"Count the Duplos on the table."

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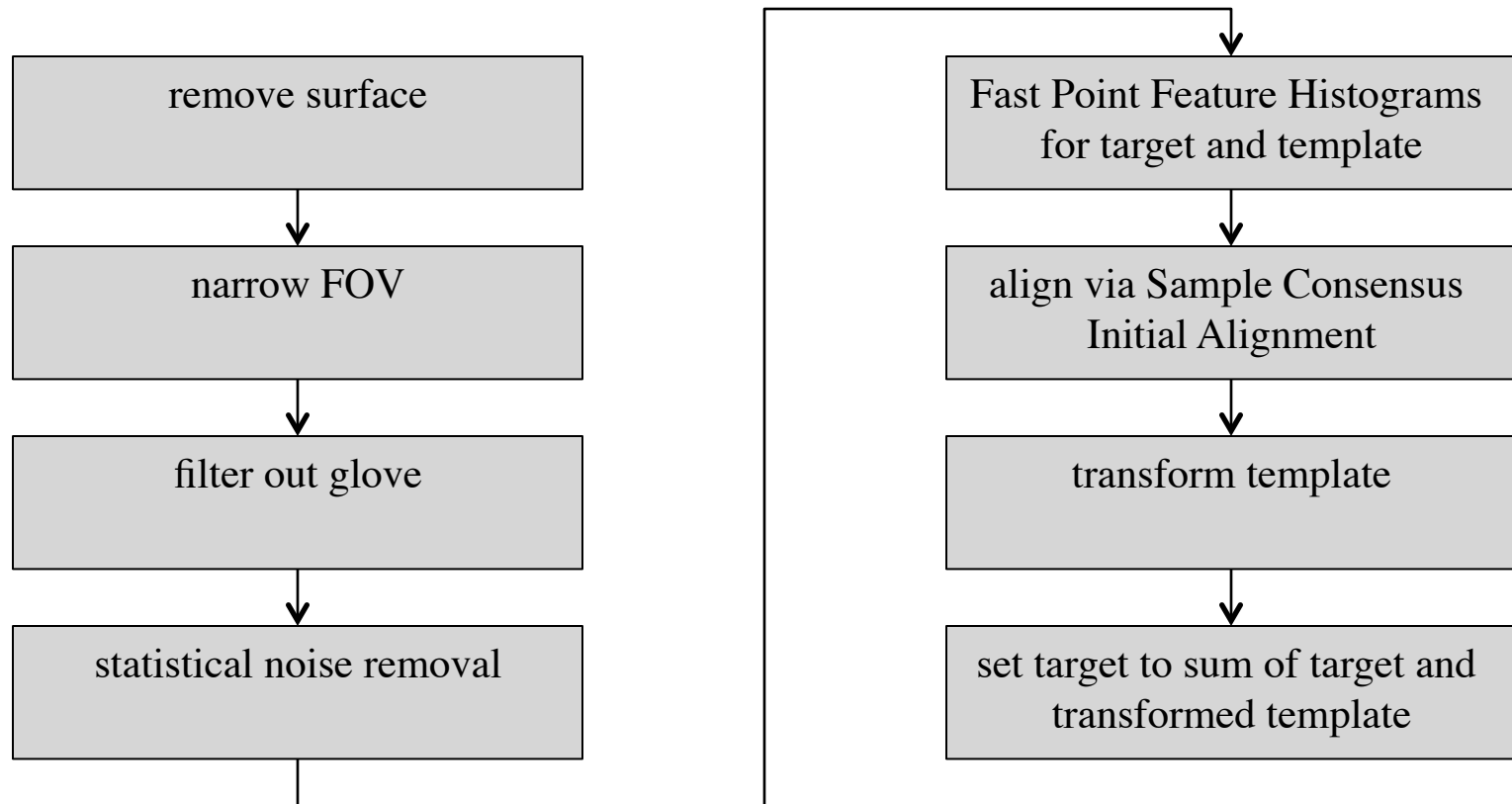
Algorithm Reasoning

- **To count Duplos, they must first be identified**
  - Strong attributes include color and shape

- **Color trainer**
  - Segments the block from background, finds mean color and standard deviation

- **Shape trainer**
  - Segments the block from background and a glove (knowing glove color)
  - Continuously adds subsequent clouds together using VHF descriptors
  - On save, align block to axes using two biggest planes -> orientation

- **To identify**
  - Segment from background, then by color, than by distance
  - Touching blocks of same color are currently return with unidentified shape

Implementation Details

- **Programs**
  - Created "identify_duplos" package in ROS
  - Includes "trainer", "identify", "visualize"

- **Colors Recognized**
  - Trained on solid red, orange, yellow, dark green, dark blue

- **Shapes Recognized**
  - Trained on standard 2x2, 2x4, 2x6, 2x8 blocks

- **Performance**
  - Full pose estimate runs as slow as 0.1 Hz on home computer, single thread
  - Quick mode operates at ~2 Hz on the same data set, single thread
    - bad orientation, position not at centroid, shape based on number of points

```
┌─────────────────────────┐              ┌─────────────────────────────────┐
│     remove surface      │              │  Fast Point Feature Histograms  │
│                         │              │     for target and template     │
└─────────────────────────┘              └─────────────────────────────────┘
            │                                           │
            ▼                                           ▼
┌─────────────────────────┐              ┌─────────────────────────────────┐
│       narrow FOV        │              │    align via Sample Consensus   │
│                         │              │        Initial Alignment        │
└─────────────────────────┘              └─────────────────────────────────┘
            │                                           │
            ▼                                           ▼
┌─────────────────────────┐              ┌─────────────────────────────────┐
│     filter out glove    │              │       transform template        │
│                         │              │                                 │
└─────────────────────────┘              └─────────────────────────────────┘
            │                                           │
            ▼                                           ▼
┌─────────────────────────┐              ┌─────────────────────────────────┐
│  statistical noise      │              │   set target to sum of target   │
│     removal             │              │     and transformed template    │
└─────────────────────────┘              └─────────────────────────────────┘
```
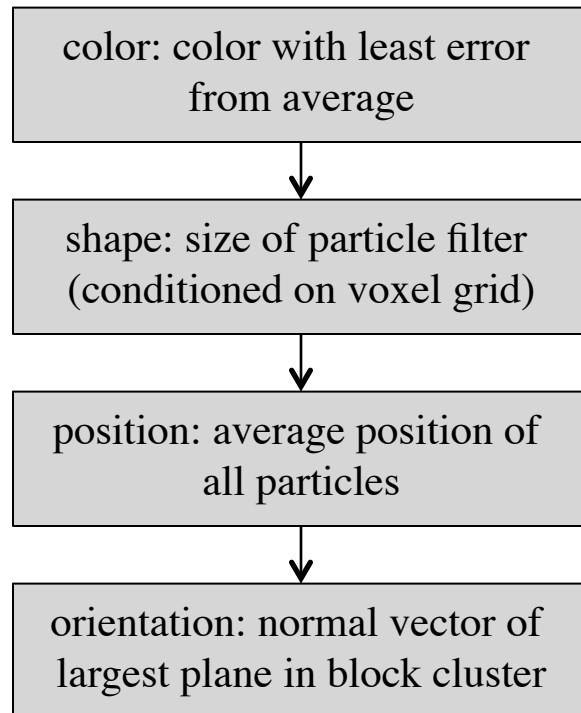
"Training" Examples

(left) Kinect viewing 2x2 Duplo

(right) isolated Duplo shown in rviz

"Identify"

Quick Mode

color: color with least error from average

↓

shape: size of particle filter (conditioned on voxel grid)

↓

position: average position of all particles

↓

orientation: normal vector of largest plane in block cluster

Template Align Mode

color: color with least error from average

↓

shape: result of best aligned template

↓

position: given as centroid of template

↓

orientation: given as normal vector of template
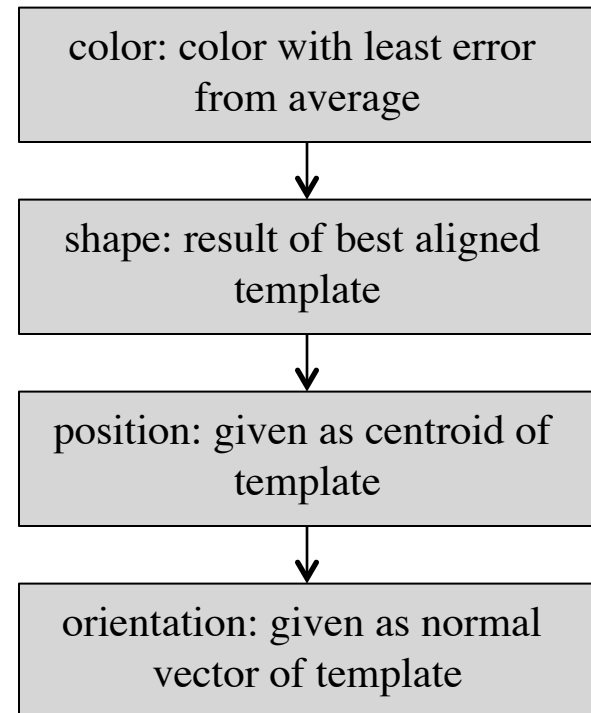
"Identify" Examples

identify_duplos/config.txt

```
COLORS
red 152 22 12 12 25 16
#orange
yellow 176 30 119 35 51 23
green 58 23 102 32 54 27
blue 39 17 50 25 117 33

SHAPES
2x2 data/2x2.pcd
2x4 data/2x4.pcd
2x6 data/2x6.pcd
2x8 data/2x8.pcd
```

```
        orientation:
          x: 0.0
          y: 0.690980911255
          z: -0.118783742189
          w: 0.713046908379
-
    shape: 2x4
    color: yellow
    pose:
      position:
          x: -0.110056132078
          y: -0.205789029598
          z: 0.842331409454
      orientation:
          x: -0.0
          y: 0.661731004715
          z: 0.126089632511
          w: 0.739062607288
-
    shape: 2x2
    color: blue
    pose:
      position:
          x: -0.116171598434
          y: -0.12408144027
          z: 0.839330554008
- -
```
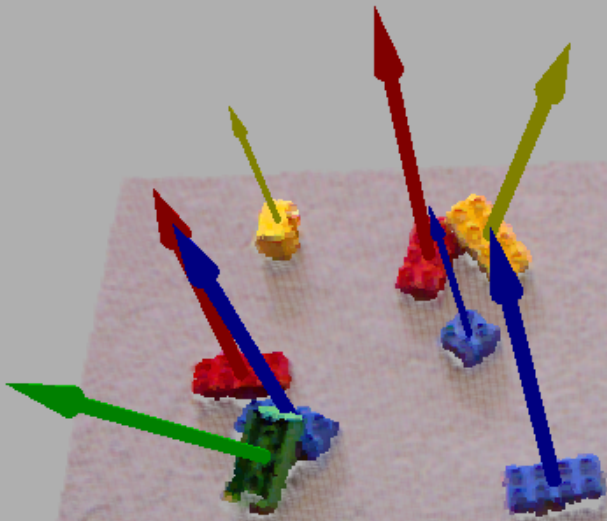
(left) config file, built from training

(right) ROS message, shown w/ rostopic

"Visualize" Examples

(left) Kinect at home (quick mode)

(right) group2_3.pcd/PR2 (quick mode)

Steps for Improvement, Further Development

- **Better shape building / pose estimation (FPFH alone limited to three faces)**
    - Possibly limit rotation during SAC alignment search for continuous build
- **HSV color to remove dependence on brightness**
- **Drop-in OpenMP replacements for PCL functions**
- **Try separating touching blocks of same color by applying and removing known shapes**
- **Internal Bayes filter could handle occlusions ^_^**
    - From robot arm
    - So many blocks, one gets covered
    - Rotation