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Aug 23, 2017

**LSD-slam and ORB-slam2, a literature based explanation**

**Monocular slam**

Both algorithms are monocular slam algorithms, where slam means Simultaneous Localization And Mapping, and monocular means that they preform slam based on a rgb image sequence (video) created by 1 camera at each time-instance.

Slam algorithms are algorithms that simultaneously tracks the movement of the camera (usually mounted onto a robot/car/etc.) and create a point cloud map of the surroundings that they passed. They create a map of the surroundings and localize them self within this map.

Monocular slam has has one big characteristic which provides it with a big pro but also a big con, it is scale independent. It cannot estimate the scale of the scenery and thus the precieved scale of the scenery will drift. This often is attempted to be fixed by trying to detect scenery that you already have been (you have traveled in a loop) and then the scale-drift can be estimated and corrected. This does bring the big pro that the algorithms work for big outdoor sceneries, small indoor sceneries and for transitions between these two.

**Feature-based vs. Direct**

Monocular slam algorithms can be divided into two groups, those who use feature-based methods and those who use direct methods:

Feature-based slam algorithms take the images and within these images, they search for certain features, key-points, (for instance corners) and only use these features to estimate the location and surroundings. This means that they throw away a lot of positional valuable information from the image, but this does simplifies the whole process.

Direct slam algorithms do not search the image for key-points but instead use the image intensities to estimate the location and surroundings. This does mean that they use more information from the images and thus tend to be robuster and create a more detailed map of the surrounding. However they do require a lot more computational costs.

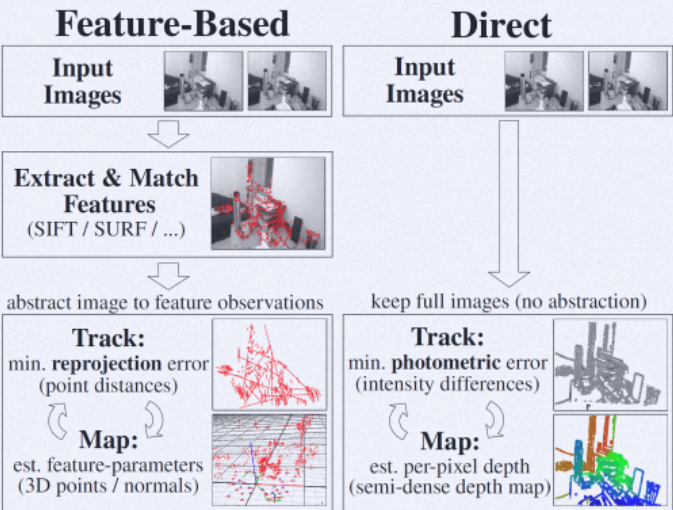


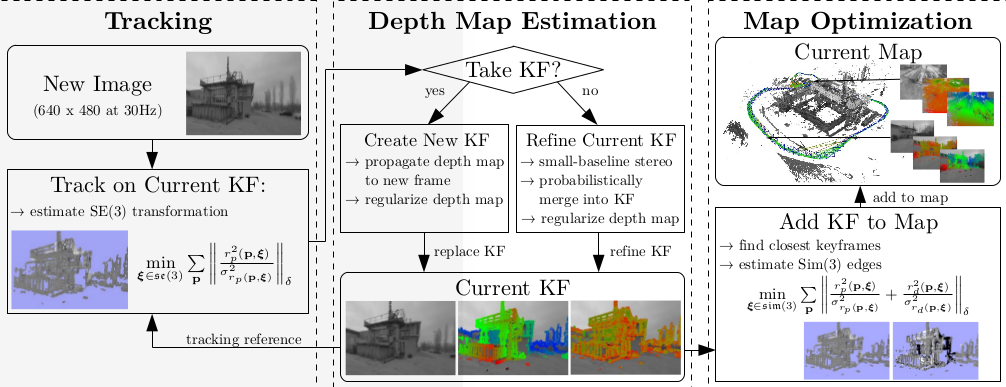
Image showing the difference between Feature-based and Direct slam algorithms.

There are many slam algorithms, many also use other data then Monocular rgb data, such as stereo images (two images taken with two camera's at the same time instance) or rgb-d images (rgb with depth information). Each slam algorithm has its own characteristics and pro's and con's. Here I will discuss two popular slam algorithms: LSD-slam and ORB-slam2, and compare them to each other.

**LSD-slam**

based on paper: <https://vision.in.tum.de/_media/spezial/bib/engel14eccv.pdf>

LSD-slam stands for Large-Scale Direct slam and is a monocular slam algorithm. The map of the surrounding is created based on certain key-frames which contain a camera image, an inverse depth map and the variance of the inverse depth map. The depth map and its variance are not created for all the pixels, but only for those in the neighborhood of large image intensity gradients, making them semi-dense. These key-frames are updated with the images that aren't key-frames. They divide the problem into three parts: tracking, depth map estimation and map optimization, as can be seen in the following figure:



**Tracking**

The tracking part takes the new image and tries to estimate the current camera pose with respect to the current key-frame pose by minimizing the variance-normalized photometric error (for exact formulas, refer to the paper). It uses the previous image pose as initialization.

**Depth Map Estimation**

Here is first decided if the image is going to be used as a new key-frame, or to refine the current key-frame. This is done based on two weights, the relative distance to the current key-frame and the angle to the current key-frame. Is the weighted sum of these two larger than a certain threshold, a new key-frame is taken. This threshold is relative to the scale of the scene as the key-frames are scaled such that the mean inverse depth is one.

If the image is to become a new key-frame, a depth-map of this key-frame needs to be initialized, this is done by projected points from the previous key-frame onto the new key-frame. Then one iteration of spatial regularization and outlier removal is done. (For more information on this, see section 2.3 of [www.cv-foundation.org/openaccess/content\_iccv\_2013/papers/Engel\_Semi-dense\_Visual\_Odometry\_2013\_ICCV\_paper.pdf](http://www.cv-foundation.org/openaccess/content_iccv_2013/papers/Engel_Semi-dense_Visual_Odometry_2013_ICCV_paper.pdf)) The key-frame is finally scaled such that the mean inverse depth is one.

If the image is not used for a new key-frame, it is used to update the depth-map on the current key-frame. This is done by preforming a lot of small-baseline stereo comparisons for the parts of the image where the expected accuracy is large enough and then incorporating this information with the information on the current key-frame.

**Map Optimization**

Because each key-frame is scaled to have an mean inverse depth of one, each key-frame has a different scale. The key-frames need to be aligned with this scale difference in mind. This is done by minimizing an error function based on the photometric residual and the depth residual, both scaled with their variance, of both images.

After the key-frame is added to the map, a number of key-frames that are close enough to detect a loop (loop-closure) are used to detect loop-closure. This is done by a reciprocal tracking check, which means that the transformation from an original key-frame to the other key-frame is compared with the transformation form the other key-frame to the original key-frame while also taking their uncertainties into account. If these to are similar enough, the algorithm has found a loop-closure.

The map is optimized using pose graph optimization from the g2o package.

**Parameters**

**Parameters change-able from the commandline (see there readme for explanation):**

bool autoRun = true;  
bool autoRunWithinFrame = true;  
  
int debugDisplay = 0;  
  
bool onSceenInfoDisplay = true;  
bool displayDepthMap = true;  
bool dumpMap = false;  
bool doFullReConstraintTrack = false;  
  
// dyn config  
bool printPropagationStatistics = false;  
bool printFillHolesStatistics = false;  
bool printObserveStatistics = false;  
bool printObservePurgeStatistics = false;  
bool printRegularizeStatistics = false;  
bool printLineStereoStatistics = false;  
bool printLineStereoFails = false;  
  
bool printTrackingIterationInfo = false;  
  
bool printFrameBuildDebugInfo = false;  
bool printMemoryDebugInfo = false;  
  
bool printKeyframeSelectionInfo = false;  
bool printConstraintSearchInfo = false;  
bool printOptimizationInfo = false;  
bool printRelocalizationInfo = false;  
  
bool printThreadingInfo = false;  
bool printMappingTiming = false;  
bool printOverallTiming = false;  
  
bool plotTrackingIterationInfo = false;  
bool plotSim3TrackingIterationInfo = false;  
bool plotStereoImages = false;  
bool plotTracking = false;  
  
  
float freeDebugParam1 = 1;  
float freeDebugParam2 = 1;  
float freeDebugParam3 = 1;  
float freeDebugParam4 = 1;  
float freeDebugParam5 = 1;  
  
float KFDistWeight = 4;  
float KFUsageWeight = 3;  
  
float minUseGrad = 5;  
float cameraPixelNoise2 = 4\*4;  
float depthSmoothingFactor = 1;  
  
bool allowNegativeIdepths = true;  
bool useMotionModel = false;  
bool useSubpixelStereo = true;  
bool multiThreading = true;  
bool useAffineLightningEstimation = true;  
  
bool useFabMap = false;  
bool doSlam = true;  
bool doKFReActivation = true;  
bool doMapping = true;  
  
int maxLoopClosureCandidates = 10;  
int maxOptimizationIterations = 100;  
int propagateKeyFrameDepthCount = 0;  
float loopclosureStrictness = 1.5;  
float relocalizationTH = 0.7;  
  
  
bool saveKeyframes = false;  
bool saveAllTracked = false;  
bool saveLoopClosureImages = false;  
bool saveAllTrackingStages = false;  
bool saveAllTrackingStagesInternal = false;  
  
bool continuousPCOutput = false;  
  
  
bool fullResetRequested = false;  
bool manualTrackingLossIndicated = false;

**Key presses:**

case 'a': case 'A':  
// autoRun = !autoRun; // disabled... only use for debugging & if you really, really know what you are doing  
 break;  
 case 's': case 'S':  
// autoRunWithinFrame = !autoRunWithinFrame; // disabled... only use for debugging & if you really, really know what you are doing  
 break;  
 case 'd': case 'D':  
 debugDisplay = (debugDisplay+1)%6;  
 printf("debugDisplay is now: %d\n", debugDisplay);  
 break;  
 case 'e': case 'E':  
 debugDisplay = (debugDisplay-1+6)%6;  
 printf("debugDisplay is now: %d\n", debugDisplay);  
 break;  
 case 'o': case 'O':  
 onSceenInfoDisplay = !onSceenInfoDisplay;  
 break;  
 case 'r': case 'R':  
 printf("requested full reset!\n");  
 fullResetRequested = true;  
 break;  
 case 'm': case 'M':  
 printf("Dumping Map!\n");  
 dumpMap = true;  
 break;  
 case 'p': case 'P':  
 printf("Tracking all Map-Frames again!\n");  
 doFullReConstraintTrack = true;  
 break;  
 case 'l': case 'L':  
 printf("Manual Tracking Loss Indicated!\n");  
 manualTrackingLossIndicated = true;  
 break;

Parameters from settings.h:

// validity can take values between 0 and X, where X depends on the abs. gradient at that location:  
// it is calculated as VALIDITY\_COUNTER\_MAX + (absGrad/255)\*VALIDITY\_COUNTER\_MAX\_VARIABLE  
#define VALIDITY\_COUNTER\_MAX (5.0f) // validity will never be higher than this  
#define VALIDITY\_COUNTER\_MAX\_VARIABLE (250.0f) // validity will never be higher than this  
  
#define VALIDITY\_COUNTER\_INC 5 // validity is increased by this on sucessfull stereo  
#define VALIDITY\_COUNTER\_DEC 5 // validity is decreased by this on failed stereo  
#define VALIDITY\_COUNTER\_INITIAL\_OBSERVE 5 // initial validity for first observations  
  
  
#define VAL\_SUM\_MIN\_FOR\_CREATE (30) // minimal summed validity over 5x5 region to create a new hypothesis for non-blacklisted pixel (hole-filling)  
#define VAL\_SUM\_MIN\_FOR\_KEEP (24) // minimal summed validity over 5x5 region to keep hypothesis (regularization)  
#define VAL\_SUM\_MIN\_FOR\_UNBLACKLIST (100) // if summed validity surpasses this, a pixel is un-blacklisted.  
  
#define MIN\_BLACKLIST -1 // if blacklist is SMALLER than this, pixel gets ignored. blacklist starts with 0.  
  
  
  
  
/\*\* ============== Depth Variance Handeling ======================= \*/  
#define SUCC\_VAR\_INC\_FAC (1.01f) // before an ekf-update, the variance is increased by this factor.  
#define FAIL\_VAR\_INC\_FAC 1.1f // after a failed stereo observation, the variance is increased by this factor.  
#define MAX\_VAR (0.5f\*0.5f) // initial variance on creation - if variance becomes larter than this, hypothesis is removed.  
  
#define VAR\_GT\_INIT\_INITIAL 0.01f\*0.01f // initial variance vor Ground Truth Initialization  
#define VAR\_RANDOM\_INIT\_INITIAL (0.5f\*MAX\_VAR) // initial variance vor Random Initialization  
  
  
  
  
  
// Whether to use the gradients of source and target frame for tracking,  
// or only the target frame gradient  
#define USE\_ESM\_TRACKING 1  
  
  
#ifdef ANDROID  
 // tracking pyramid levels.  
 #define MAPPING\_THREADS 2  
 #define RELOCALIZE\_THREADS 4  
#else  
 // tracking pyramid levels.  
 #define MAPPING\_THREADS 4  
 #define RELOCALIZE\_THREADS 6  
#endif  
  
#define SE3TRACKING\_MIN\_LEVEL 1  
#define SE3TRACKING\_MAX\_LEVEL 5  
  
#define SIM3TRACKING\_MIN\_LEVEL 1  
#define SIM3TRACKING\_MAX\_LEVEL 5  
  
#define QUICK\_KF\_CHECK\_LVL 4  
  
#define PYRAMID\_LEVELS (SE3TRACKING\_MAX\_LEVEL > SIM3TRACKING\_MAX\_LEVEL ? SE3TRACKING\_MAX\_LEVEL : SIM3TRACKING\_MAX\_LEVEL)  
  
  
  
  
  
// ============== stereo & gradient calculation ======================  
#define MIN\_DEPTH 0.05f // this is the minimal depth tested for stereo.  
  
// particularely important for initial pixel.  
#define MAX\_EPL\_LENGTH\_CROP 30.0f // maximum length of epl to search.  
#define MIN\_EPL\_LENGTH\_CROP (3.0f) // minimum length of epl to search.  
  
// this is the distance of the sample points used for the stereo descriptor.  
#define GRADIENT\_SAMPLE\_DIST 1.0f  
  
// pixel a point needs to be away from border... if too small: segfaults!  
#define SAMPLE\_POINT\_TO\_BORDER 7  
  
// pixels with too big an error are definitely thrown out.  
#define MAX\_ERROR\_STEREO (1300.0f) // maximal photometric error for stereo to be successful (sum over 5 squared intensity differences)  
#define MIN\_DISTANCE\_ERROR\_STEREO (1.5f) // minimal multiplicative difference to second-best match to not be considered ambiguous.  
  
// defines how large the stereo-search region is. it is [mean] +/- [std.dev]\*STEREO\_EPL\_VAR\_FAC  
#define STEREO\_EPL\_VAR\_FAC 2.0f  
  
  
  
  
// ============== Smoothing and regularization ======================  
// distance factor for regularization.  
// is used as assumed inverse depth variance between neighbouring pixel.  
// basically determines the amount of spacial smoothing (small -> more smoothing).  
#define REG\_DIST\_VAR (0.075f\*0.075f\*depthSmoothingFactor\*depthSmoothingFactor)  
  
// define how strict the merge-processes etc. are.  
// are multiplied onto the difference, so the larger, the more restrictive.  
#define DIFF\_FAC\_SMOOTHING (1.0f\*1.0f)  
#define DIFF\_FAC\_OBSERVE (1.0f\*1.0f)  
#define DIFF\_FAC\_PROP\_MERGE (1.0f\*1.0f)  
#define DIFF\_FAC\_INCONSISTENT (1.0f \* 1.0f)  
  
  
  
  
// ============== initial stereo pixel selection ======================  
#define MIN\_EPL\_GRAD\_SQUARED (2.0f\*2.0f)  
#define MIN\_EPL\_LENGTH\_SQUARED (1.0f\*1.0f)  
#define MIN\_EPL\_ANGLE\_SQUARED (0.3f\*0.3f)  
  
// abs. grad at that location needs to be larger than this.  
#define MIN\_ABS\_GRAD\_CREATE (minUseGrad)  
#define MIN\_ABS\_GRAD\_DECREASE (minUseGrad)  
  
// ============== RE-LOCALIZATION, KF-REACTIVATION etc. ======================  
// defines the level on which we do the quick tracking-check for relocalization.  
  
  
  
#define MAX\_DIFF\_CONSTANT (40.0f\*40.0f)  
#define MAX\_DIFF\_GRAD\_MULT (0.5f\*0.5f)  
  
#define MIN\_GOODPERGOODBAD\_PIXEL (0.5f)  
#define MIN\_GOODPERALL\_PIXEL (0.04f)  
#define MIN\_GOODPERALL\_PIXEL\_ABSMIN (0.01f)  
  
#define INITIALIZATION\_PHASE\_COUNT 5  
  
#define MIN\_NUM\_MAPPED 5

**In DepthMap::observeDepthRow():**

The row is being processed for gradients from the 3rd x (column) till the width of the image-3. Here is also checked if the gradient is smaller than the MIN\_ABS\_GRAD\_DECREASE. If so, it is skipped, just as when the gradient is smaller then MIN\_ABS\_GRAD\_CREATE or if the pixel is blacklisted (when the stereo fails repeatedly on this pixel.

**ORB-slam2**

based on: <http://ieeexplore.ieee.org/document/7219438/?part=1> and <https://arxiv.org/abs/1610.06475>

ORB-slam2 is more feature based, and uses ORB features because of the speed in which these can be extracted from images and there rotational invariance.

An overview of how the algorithm works:

The algorithms works on three threads, a tracking thread, a local mapping thread and a loop closing thread.

**Initializing the map**

To initialize the map starting by computing the relative pose between two scenes, they compute two geometrical models in parallel, one for a planar scene, a homography and one for non-planar scenes, a fundamental matrix. They then choose one of both based on a relative score of both. Using the selected model they estimate multiple motion hypotheses and en see if one is significantly better then the others, if so, a full bundle adjustment is done, otherwise the initialization starts over.

**Tracking**

The tracking part localizes the camera and decides when to insert a new keyframe. Features are matched with the previous frame and the pose is optimized using motion-only bundle adjustment. The features extracted are FAST corners. (for res. till 752x480, 1000 corners should be good, for higher (KITTI 1241x376) 2000 corners works). Multiple scale-levels (factor 1.2) are used and each level is divided into a grid in which 5 corners per cell are attempted to be extracted. These FAST corners are then described using ORB. The initial pose is estimated using a constant velocity motion model. If the tracking is lost, the place recognition module kicks in and tries to re-localize itself. When there is an estimation of the pose and feature matches, the co-visibility graph of keyframes, that is maintained by the system, is used to get a local visible map. This local map consists of keyframes that share map point with the current frame, the neighbors of these keyframes and a reference keyframe which share the most map points with the current frame. Through re-projection, matches of the local map are searched on the frame and the camera pose is optimized using these matches. Finally is decided if a new Keyframe needs to be created, new keyframes are inserted very frequently to make tracking more robust. A new keyframe is created when at least 20 frames has passed from the last keyframe, and last global re-localization, the frame tracks at least 50 points of which less then 90% are point from the reference keyframe.

**Local mapping**

First the new keyframe is inserted into the covisibility graph, the spanning tree linking a keyframe to the keyframe with the most points in common, and a 'bag of words' representation of the keyframe (used for data association for triangulating new points) is created.

New map points are created by triangulating ORB from connected keyframes in the covisibility graph. The unmachted ORB in a keyframe are compared with other unmatched ORB in other keyframes. The match must fulfill the epipolare constraint to be valid. To be a match, the ORB pairs are triangulated and checked if in both frames they have a positive depth, and the parallax, re projection error and scale consistency is checked. Then the match is projected to other connected keyframes to check if it is also in these.

The new map points first need to go through a test to increase the likelihood of these map points being valid. They need to be found in more than 25 % of the frames in which it is predicted to be visible and it must be observed by at least three keyframes.

Then through local bundle adjustment, the current keyframe, all keyframes connected to it through the co-visibility graph and all the map points seen by these keyframes are optimized using the keyframes that do see the map points but are not connected to the current keyframe.

Finally keyframes that are abundent are discarded to remain a certain simplicity. Keyframes from which more than 90 % of the map points can be seen by three other keyframes in the same scale-level are discarded.

**Loop closing**

To detect possible loops, they check bag of words vectors of the current keyframe and its neighbors in the covisibitlity graph. The min. simularity of these bag of words vectors is taken as a benchmark and from all the keyframes with a bag of words simulatrity to the current key frame that is greater that this benchmark, all the keyframes that are allready connected to the current keyframe are removed. If three loop canditates that are consistant are detected consecutively, this loop is regarded as a serious candiddate.

For these loops, the similarity transformation is calculated (7DOF, 3 trans, 3 rot, 1 scale) RANSAC itterations are prformed to find them and these are then optimized after which more correspondences are searched and then again an optimization is preformed. If the similarity is supported by having enough inlier's, the loop is accepted.

The current keyframe pose in then adjusted and this is propagated to its neighbors and the corresponding map-points are fused. Finally a pose graph optimization is preformed over the essential graph to take out the loop closure created errors along the graph. This also corrects for scale drift.

**Parameters**

**Parameters from the settingfile:**

intrinsic camera parameters: fx fy cx cy as K matrix  
 k1 k2 p1 p2 k3 as D matrix  
 *fps: frames per second, default: 30  
rgb* = color order (RGB,1, or RBG,0,)

Orb parameters:  
*nFeatures* : number of features per image  
*scaleFactor*: Scale factor between levels in the scale pyramid  
*nLevels* : Number of levels in the scale pyramid

Image is divided in a grid. At each cell FAST are extracted imposing a minimum response.Firstly we impose iniThFAST. If no corners are detected we impose a lower value minThFAST You can lower these values if your images have low contrast  
*IniThFAST :  
MinThFast* :

**Parameters from Frame.cc:**

The sigma squared of the frame is obtained from mpORBextractorLeft->GetScaleSigmaSquares();

in Frame::ComputeStereoMatches():  
 There is searched in the right image for the keypoints of the   
 left image in a limit of: minZ = mb = stereo baseline, minD = 0   
 and maxD = mbf/minZ = stereo baseline times the focal length   
 devided by minZ = focallength.

**Parameters from Initializer.cc:**

in Initializer::Initialize():  
 The choice between using the homography or fundamental method   
 is made by calculating both in seperate threads and calculating   
 a ratio based on the scores: RH=SH/(SH+SF), if this is greater   
 than 0.4, the homography is used, otherwise, the fundamental is   
 used.

**Parameters from LocalMapping.cc:**

in LocalMapping::CreateNewMapPoint():  
 Uses the 20 (10 if not monocular) nearest keyframes in the   
 covisibility graph and of these only the ones with a large   
 enough baseline. and a ORB matcher with nnratio of 0.6.

The reprojection error due to triangulation is checked to be   
 smaller than 5.991 (7.8 in case of stereo) times the sigma   
 squared.

in LocalMapping::SearchInNeighbors():  
 Uses the 20 (10 if not monocular) nearest keyframes in the   
 covisibility graph.

in LocalMapping::KeyFrameCulling():  
 Check redundant keyframes (only local keyframes)  
 A keyframe is considered redundant if the 90% of the MapPoints   
 it sees, are seen in at least other 3 keyframes (in the same or   
 finer scale)

**Parameters from LoopClosing.cc**

in LoopClosing::LoopClosing():  
 the CovisibilityConsistency Threshold is set to 3.

in LoopClosing::DetectLoop():  
 if a loop is detected within the last 10 keyframes or 10   
 keyframes have not been created yet, the function immediately   
 returns false.

in LoopClosing::ComputeSim3():  
 An ORB matcher is used of a nn ratio of 0.75. If there are more   
 than 20 matches between a the keyframe and the candidate, a   
 Sim3solver is used with the ransacparamters of a probability of   
 0.99, 20 minimal inliers and 300 as max iterations.

A loop is defined as a loop when more than 40 matches have been   
 found.

**Parameters from Optimizer.cc:**

in Optimizer::BundleAdjustment():  
 a 2D Huber threshold is set as sqrt(5.99) and a 3D Huber   
 threshold is set as sqrt(7.815).

in Optimizer::OptimizeEssentialGraph():  
 An Levenburg algorithm is used with an initial Lambda of 1e-16.

The amount of covisible KF is set to 100.

The optimization is done for 20 iterations.

in Optimizer::OptimizeSim3():  
 Here the optimization is done for 5 iterations. After which the   
 optimezation is done again with only the inliers. (for 10   
 iterations if there are outliers, otherwise 5 iterations, or if   
 there are less than 10 inliers left, the whole optimization   
 fails).

**Parameters from ORBextractor.cc:**

patch\_size = 31 , half\_patch\_size = 15 , edge\_threshold = 19

**Parameters from ORBmatcher.cc:**

TH\_HIGH = 100 , TH\_LOW = 50 , HISTO\_LENGTH = 30

NOT FINISHED YET

**Parameters from Tracking.cc:**

Max/Min Frames to insert keyframes and to check relocalisation  
*mMinFrames* = 0;  
*mMaxFrames* = fps;

Threshold close/far points  
Points seen as close by the stereo/RGBD sensor are considered reliable and inserted from just one frame. Far points require a match in two keyframes. *mbf = camera.bf: some kind of scale*mThDepth = mbf\*(float)fSettings["ThDepth"]/fx;

For RGB-D inputs only. For some datasets (e.g. TUM) the depthmap values are scaled.  
mDepthMapFactor = fSettings["DepthMapFactor"];  
if(fabs(mDepthMapFactor)<1e-5)  
 mDepthMapFactor=1;  
else  
 mDepthMapFactor = 1.0f/mDepthMapFactor;

in Tracking::StereoInitialization():  
 hardcoded: if the amount of keypoints   
 (mCurrentFrame.N) is less than 500,it is not   
 initialized. on line 511

in Tracking::MonocularInitialization():  
 hardcoded: if the amount of keypoints   
 (mCurrentFrame.mvKeys.size()) is less than 100,it is not   
 initialized. on line 590 and 603

in Tracking::CreateInitialMapMonocular():  
 If the number of cepoints on the current keyframe is less than   
 100, Then the initializatoin has gone rong and the map resets.  
 on line 694

In Tracking::TrackReferenceKeyFrame():  
 An ORBMatcher is created with a nnratio of 0.7. line 764

if the amount of orb matches is less then 15, the function   
 returns False (line 769) Then it removes outliers and returns   
 the result of the comparison if the number of matches is more   
 or equal then 10.

In Tracking::UpdateLastFrame():  
 All the points closer than mThDepth (see above) are inserted   
 unless these are less than 100, then the 100 closest are used.  
 line 862

In Tracking::TrackWithMotionModel():  
 An ORBMatcher is created with a nnratio of 0.9. line 764

If stereo tracking is done, th is set to 15, else to 7. th is   
 passed on to matcher.SearchByProjection to determine the   
 searchingradius (after being scaled). If this results in less  
 then 20 matches, twice the th is used. If still not 20 matches   
 are found, it fails.

it removes outliers and returns   
 the result of the comparison if the number of matches is more   
 or equal then 10.

In Tracking::TrackLocalMap():  
 if the amount of found matches are less then 30, it return   
 false, else it returns true. (50 if there have been less then   
 nMaxFrames since the last relocalization)

In Tracking::CreateNewKeyFrame():  
 All the points closer than mThDepth (see above) are inserted   
 unless these are less than 100, then the 100 closest are used.  
 line 1129

In Tracking::SearchLocalPoints():  
 The mappoints are projected into the frame and if the cosine   
 between the last en current viewing angle is smaller then 0.5   
 (line 1175) then it is used. Then an orbmatcher is used with an   
 nnratio of 0.8, and again a th is set (3 for RGBD, 5 if the   
 camera has recently been relocalised and otherwise 1) for   
 matcher.SearchByProjection (see under TrackWithMotionModel()

In Tracking::UpdateLocalKeyframe():  
 If less than 80 keyframes that observe a map point are included   
 in the local map, then it is filled up to 80 using keyframes   
 that are neigbors to already-included keyframes.

In Tracking::Relocalization():  
 Here a ORBMatcher is used with an nnratio of 0.75. If more than   
 15 matches are found between the local frame and one of the   
 keyframes, this keyframe is considered a candidate and a PNP   
 solver is run using the ransac parameters: probability of 0.99,   
 minInliers of 10, maxIterations of 300, minSEt of 4, epsilon of   
 0.5, th2 of 5.991.

Then some iterations of P4P RANSAC is done until a match is   
 found or there are no candidates anymore. For each candidate, 5   
 ransac itterations are done, and if ransac reaches the max.   
 iterations, the candidate is discarded. If not, the pose is   
 optimized: If the amount of correspondences is less then 10, it   
 is skipped. If it is less then 50, there is searched by   
 projection (in a coarse window) with a threshold of 3 and a   
 ORBDist of 100, and then it is optimized again if it returns   
 more than 50 total correspondences. If after this optimization,   
 between the 30 and 50 correspondeces are left over, there is   
 again searched by projection, this time with a threshold of 3   
 and a ORBDist of 64, and it is optimized again. If more than 50   
 correspondeces where found, then the correct frame has been   
 found, otherwise, it returns false.