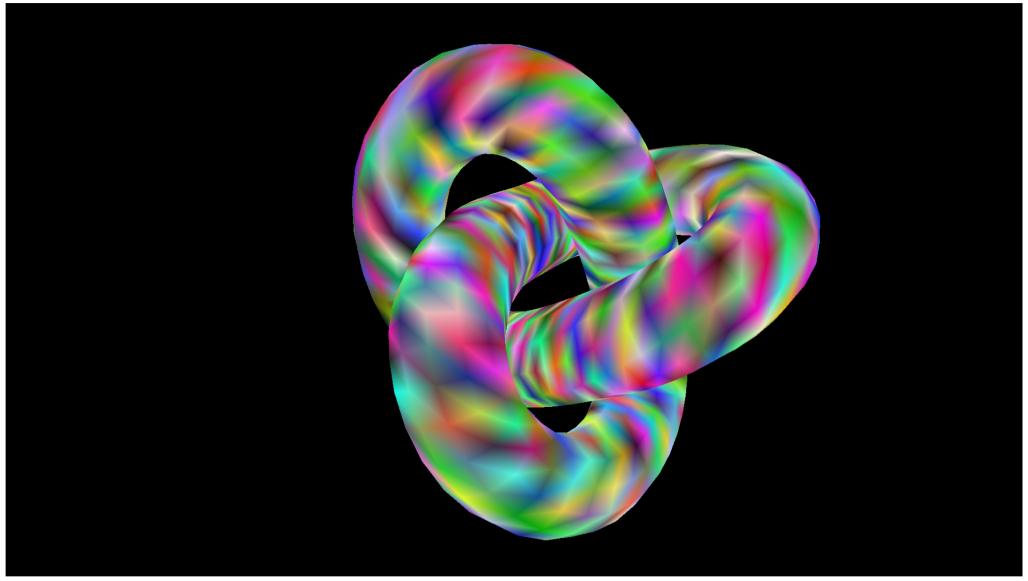
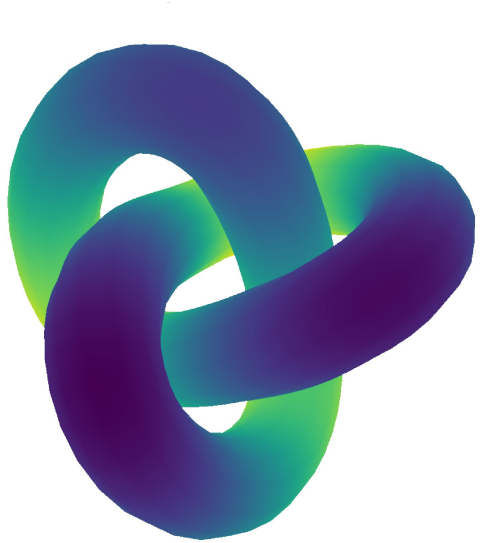
26 stars 5 forks

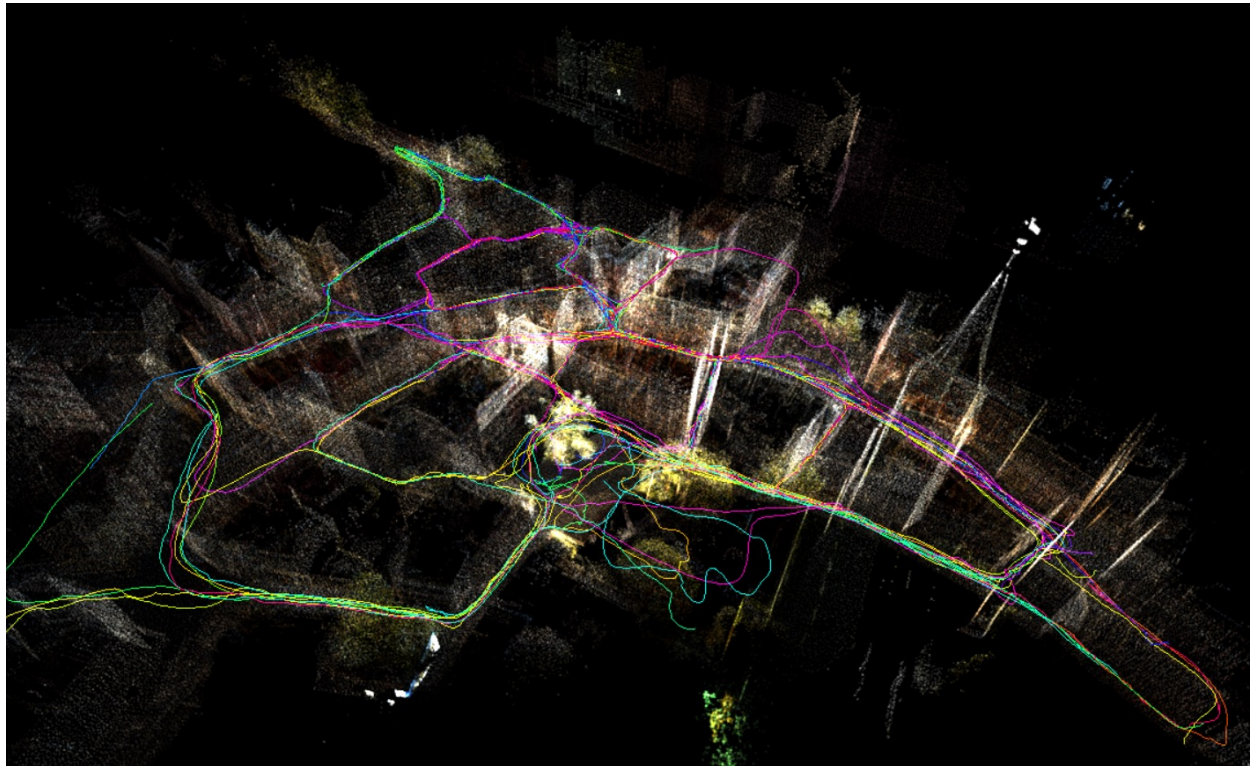
- CPU ray tracing with Intel Embree from Python
- Contributions
  - Support for multiple meshes in the same scene
  - Multi-ray single-operation tracing (AVX-512)





CVisG

- Browser visualizer (TypeScript + ThreeJS) supporting
  - Adaptive pointcloud rendering (PoTree)
  - Trajectories, frustums, images



e) Conclusions

Conclusions

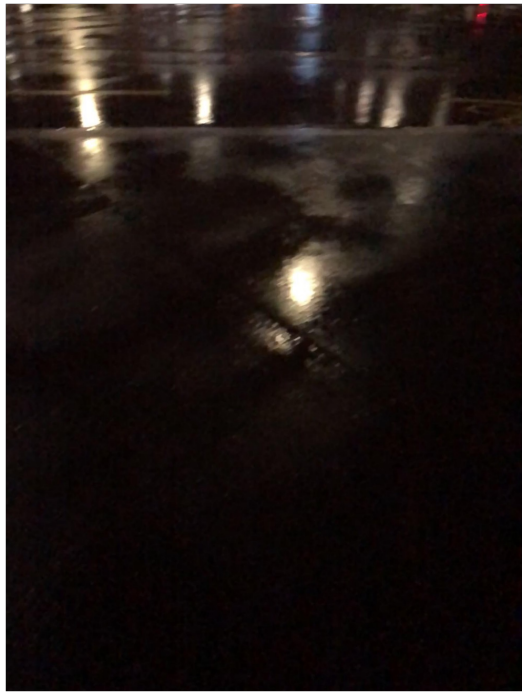
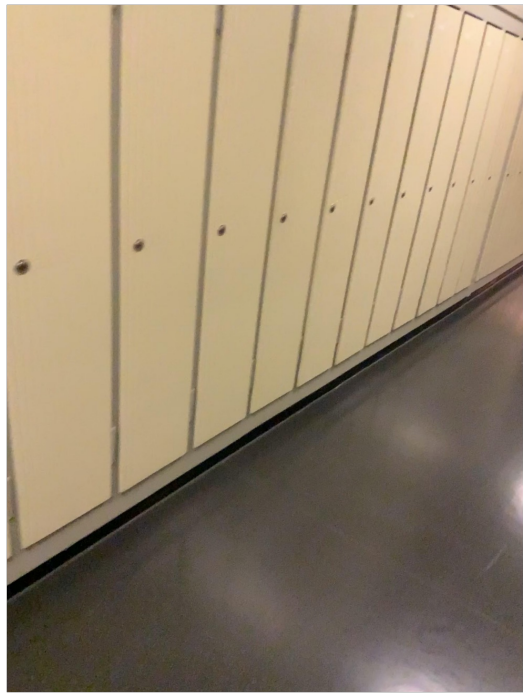
- Making this kind of dataset is a long-term investment (2+ years)
  - Requires good hardware (and preferably good vendor support)
  - Figure out how to get best performance out of your GT sensors
  - Pipelines designed with real-world constraints in mind
  - Constant feedback loop between data and code
  - Set realistic goals, constantly revisit them based on progress
    - Focused on 3 locations, but prioritized coverage / GT quality
    - Still some trade-off between scale and (automated) GT accuracy

Conclusions

- Benchmarking is a combinatorial problem
  - A lot of features, matchers, solvers, RANSAC variants
  - Difficult to include everything
    - Lack of open source implementations
    - Effort to interface everything with the benchmarking pipeline
  - Need to make some hard decision on what to prioritize
    - Representative baselines of large-scale localization methods
  - Benchmark – crowd-source this!
- Very curious what you will come up with!

Conclusions

- For AR, single-image localization is not realistic
  - Makes it harder (or even impossible)
  - Minor improvements might not translate to practical applications
  - Scalability in mind – some methods required 100+GB RAM for triangulation


Q&A