Appendix A. Code

```scala
package r3bot

import boofcv.alg.distort.brown.LensDistortionBrown
import boofcv.alg.geo.PerspectiveOps
import boofcv.struct.calib.{CameraModel, CameraPinholeBrown}
import georegression.struct.point.{Point2D_F64, Point3D_F64}
import r3bot.CameraInTheWorld.{AverageEstimation, RobustEstimation}
import r3bot.QRVision1.{cameraModel, logger, streamCamera}
import scalismo.registration.LandmarkRegistration
import scalismo.sampling._
import scalismo.sampling.proposals._
import scalismo.sampling.evaluators._
import scalismo.sampling.algorithms._
import scalismo.sampling.loggers.AcceptRejectLogger
import scalismo.sampling.proposals.MixtureProposal.implicits._
import scalismo.utils.Random

import scala.collection.{immutable, mutable}

object UncertaintyVision {

  implicit val random: Random = Random(56L)

  case class CameraTProposal(proposalTSdev: Double)(implicit rnd: Random)
    extends ProposalGenerator[PoseWithFocalLength] with
SymmetricTransitionRatio[PoseWithFocalLength] {
    override def propose(current: PoseWithFocalLength):
PoseWithFocalLength = {
      // given `current` -> create a new camera proposal
      val x = current.location.x + proposalTSdev *
rnd.scalaRandom.nextGaussian()
      val y = current.location.y + proposalTSdev *
rnd.scalaRandom.nextGaussian()
      val z = current.location.z + proposalTSdev *
rnd.scalaRandom.nextGaussian()
      PoseWithFocalLength(Location(x, y, z), current.orientation,
current.focallengthX, current.focallengthY)
    }
  }
  case class CameraRProposal(proposalRSdev: Double)(implicit rnd: Random)
    extends ProposalGenerator[PoseWithFocalLength] with
SymmetricTransitionRatio[PoseWithFocalLength] {
    override def propose(current: PoseWithFocalLength):
PoseWithFocalLength = {
      val xAngle = current.orientation.xAngle + proposalRSdev *
rnd.scalaRandom.nextGaussian()
      val yAngle = current.orientation.yAngle + proposalRSdev *
rnd.scalaRandom.nextGaussian()
      val zAngle = current.orientation.zAngle + proposalRSdev *
rnd.scalaRandom.nextGaussian()
      // new angles are range limited, so that angles > than 360 deg
reshape to the deg from 0
```

```scala
      PoseWithFocalLength(
        current.location,
        Orientation(xAngle % (2 * math.Pi), yAngle % (2 * math.Pi),
zAngle % (2 * math.Pi)),
        current.focallengthX, current.focallengthY
      )
    }
  }
  case class IntrinsicProposal(focallengthProposalSdev: Double)(implicit
rnd: Random)
    extends ProposalGenerator[PoseWithFocalLength] with
SymmetricTransitionRatio[PoseWithFocalLength] {
    override def propose(current: PoseWithFocalLength):
PoseWithFocalLength = {
      val focallengthX = current.focallengthX + focallengthProposalSdev *
rnd.scalaRandom.nextGaussian()
      val focallengthY = current.focallengthY + focallengthProposalSdev *
rnd.scalaRandom.nextGaussian()
      PoseWithFocalLength(current.location, current.orientation,
focallengthX, focallengthY)
    }
  }

  /// project uncertainties in the world to the image plane
  // using the specified world-to-image transform and evaluate around the
anchor point
  def projectWorldUncertaintyToImage(dx: Double, dy: Double, dz: Double,
                                     worldToImage: Point3D_F64 =>
Point2D_F64,
                                     anchorPoint: Point3D_F64): (Double,
Double) = {
    // idea:
    // build 8 points of 3d cube dx, dy, dz around anchorPoint
    // project all to image plane
    // take min/max in x and y direction
    val cubePoints: IndexedSeq[(Double, Double, Double)] = IndexedSeq(
      (0,   0,  0),
      (dx,  0,  0),
      (0,  dy,  0),
      (0,   0, dz),
      (dx, dy,  0),
      (0,  dy, dz),
      (dx,  0, dz),
      (dx, dy, dz)
    )
    // place around anchor point
    val anchoredCube = cubePoints.map{case (x, y, z) =>
      new Point3D_F64(
        anchorPoint.x + x - dx/2,
        anchorPoint.y + y - dy/2,
        anchorPoint.z + z - dz/2)
    }
    // project to image
    val imagePoints = anchoredCube.map(worldToImage)
    // min / max
    val minY = imagePoints.map(_.y).min
    val maxY = imagePoints.map(_.y).max
    val minX = imagePoints.map(_.x).min
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    val maxX = imagePoints.map(_.x).max
    // lengths in each direction
    // minimal uncertainty in image is always half a pixel positioning
error
    (math.max(0.5, maxX - minX), math.max(0.5, maxY - minY))
  }

  case class ImageFiducialLikelihood(measurementXSdev: Double,
                                     measurementYSdev: Double,
                                     measurementZSdev: Double,
                                     detectedFiducials:
IndexedSeq[Fiducial],
                                     cameraModel: CameraPinholeBrown)
    extends DistributionEvaluator[PoseWithFocalLength] {

    override def logValue(sample: PoseWithFocalLength): Double = {
      // get the camera from the pose we introduced
      val camera = PoseWithFocalLengthToCamera(sample, cameraModel)

      // total transform from world onto image plane, including
perspective camera transform
      val worldToImage: Point3D_F64 => Point2D_F64 =
PerspectiveOps.createWorldToPixel(
        camera.cameraModel,
        camera.worldToCamera).transform

      val fidLikelihoods: IndexedSeq[Double] = detectedFiducials.map {
fid: Fiducial =>
        // fiducial 2d image position of all 4 corners
        val controlsInImage = fid.controls2D

        // fiducial 3d world positions of all 4 corners
        val worldPosition =
YuMiReferenceFiducials.referenceFiducialTransforms(fid.id)
        val refControls = fid.controlsInWorld(worldPosition)

        // evaluate distance
        val fiducialLH: Double = refControls.zip(controlsInImage).map {
          case (refPoint, observedPoint) =>
            // project reference into image
            val projectedRef: Point2D_F64 = worldToImage(refPoint)
            // pixel uncertainties of each corner in the image plane
            val (pixelXSdev, pixelYSdev) =
projectWorldUncertaintyToImage(
              measurementXSdev,
              measurementYSdev,
              measurementZSdev,
              worldToImage,
              refPoint)
            // evaluate difference to observed point with Gaussian model
            val logLHX = GaussianEvaluator(projectedRef.x,
pixelXSdev).logValue(observedPoint.x)
            val logLHY = GaussianEvaluator(projectedRef.y,
pixelYSdev).logValue(observedPoint.y)
            logLHX + logLHY
        }.sum
        // total likelihood of this fiducial (all corner cond.
independent)
```

```scala
      fiducialLH
    }
    // total likelihood of all fiducials (all fiducials cond.
independent)
    fidLikelihoods.sum
  }
}


  class ProposalLogger() extends AcceptRejectLogger[PoseWithFocalLength]
{
    var accepted: Int = 0
    var rejected: Int = 0

    var acceptedMap: mutable.Map[String, Int] = mutable.Map.empty[String,
Int].withDefaultValue(0)
    var rejectedMap: mutable.Map[String, Int] = mutable.Map.empty[String,
Int].withDefaultValue(0)

    override def accept(current: PoseWithFocalLength,
                        sample: PoseWithFocalLength,
                        generator:
ProposalGenerator[PoseWithFocalLength],
                        evaluator:
DistributionEvaluator[PoseWithFocalLength]): Unit = {
      //println(f"Sample has been ACCEPTED: proposal=$sample (from
current=$current)")
      acceptedMap(generator.toString) += 1
      accepted += 1
    }

    override def reject(current: PoseWithFocalLength,
                        sample: PoseWithFocalLength,
                        generator:
ProposalGenerator[PoseWithFocalLength],
                        evaluator:
DistributionEvaluator[PoseWithFocalLength]): Unit = {
      //println(f"Sample has been REJECTED: proposal=$sample (from
current=$current)")
      rejectedMap(generator.toString) += 1
      rejected += 1
    }
  }

  def SphericalGeomStats(angles: Seq[Double]): (Double, Double) = {
    // transform each angle to x, y
    def toXY(angle: Double): (Double, Double) = (math.cos(angle),
math.sin(angle))
    val XYAngles = angles.map(toXY)
    val xCoord = XYAngles.map(CartCoordinates => CartCoordinates._1)
    val yCoord = XYAngles.map(CartCoordinates => CartCoordinates._2)

    // average of [x, y]
    val xAnglesMean = xCoord.sum / xCoord.size
    val yAnglesMean = yCoord.sum / yCoord.size

    // standard deviation of [x, y]. Std Dev like sqrt(-2*ln(Module of
mean of samples))
    val AnglesStDev = math.sqrt(-math.log(math.pow(xAnglesMean,2) +
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math.pow(yAnglesMean,2)))

    // transform [x, y] -> angle
    def toAngle(x: Double, y: Double): Double = {
      if (math.atan2(y, x) > 0) {
        math.atan2(y, x)
      }
      else {
        math.atan2(y, x) + 2 * math.Pi
      }
    }
    (toAngle(xAnglesMean, yAnglesMean), AnglesStDev)
  }

  def EuclideanGeomStats(values: Seq[Double]): (Double, Double) = {
    // average of [x, y]
    val Mean = values.sum / values.size

    // standard deviation of [x, y]. Variance like E[x^2]/N - M[x]^2
    val valuesSq = values.map(value => math.pow(value,2))
    val StDev = math.sqrt(valuesSq.sum / valuesSq.size - math.pow(Mean,
2))
    (Mean, StDev)
  }

  // get camera with the focal length parameters from the new proposal
  def PoseWithFocalLengthToCamera(PoseWithFocalLength:
PoseWithFocalLength, cameraModel: CameraPinholeBrown): CameraInTheWorld =
{
    val currentPose = Pose(PoseWithFocalLength.location,
PoseWithFocalLength.orientation)
    val newCameraModel: CameraPinholeBrown = new CameraPinholeBrown(
      PoseWithFocalLength.focallengthX, PoseWithFocalLength.focallengthY,
      cameraModel.skew, cameraModel.cx, cameraModel.cy,
cameraModel.width, cameraModel.height
    )
    newCameraModel.radial = cameraModel.radial.clone()
    newCameraModel.t1 = cameraModel.getT1
    newCameraModel.t2 = cameraModel.getT2

    CameraInTheWorld.fromCamera(currentPose.toSe3, newCameraModel)
  }

  def main(args: Array[String]): Unit = {
    val image = streamCamera.nextGrayImage

    val proposalBroadTSdev: Double = 10
    val proposalBroadRSdev: Double = 0.1
    val proposalNarrowTSdev: Double = 1
    val proposalNarrowRSdev: Double = 0.01
    val FocalLengthProposalSdev: Double = 15
    val measurementXSdev: Double = 20
    val measurementYSdev: Double = 20
    val measurementZSdev: Double = 20

    // getting the IDs of reference fiducials
    val refIds = YuMiReferenceFiducials.referenceIds
    // detecting all fiducials that match the large size. In our case
```

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reference + objects are both large
    val fidSqBinaryLarge = Fiducial.findAllFiducials(image,
Fiducial.defaultSquareBinaryDetector(cameraModel, 47.0))
    // from all those fiducials, take only the ones that match the
reference IDs (to find the camera)
    val refFids = fidSqBinaryLarge.filter { fid =>
refIds.contains(fid.id) }
    // object fiducials set (no use for now)
    val objFids = fidSqBinaryLarge.filter { fid =>
!refIds.contains(fid.id) && fid.id != MagicWand.wandId }

    val likelihoodEvaluator: DistributionEvaluator[PoseWithFocalLength] =
ImageFiducialLikelihood(
      measurementXSdev, measurementYSdev, measurementZSdev,
      refFids,
      cameraModel
    )

    // 4 proposals. A broad (bigger jumps) and a narrow (local
exporation) for T and R
    val proposalBroadT: ProposalGenerator[PoseWithFocalLength]
      with SymmetricTransitionRatio[PoseWithFocalLength] =
CameraTProposal(proposalBroadTSdev)
    val proposalBroadR: ProposalGenerator[PoseWithFocalLength]
      with SymmetricTransitionRatio[PoseWithFocalLength] =
CameraRProposal(proposalBroadRSdev)
    val proposalNarrowT: ProposalGenerator[PoseWithFocalLength]
      with SymmetricTransitionRatio[PoseWithFocalLength] =
CameraTProposal(proposalNarrowTSdev)
    val proposalNarrowR: ProposalGenerator[PoseWithFocalLength]
      with SymmetricTransitionRatio[PoseWithFocalLength] =
CameraRProposal(proposalNarrowRSdev)
    val proposalFocalLength: ProposalGenerator[PoseWithFocalLength]
      with SymmetricTransitionRatio[PoseWithFocalLength] =
IntrinsicProposal(FocalLengthProposalSdev)

    val mixedProposal: ProposalGenerator[PoseWithFocalLength]
      with SymmetricTransitionRatio[PoseWithFocalLength] =
MixtureProposal(
      0.20 *: proposalBroadT + 0.20 *: proposalBroadR + 0.20 *:
proposalNarrowT + 0.20 *: proposalNarrowR + 0.20 *: proposalFocalLength
    )

    val mh = Metropolis(mixedProposal, likelihoodEvaluator)

    // finding camera translation vector and rotation matrix
    val camera = CameraInTheWorld.findCameraPositionUsingManyFiducials(
      refFids,
      YuMiReferenceFiducials.referenceFiducialTransforms,
      cameraModel,
      //MostStableEstimation,
      AverageEstimation,
      //RobustEstimation(maxIteration = 100, inlierThreshold = 4.0)
    )

    // obtain the CamParameters we need from the camera
    camera match {
      case Some(camera: CameraInTheWorld) =>
```

```scala
        // translation
        val x = camera.centerTranslation.getX
        val y = camera.centerTranslation.getY
        val z = camera.centerTranslation.getZ

        // rotation
        // transform of the matrix to a square matrix
        val OrientationMatrix =
GeoUtils.boofToScalismo3D(camera.orientation)
        // determination of Euler angles (phi, theta, psi) from the
retrieved rotation matrix
        val Angles_3D =
LandmarkRegistration.rotMatrixToEulerAngles(OrientationMatrix.toBreezeMat
rix)

        val xAngle = Angles_3D(2)
        val yAngle = Angles_3D(1)
        val zAngle = Angles_3D(0)

        val focallengthX = cameraModel.fx
        val focallengthY = cameraModel.fy

        val initialCamEstimate = PoseWithFocalLength(x, y, z, xAngle,
yAngle, zAngle, focallengthX, focallengthY)
        val logger = new ProposalLogger()

        val samples = mh.iterator(initialCamEstimate,
logger).take(10000).toIndexedSeq

        val posteriorSamples: IndexedSeq[PoseWithFocalLength] =
samples.drop(5000).take(5000)

        // calculate the mean and standard deviation of the samples
        // translation coordinates.
        val xValues = posteriorSamples.map{case
PoseWithFocalLength(Location(x, _, _), Orientation(_, _, _),_,_) => x}
        val yValues = posteriorSamples.map{case
PoseWithFocalLength(Location(_, y, _), Orientation(_, _, _),_,_) => y}
        val zValues = posteriorSamples.map{case
PoseWithFocalLength(Location(_, _, z), Orientation(_, _, _),_,_) => z}
        val (xMean, xStDev) = EuclideanGeomStats(xValues)
        val (yMean, yStDev) = EuclideanGeomStats(yValues)
        val (zMean, zStDev) = EuclideanGeomStats(zValues)

        // rotation coordinates.
        val xAngles = posteriorSamples.map(pose =>
pose.orientation.xAngle)
        val yAngles = posteriorSamples.map(pose =>
pose.orientation.yAngle)
        val zAngles = posteriorSamples.map(pose =>
pose.orientation.zAngle)
        val (xAnglesMean, xAnglesStDev) = SphericalGeomStats(xAngles)
        val (yAnglesMean, yAnglesStDev) = SphericalGeomStats(yAngles)
        val (zAnglesMean, zAnglesStDev) = SphericalGeomStats(zAngles)

        // focal length
        val fx = posteriorSamples.map{case
PoseWithFocalLength(Location(_, _, _), Orientation(_, _, _),fx,_) => fx}
```

```scala
        val fy = posteriorSamples.map{case
PoseWithFocalLength(Location(_, _, _), Orientation(_, _, _),_,fy) => fy}
        val (fxMean, fxStDev) = EuclideanGeomStats(fx)
        val (fyMean, fyStDev) = EuclideanGeomStats(fy)


        println(f"accepted = ${logger.accepted} and rejected =
${logger.rejected}")
        println(f"acceptedMap = ${logger.acceptedMap}")
        println(f"rejectedMap = ${logger.rejectedMap}")

        println(f"Initial focal length: ${focallengthX},
${focallengthY}")
        println(f"All the results are shown in the order: x, y, z,
xAngle, yAngle, zAngle")
        println(f"The Camera is located in:")
        println(f"Means: ${xMean}, ${yMean}, ${zMean}, " +
          f"${xAnglesMean}, ${yAnglesMean}, ${zAnglesMean}")
        println(f"StdDev: ${xStDev}, ${yStDev}, ${zStDev}, " +
          f"${xAnglesStDev}, ${yAnglesStDev}, ${zAnglesStDev}")
        println(f"The Camera has the following focal length:")
        println(f"Mean: ${fxMean}, ${fyMean}")
        println(f"StdDev: ${fxStDev}, ${fyStDev}")

        // propagation of camera uncertainty to object uncertainty
        // get all cameras from the location samples sequence obtained
        val cameras: IndexedSeq[CameraInTheWorld] = samples.map(pose =>
PoseWithFocalLengthToCamera(pose, cameraModel))

        println("In process: estimation of the pose of the detected
fiducials/objects")
        val objectsForCam: IndexedSeq[IndexedSeq[VisualObject]] =
        // case focal length is constant. Initial cameraModel
maintained
        if (logger.acceptedMap(proposalFocalLength.toString) == 0) {
          // fiducials carry the camera model internally to provide an
estimated pose, and there's no need to change it now
          val objectsForCam: IndexedSeq[IndexedSeq[VisualObject]] =
cameras.map(
            (camera: CameraInTheWorld) =>
VisualObject.fromFiducials(objFids, camera)
          )
          objectsForCam
        }
        // case focal length independent to avoid calibration step
        else {
          // need to redetect and keep detector to reconfigure for each
intrinsic setting
          val fiducialDetector =
Fiducial.defaultSquareBinaryDetector(cameraModel, 47.0)
          fiducialDetector.detect(image)

          val objectsForCam: IndexedSeq[IndexedSeq[VisualObject]] = for
(camera <- cameras) yield {
            // need to update the camera model used by this fiducial
(internally)
            // reconfiguration of the detector with the new camera
model
```

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            val lensDistortion = new
LensDistortionBrown(camera.cameraModel)
            fiducialDetector.setLensDistortion(lensDistortion,
camera.cameraModel.width, camera.cameraModel.height)

            // re-estimation of fiducials pose
            val allFiducials =
Fiducial.fromAllDetections(fiducialDetector)
            val objFids = allFiducials.filter { fid =>
!refIds.contains(fid.id) && fid.id != MagicWand.wandId }

            // save all the visual object pose of all detected objects,
for this specific camera
            objFids.map(fid => VisualObject.fromFiducial(fid, camera))
          }
          objectsForCam
        }
    println(s"Calculation of object statistics")

    // 1: create long list of all objects (flatten: unpack inner
lists to 1 large list)
    val allObjectSamples: IndexedSeq[VisualObject] =
objectsForCam.flatten
    // 2: group by the object ids to get corresponding groups of
samples of the same object
    val objSamples = allObjectSamples.groupBy(obj => obj.id)
    // 3: for each id / object run the statistics analysis
    for (objId <- objSamples.keys) {
      // all samples belonging to this object id
      val visObjSamples = objSamples(objId)
      // mapping the Visual Object to a Pose (with Euler angles (phi,
theta, psi))
      val objectPoses = visObjSamples.map { case
VisualObject(location, orientation, _) =>
        val orientationMatrix =
GeoUtils.boofToScalismo3D(orientation)
        val Angles_3D =
LandmarkRegistration.rotMatrixToEulerAngles(orientationMatrix.toBreezeMat
rix)
        Pose(Location(location.x, location.y, location.z),
Orientation(Angles_3D(2), Angles_3D(1), Angles_3D(0)))
      }

      val posteriorObjPoses: IndexedSeq[Pose] =
objectPoses.drop(19).take(19)
      val fidXValues = posteriorObjPoses.map(pose => pose.location.x)
      val fidYValues = posteriorObjPoses.map(pose => pose.location.y)
      val fidZValues = posteriorObjPoses.map(pose => pose.location.z)
      val (fidXMean, fidXStDev) = EuclideanGeomStats(fidXValues)
      val (fidYMean, fidYStDev) = EuclideanGeomStats(fidYValues)
      val (fidZMean, fidZStDev) = EuclideanGeomStats(fidZValues)

      val fidXAngles = posteriorObjPoses.map(pose =>
pose.orientation.xAngle)
      val fidYAngles = posteriorObjPoses.map(pose =>
pose.orientation.yAngle)
      val fidZAngles = posteriorObjPoses.map(pose =>
pose.orientation.zAngle)
```

```scala
        val (fidXAnglesMean, fidXAnglesStDev) =
SphericalGeomStats(fidXAngles)
        val (fidYAnglesMean, fidYAnglesStDev) =
SphericalGeomStats(fidYAngles)
        val (fidZAnglesMean, fidZAnglesStDev) =
SphericalGeomStats(fidZAngles)

        println(f"Object fiducial with id: ${objId}")
        println(f"has the location:")
        println(f"${fidXMean} ${fidXStDev}")
        println(f"${fidYMean}  ${fidYStDev}")
        println(f"${fidZMean} ${fidZStDev}")
        println(f"${fidXAnglesMean} ${fidXAnglesStDev}")
        println(f"${fidYAnglesMean} ${fidYAnglesStDev}")
        println(f"${fidZAnglesMean} ${fidZAnglesStDev}")

      }

    case None =>
      logger.debug("no origin found")
  }
 }
}
```

Appendix B. Improving the camera accuracy

Object	fiducial	with	id:	30#	
has	the	location:	0.92355	229.602	-8.5106
with	this	uncertainty:	2.20928	3.00226	2.42432
and	the	orientation:	6.23382	6.17671	3.12644
with	this	uncertainty:	0.00412	0.0031	0.00654
Object	fiducial	with	id:	944#	
has	the	location:	494.919	381.967	-35.88
with	this	uncertainty:	2.28966	4.9687	2.8406
and	the	orientation:	0.10424	0.10058	0.02039
with	this	uncertainty:	0.00404	0.0032	0.00651
Object	fiducial	with	id:	20#	
has	the	location:	244.763	-44.995	-28.618
with	this	uncertainty:	3.03118	3.79848	2.565
and	the	orientation:	0.0394	6.27264	2.30164
with	this	uncertainty:	0.00464	0.00222	0.00617
Object	fiducial	with	id:	5#	
has	the	location:	369.875	295.57	-36.377
with	this	uncertainty:	2.2278	4.36358	2.53425
and	the	orientation:	0.04777	6.25714	0.96565
with	this	uncertainty:	0.00198	0.00475	0.00611

Table B. 1. Object uncertainties in the case: Objects in Z = 0 + 3 Ref Fid + Ref Fid Z > 0 + High Std Dev

Object	fiducial	with	id:	30#	
has	the	location:	1.59563	229.708	-6.017
with	this	uncertainty:	0.1781	0.40934	0.18743
and	the	orientation:	6.2324	6.18237	3.12218
with	this	uncertainty:	1.49E-08	2.11E-08	1.49E-08
Object	fiducial	with	id:	944#	
has	the	location:	494.891	383.128	-34.489
with	this	uncertainty:	0.1781	0.40934	0.18743
and	the	orientation:	0.10327	0.05112	0.01252
with	this	uncertainty:	1.49E-08	1.49E-08	1.83E-08
Object	fiducial	with	id:	20#	
has	the	location:	244.531	-44.754	-23.411
with	this	uncertainty:	0.1781	0.40934	0.18743
and	the	orientation:	0.02609	6.27058	2.29863
with	this	uncertainty:	0	1.83E-08	0
Object	fiducial	with	id:	5#	
has	the	location:	370.101	295.591	-31.715
with	this	uncertainty:	0.1781	0.40934	0.18743
and	the	orientation:	0.04141	6.26883	0.96606
with	this	uncertainty:	2.11E-08	1.05E-08	0

Table B. 2: Object uncertainties in the case: Objects in Z = 0 + 3 Ref Fid + Ref Fid Z > 0 + Low Std Dev

Object	fiducial	with	id:	30#		
has	the	location:	-1.9207	235.056	-9.3583	
with	this	uncertainty:	2.14911	4.67679	5.54922	
and	the	orientation:	0.01316	6.2378	3.10821	
with	this	uncertainty:	0.00251	0.00237	0.00644	
Object	fiducial	with	id:	20#		
has	the	location:	238.642	-43.097	4.91044	
with	this	uncertainty:	3.28564	3.33607	4.66941	
and	the	orientation:	0.0271	0.0805	2.28619	
with	this	uncertainty:	4.82E-04	0.00341	0.0065	
Object	fiducial	with	id:	5#		
has	the	location:	369.256	294.44	-15.081	
with	this	uncertainty:	2.02934	2.79574	5.02487	
and	the	orientation:	6.23944	0.01987	0.95445	
with	this	uncertainty:	0.00332	9.12E-04	0.00646	
Object	fiducial	with	id:	22#		
has	the	location:	-25.855	-24.066	143.564	
with	this	uncertainty:	2.93029	4.45415	5.1188	
and	the	orientation:	6.18765	0.11013	0.01062	
with	this	uncertainty:	0.00262	0.00226	0.0063	

Table B. 3: Objects uncertainties in the case: Objects in Z = 0 + 3 Ref Fid + Ref Fid Z = 0 + High Std Dev

Object	fiducial	with	id:	30#		
has	the	location:	-1.6961	231.499	-1.1781	
with	this	uncertainty:	0.1781	0.40934	0.18743	
and	the	orientation:	0.01503	6.23368	3.12367	
with	this	uncertainty:	3.49E-08	1.49E-08	0	
Object	fiducial	with	id:	20#		
has	the	location:	242.767	-43.473	11.8341	
with	this	uncertainty:	0.1781	0.40934	0.18743	
and	the	orientation:	0.3686	6.11362	2.25139	
with	this	uncertainty:	0	0	0	
Object	fiducial	with	id:	5#		
has	the	location:	368.472	296.301	-10.555	
with	this	uncertainty:	0.1781	0.40934	0.18743	
and	the	orientation:	6.25082	0.0058	0.967	
with	this	uncertainty:	0	1.05E-08	0	
Object	fiducial	with	id:	22#		
has	the	location:	-21.859	-27.959	151.284	
with	this	uncertainty:	0.1781	0.40934	0.18743	
and	the	orientation:	6.18366	0.11315	0.02538	
with	this	uncertainty:	0	1.05E-08	3.16E-08	

Table B. 4: Objects uncertainties in the case: Objects in Z = 0 + 3 Ref Fid + Ref Fid Z = 0 + Low Std Dev

Object	fiducial	with	id:	22#		
has	the	location:	-24.762	-35.582	134.358	
with	this	uncertainty:	0.20757	0.3642	0.19634	
and	the	orientation:	6.24185	0.08732	0.03388	
with	this	uncertainty:	0	0	0	
Object	fiducial	with	id:	30#		
has	the	location:	4.68791	227.862	5.16268	
with	this	uncertainty:	0.20757	0.3642	0.19634	
and	the	orientation:	0.00623	0.02093	3.12648	
with	this	uncertainty:	0	1.49E-08	0	
Object	fiducial	with	id:	944#		
has	the	location:	495.205	382.297	10.3585	
with	this	uncertainty:	0.20757	0.3642	0.19634	
and	the	orientation:	0.04046	6.246	0.00251	
with	this	uncertainty:	0	0	2.58E-08	
Object	fiducial	with	id:	5#		
has	the	location:	370.151	295.385	0.45136	
with	this	uncertainty:	0.20757	0.3642	0.19634	
and	the	orientation:	6.23916	6.23069	0.96662	
with	this	uncertainty:	0	0	2.11E-08	
Object	fiducial	with	id:	20#		
has	the	location:	243.419	-45.223	1.6539	
with	this	uncertainty:	0.20757	0.3642	0.19634	
and	the	orientation:	6.23366	0.06898	2.29511	
with	this	uncertainty:	0	0	0	

Table B. 5: Objects uncertainties in the case: Objects in Z = 0 + 2 Ref Fid + Ref Fid Z = 0 + Low Std Dev

Object	fiducial	with	id:	22#	
has	the	location:	-4.5016	3.25411	-15.944
with	this	uncertainty:	3.19382	4.00857	5.21947
and	the	orientation:	6.25431	0.04543	0.00593
with	this	uncertainty:	0.0026	0.00227	0.00645
Object	fiducial	with	id:	30#	
has	the	location:	2.74369	233.388	-9.5111
with	this	uncertainty:	2.20763	3.96029	5.62994
and	the	orientation:	6.26095	6.26352	3.1139
with	this	uncertainty:	0.00252	0.00235	0.0065
Object	fiducial	with	id:	944#	
has	the	location:	498.319	378.266	-7.4502
with	this	uncertainty:	1.9692	2.51964	5.04907
and	the	orientation:	0.02536	6.26101	6.27613
with	this	uncertainty:	0.00257	0.0023	0.00658
Object	fiducial	with	id:	5#	
has	the	location:	372.311	294.4	-16.882
with	this	uncertainty:	2.06371	2.60801	5.10793
and	the	orientation:	6.26949	6.25753	0.95811
with	this	uncertainty:	0.00332	9.26E-04	0.00661
Object	fiducial	with	id:	20#	
has	the	location:	241.337	-44.596	-4.6617
with	this	uncertainty:	3.41936	2.91574	4.74621
and	the	orientation:	0.02073	0.04914	2.28843
with	this	uncertainty:	4.81E-04	0.00341	0.00652

Table B. 6: Object uncertainties in the case: Objects in Z = 0 + 2 Ref Fid + Ref Fid Z = 0 + High Std Dev

Object	fiducial	with	id:	911#		
has	the	location:	500.588	10.5468	-40.039	
with	this	uncertainty:	5.43005	4.94856	0.62981	
and	the	orientation:	6.23028	6.26897	0.03945	
with	this	uncertainty:	0.00436	0.00459	0.00623	
Object	fiducial	with	id:	30#		
has	the	location:	-1.6525	233.67	-21.975	
with	this	uncertainty:	6.63212	2.87473	2.83946	
and	the	orientation:	6.18424	6.22353	3.14025	
with	this	uncertainty:	0.00418	0.00476	0.00647	
Object	fiducial	with	id:	1234#		
has	the	location:	-4.0998	387.802	-13.345	
with	this	uncertainty:	7.49966	2.83976	3.48794	
and	the	orientation:	0.07028	0.04553	0.0128	
with	this	uncertainty:	0.00424	0.0047	0.00643	
Object	fiducial	with	id:	5#		
has	the	location:	367.685	304.483	-30.186	
with	this	uncertainty:	7.07528	4.24802	1.41603	
and	the	orientation:	0.03905	6.21722	0.98225	
with	this	uncertainty:	0.00627	9.77E-04	0.00595	
Object	fiducial	with	id:	20#		
has	the	location:	246.319	-38.181	-34.163	
with	this	uncertainty:	5.13921	3.71373	0.63346	
and	the	orientation:	6.25457	0.00242	2.31175	
with	this	uncertainty:	8.67E-04	0.00627	0.00629	

Table B. 7: Object uncertainties in the case: Objects in Z = 0 + 2 Ref Fid + Ref Fid Z > 0 + High Std Dev

Object	fiducial	with	id:	30#		
has	the	location:	2.35065	235.409	-4.6234	
with	this	uncertainty:	1.96174	2.30138	2.02108	
and	the	orientation:	6.25358	6.22379	3.12026	
with	this	uncertainty:	0.00105	0.00225	0.00458	
Object	fiducial	with	id:	20#		
has	the	location:	239.857	-41.016	-23.522	
with	this	uncertainty:	2.55899	1.68584	1.51554	
and	the	orientation:	6.27176	6.28128	2.28648	
with	this	uncertainty:	0.00116	0.0022	0.00463	
Object	fiducial	with	id:	5#		
has	the	location:	370.349	298.38	-19.735	
with	this	uncertainty:	1.93081	1.56877	1.46704	
and	the	orientation:	0.01758	6.24144	0.95575	
with	this	uncertainty:	0.00238	7.40E-04	0.00473	

Table B. 8: Object uncertainties in the case: Objects in Z = 0 + 4 Ref Fid + Ref Fid Z > 0 + High Std Dev

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Object	fiducial	with	id:	30#	
has	the	location:	2.01142	234.625	-7.2768
with	this	uncertainty:	1.9978	2.14117	5.0594
and	the	orientation:	0.01338	6.24291	3.11375
with	this	uncertainty:	1.05E-03	0.00226	0.00458
Object	fiducial	with	id:	20#	
has	the	location:	239.26	-42.987	-11.218
with	this	uncertainty:	2.85144	1.55852	4.38253
and	the	orientation:	0.00394	0.05865	2.2847
with	this	uncertainty:	1.16E-03	0.0022	0.00455
Object	fiducial	with	id:	5#	
has	the	location:	370.516	296.368	-20.29
with	this	uncertainty:	1.88842	1.50249	4.49007
and	the	orientation:	6.27235	6.26685	0.95273
with	this	uncertainty:	0.00238	7.38E-04	4.65E-03

Table B. 9: Object uncertainties in the case: Objects in Z = 0 + 4 Ref Fid + Ref Fid Z = 0 + High Std Dev

Object	fiducial	with	id:	30#	
has	the	location:	4.06566	228.871	4.94772
with	this	uncertainty:	0.10781	0.09841	0.18964
and	the	orientation:	0.0167	6.24815	3.12782
with	this	uncertainty:	0	1.49E-08	0
Object	fiducial	with	id:	20#	
has	the	location:	244.412	-44.601	0.43258
with	this	uncertainty:	0.10781	0.09841	0.18964
and	the	orientation:	6.28202	0.06479	2.29861
with	this	uncertainty:	2.79E-08	0	0
Object	fiducial	with	id:	5#	
has	the	location:	370.496	295.68	-10.024
with	this	uncertainty:	0.10781	0.09841	0.18964
and	the	orientation:	6.27103	6.2737	0.96712
with	this	uncertainty:	0	1.83E-08	1.05E-08

Table B. 10: Object uncertainties in the case: Objects in Z = 0 + 4 Ref Fid + Ref Fid Z = 0 + Low Std Dev

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Object	fiducial	with	id:	30#	
has	the	location:	241.344	-28.034	-5.6227
with	this	uncertainty:	2.50102	1.61736	1.48714
and	the	orientation:	6.26331	0.0351	2.24303
with	this	uncertainty:	0.00125	0.00215	0.00461
Object	fiducial	with	id:	20#	
has	the	location:	263.913	199.203	153.952
with	this	uncertainty:	1.92917	1.49858	1.53496
and	the	orientation:	5.98133	6.2603	3.17661
with	this	uncertainty:	0.00115	0.0022	0.00463
Object	fiducial	with	id:	5#	
has	the	location:	259.595	274.494	153.483
with	this	uncertainty:	1.92812	1.50136	1.57358
and	the	orientation:	0.23016	6.11412	3.71323
with	this	uncertainty:	0.00206	0.00143	0.00431

Table B. 11: Object uncertainties in the case: Objects in Z > 0 + 4 Ref Fid + Ref Fid Z > 0 + High Std Dev

Object	fiducial	with	id:	911#	
has	the	location:	502.204	7.46524	-14.832
with	this	uncertainty:	3.46091	3.3008	0.7409
and	the	orientation:	6.16667	0.04869	0.03775
with	this	uncertainty:	0.00359	0.00318	0.00202
Object	fiducial	with	id:	30#	
has	the	location:	249.228	-25.98	-15.575
with	this	uncertainty:	3.40172	2.85699	1.1954
and	the	orientation:	6.25252	6.26938	2.26323
with	this	uncertainty:	3.39E-04	0.00478	0.00184
Object	fiducial	with	id:	1234#	
has	the	location:	-0.4215	383.312	3.63118
with	this	uncertainty:	4.09051	2.36221	3.29135
and	the	orientation:	0.05504	0.02316	0.0127
with	this	uncertainty:	0.00351	0.00327	0.00193
Object	fiducial	with	id:	5#	
has	the	location:	263.172	268.094	157.77
with	this	uncertainty:	3.36956	2.31835	2.06476
and	the	orientation:	0.16295	6.11999	3.74796
with	this	uncertainty:	0.0048	7.48E-04	0.00263
Object	fiducial	with	id:	20#	
has	the	location:	267.517	194.468	146.096
with	this	uncertainty:	3.27287	2.36314	1.81335
and	the	orientation:	5.63519	0.04695	3.1874
with	this	uncertainty:	0.00362	0.00315	0.00168

Table B. 12: Object uncertainties in the case: Objects in Z > 0 + 2 Ref Fid + Ref Fid Z > 0 + High Std Dev

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Object	fiducial	with	id:	30#	
has	the	location:	247.937	-30.58	-12.069
with	this	uncertainty:	2.88092	3.95016	2.53007
and	the	orientation:	6.2675	6.26524	2.25294
with	this	uncertainty:	0.00459	0.00232	0.00616
Object	fiducial	with	id:	944#	
has	the	location:	495.875	380.497	-14.494
with	this	uncertainty:	2.22603	5.112	2.91929
and	the	orientation:	0.02185	0.00239	0.00267
with	this	uncertainty:	0.00405	0.00315	0.00609
Object	fiducial	with	id:	20#	
has	the	location:	272.44	195.15	153.621
with	this	uncertainty:	1.91809	3.70817	2.42093
and	the	orientation:	6.19834	6.24759	3.19219
with	this	uncertainty:	0.00395	0.00329	0.00621
Object	fiducial	with	id:	5#	
has	the	location:	265.5	271.635	146.617
with	this	uncertainty:	1.94914	3.69518	2.45796
and	the	orientation:	0.20741	6.08683	3.73167
with	this	uncertainty:	0.00258	0.00447	0.00644

Table B. 13: Object uncertainties in the case: Objects in Z > 0 + 3 Ref Fid + Ref Fid Z > 0 + High Std Dev

Object	fiducial	with	id:	30#	
has	the	location:	238.8	-25.739	-1.5944
with	this	uncertainty:	2.05401	2.90163	4.63761
and	the	orientation:	6.2641	0.04792	2.23471
with	this	uncertainty:	2.80E-04	0.00231	0.00162
Object	fiducial	with	id:	20#	
has	the	location:	260.836	202.453	145.677
with	this	uncertainty:	1.91336	2.64682	4.72
and	the	orientation:	5.70208	0.05342	3.15851
with	this	uncertainty:	0.00201	0.00119	0.00167
Object	fiducial	with	id:	5#	
has	the	location:	259.04	275.883	156.31
with	this	uncertainty:	1.90712	2.63028	4.75803
and	the	orientation:	0.23096	6.10012	3.70662
with	this	uncertainty:	0.00237	1.06E-04	0.00142

Table B. 14: Object uncertainties in the case: Objects in Z > 0 + 3 Ref Fid + Ref Fid Z = 0 + High Std Dev

Object	fiducial	with	id:	30#	
has	the	location:	240.076	-28.094	-9.1961
with	this	uncertainty:	2.73874	1.51482	4.37142
and	the	orientation:	6.26346	0.06497	2.24153
with	this	uncertainty:	0.00124	0.00215	0.00457
Object	fiducial	with	id:	20#	
has	the	location:	262.85	201.969	147.643
with	this	uncertainty:	1.87838	1.41427	4.55176
and	the	orientation:	5.88554	0.04769	3.16179
with	this	uncertainty:	0.00113	0.00221	0.00469
Object	fiducial	with	id:	5#	
has	the	location:	259.401	276.997	148.525
with	this	uncertainty:	1.78044	1.4147	4.62938
and	the	orientation:	0.23776	6.1165	3.71156
with	this	uncertainty:	0.00206	0.00143	0.00431

Table B. 15: Object uncertainties in the case:Objects in Z > 0 + 4 Ref Fid + Ref Fid Z = 0 + High Std Dev

Object	fiducial	with	id:	22#	
has	the	location:	-3.9134	5.26125	-39.154
with	this	uncertainty:	3.27459	3.84488	5.33299
and	the	orientation:	0.06918	0.03837	6.27728
with	this	uncertainty:	0.00257	0.0023	0.00635
Object	fiducial	with	id:	30#	
has	the	location:	242.426	-28.33	-18.69
with	this	uncertainty:	3.40457	2.85058	4.87159
and	the	orientation:	0.26407	6.13221	2.2204
with	this	uncertainty:	5.46E-04	0.0034	0.00649
Object	fiducial	with	id:	944#	
has	the	location:	496.835	378.245	13.2805
with	this	uncertainty:	1.97802	2.5953	5.15648
and	the	orientation:	0.05684	6.24132	6.27621
with	this	uncertainty:	0.00257	0.0023	0.0065
Object	fiducial	with	id:	5#	
has	the	location:	252.89	265.194	155.917
with	this	uncertainty:	1.99202	2.51637	5.36524
and	the	orientation:	0.21235	6.18177	3.71246
with	this	uncertainty:	0.00339	7.01E-04	0.00614
Object	fiducial	with	id:	20#	
has	the	location:	256.098	191.601	146.145
with	this	uncertainty:	2.17437	2.52559	5.22639
and	the	orientation:	5.79264	0.10866	3.15647
with	this	uncertainty:	0.00263	0.00225	0.00664

Table B. 16: Object uncertainties in the case: Objects in Z > 0 + 2 Ref Fid + Ref Fid Z = 0 + High Std Dev
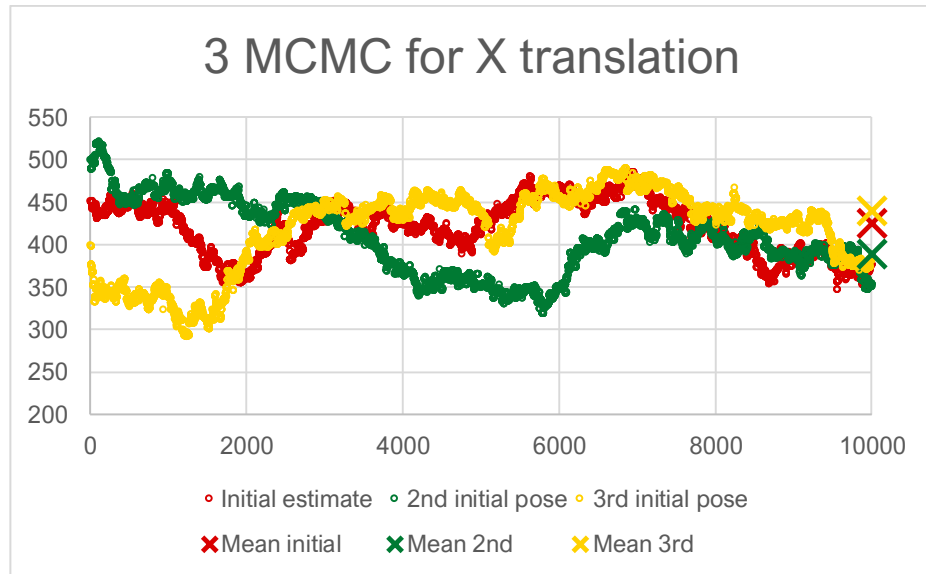
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Figure B. 1: Evolution of the X translation coordinate of the camera, in 3 MCMC methods
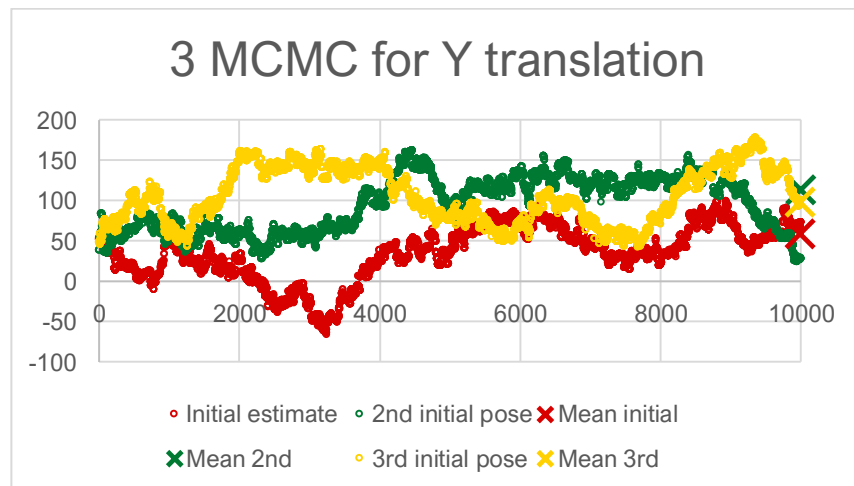

Figure B. 2: Evolution of the Y translation coordinate of the camera, in 3 MCMC methods
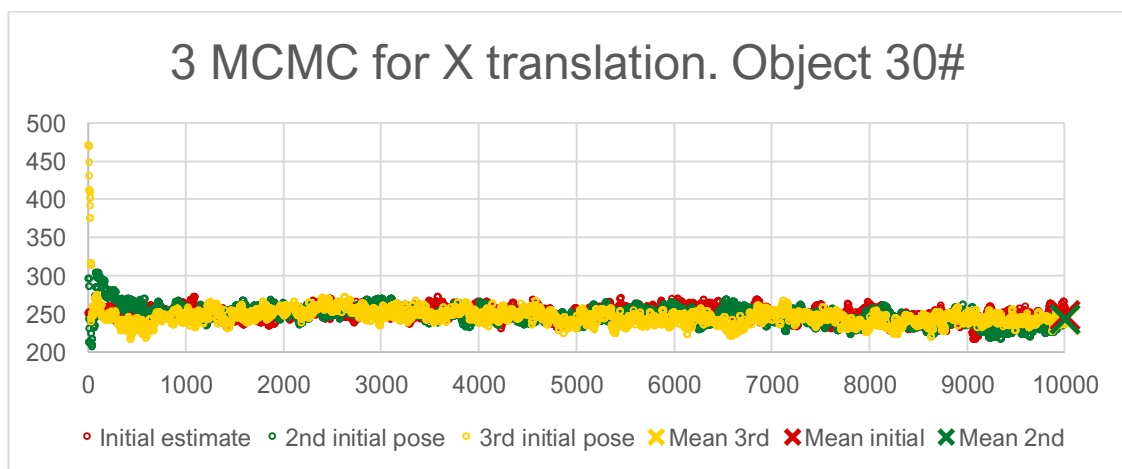

Figure B. 3: Evolution of the X translation coordinate of an object, in 3 MCMC methods

Appendix C. Intrinsic parameters impact

Object	fiducial	with	id:	30#
has	the	pose:		
Mean X	Std Dev X	249.4378931	0.898353736	
Mean Y	Std Dev Y	-62.85138487	0.186605302	
Mean Z	Std Dev Z	12.74248219	4.313840605	
Mean xAngle	Std Dev xA	6.278405299	0.017745785	
Mean yAngle	Std Dev yA	6.231667018	0.024583443	
Mean xAngle	Std Dev zA	5.443930226	0.001373991	
Object	fiducial	with	id:	20#
has	the	pose:		
Mean X	Std Dev X	-15.42570742	2.297913617	
Mean Y	Std Dev Y	-13.12542412	0.179546326	
Mean Z	Std Dev Z	275.7215594	2.82577714	
Mean xAngle	Std Dev xA	6.069678517	0.013958115	
Mean yAngle	Std Dev yA	0.244792475	0.0197343	
Mean xAngle	Std Dev zA	6.086226513	0.002012382	
Object	fiducial	with	id:	5#
has	the	pose:		
Mean X	Std Dev X	401.0619108	0.237139943	
Mean Y	Std Dev Y	297.6414632	1.766137725	
Mean Z	Std Dev Z	-9.19976052	1.982712984	
Mean xAngle	Std Dev xA	0.017250772	0.023654795	
Mean yAngle	Std Dev yA	0.017159622	0.010802006	
Mean xAngle	Std Dev zA	2.613154434	7.59E-04	

Table C. 1: Object uncertainties with 5 mm Std Dev + estimating focal length

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Object	fiducial			30#
has	the	pose:		
Mean X	Std Dev X	249.4175762	0.178099791	
Mean Y	Std Dev Y	-61.0001765	0.409337281	
Mean Z	Std Dev Z	9.451857476	0.187427837	
Mean xAngle	Std Dev xA	6.265747386	0	
Mean yAngle	Std Dev yA	6.225588714	0	
Mean xAngle	Std Dev zA	5.444159811	1.49E-08	
Object	fiducial			20#
has	the	pose:		
Mean X	Std Dev X	-15.46400378	0.178099791	
Mean Y	Std Dev Y	-10.96631213	0.409337281	
Mean Z	Std Dev Z	272.9666053	0.187427836	
Mean xAngle	Std Dev xA	6.07857865	2.11E-08	
Mean yAngle	Std Dev yA	0.238238949	2.36E-08	
Mean xAngle	Std Dev zA	6.089765554	0	
Object	fiducial			5#
has	the	pose:		
Mean X	Std Dev X	401.2685094	0.178099791	
Mean Y	Std Dev Y	298.6748113	0.409337281	
Mean Z	Std Dev Z	-10.82710407	0.187427837	
Mean xAngle	Std Dev xA	0.02296895	0	
Mean yAngle	Std Dev yA	0.016001476	0	
Mean xAngle	Std Dev zA	2.616416262	0	

Table C. 2: Object uncertainties with 5 mm Std Dev + focal length constant

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```
acceptedMap = Map(IntrinsicProposal(15.0) -> 1367 CameraRProposal(0.1) -> 21
CameraTProposal(10.0) -> 983 CameraTProposal(1.0) -> 1922 CameraRProposal(0.01) -> 995)
rejectedMap = Map(IntrinsicProposal(15.0) -> 683 CameraRProposal(0.1) -> 1935
CameraTProposal(10.0) -> 1041 CameraTProposal(1.0) -> 127 CameraRProposal(0.01) -> 925)
PoseWithFocalLength(Location(422.99933458317656 14.8901435285044 940.7073152121089)
Orientation(-3.1050971974640373 0.067655064596953 0.0020328821351304053)
580.720301286552 581.2618104860386)
```

All the results are shown in the order: x y z xAngle yAngle zAngle

The Camera is located in:

Means: 295.174308164837 64.3635363604006 945.424275306897 3.12146070172515
6.22828449309208 0.0629799379196312

StdDev: 54.8958658659404 53.3494704311281 112.121733207559 0.0568481664824254
0.0489719665061318 0.0751904983166392

The Camera has the following focal length:

Mean:	593.6213	510.8725
StdDev:	98.47362	37.5573

Calculation	of	object	statistics	
Object has	fiducial the	with location:	id:	11#
12.94205	7.616208			
3.842521	1.391751			
21.78267	9.847711			
6.192256	0.006847			
6.232272	0.035977			
0.00361	4.87E-04			
Object has	fiducial the	with location:	id:	22#
187.3476	4.454538			
-128.131	1.307066			
8.195664	9.545368			
6.03689	0.003881			
0.583946	0.046503			
6.216749	0.010734			
Object has	fiducial the	with location:	id:	30#
255.2074	3.37904			
-57.1555	1.374863			
24.98802	10.01016			
0.082207	0.03533			
6.160532	0.040915			
5.444032	8.83E-04			
Object has	fiducial the	with location:	id:	5#
166.1087	4.806502			
217.9509	1.584807			
181.9603	7.868248			
1.33E-04	0.032175			
6.113574	0.027241			
1.103111	0.004518			
Object has	fiducial the	with location:	id:	20#
353.5479	1.180415			
283.9283	3.616539			
-2.5854	4.5465			
6.200796	0.034345			
0.110499	0.073799			
3.543301	0.014839			

Table C. 3: Output when estimating the focal length with: Std Dev = 20 mm + 2 Ref Fid + All in Z = 0

ETSEIB

accepted = 4660 and rejected = 5339
acceptedMap = Map(IntrinsicProposal(15.0) -> 1173 CameraRProposal(0.1) -> 9 CameraTProposal(10.0) -> 825
CameraTProposal(1.0) -> 1792 CameraRProposal(0.01) -> 861)
rejectedMap = Map(IntrinsicProposal(15.0) -> 877 CameraRProposal(0.1) -> 1967 CameraTProposal(10.0) ->
1183 CameraTProposal(1.0) -> 132 CameraRProposal(0.01) -> 1180)
PoseWithFocalLength(Location(440.90440370577 54.1921132889342 946.2479341791751)
Orientation(3.1373114662223394 0.0858343128047822 -0.002704213195178162) 580.720301286552
581.2618104860386)
All the results are shown in the order: x y z xAngle yAngle zAngle
The Camera is located in:
Means: 348.262095086735 294.293613548004 1112.45560756849 2.93084641705198 6.27977411156971
6.25744242639689
StdDev: 32.9114338928901 51.6134582145996 131.752753497808 0.026993791628002 0.0309173698571412
0.0192909654605179
The Camera has the following focal length:
Mean: 635.689460851006 675.898014048142
StdDev: 74.8251386338849 89.9315656191675
In process: estimation of the pose of the detected fiducials/objects
Calculation of object statistics

Object has	fiducial the	with location:	id:	11#
	-1.01578	7.066187		
	4.742659	1.579209		
	12.50307	9.58304		
	6.131422	0.010764		
	0.036334	0.039451		
	6.28293	0.002199		
Object has	fiducial the	with location:	id:	22#
	180.7668	3.664533		
	-125.973	1.481631		
	8.668105	8.328417		
	6.193071	0.025771		
	0.022557	0.059224		
	0.026512	0.011253		
Object has	fiducial the	with location:	id:	30#
	249.8437	2.67433		
	-55.6919	1.50696		
	14.86237	8.227244		
	6.246847	0.037726		
	6.254129	0.078949		
	5.442588	0.010067		
Object has	fiducial the	with location:	id:	5#
	161.2141	4.124127		
	224.8807	1.816971		
	167.8965	7.089414		
	0.057995	0.034034		
	6.221341	0.036231		
	1.11515	0.008497		
Object has	fiducial the	with location:	id:	20#
	352.6434	1.055188		
	278.4609	4.457284		
	-6.76299	7.543578		
	0.013402	0.047863		
	6.251164	0.039269		
	3.563337	0.003414		

Table C. 4: Output when estimating the focal length with: Std Dev = 20 mm + 3 Ref Fid + All in Z = 0

accepted = 4348 and rejected = 5651
acceptedMap = Map(IntrinsicProposal(15.0) -> 1037 CameraRProposal(0.1) -> 11
CameraTProposal(10.0) -> 721 CameraTProposal(1.0) -> 1788 CameraRProposal(0.01) ->
791)
rejectedMap = Map(IntrinsicProposal(15.0) -> 1017 CameraRProposal(0.1) -> 1944
CameraTProposal(10.0) -> 1311 CameraTProposal(1.0) -> 150 CameraRProposal(0.01) ->
1229)
PoseWithFocalLength(Location(440.79476016937446 20.7902031889537
934.5812332907284) Orientation(-3.1095690914029737 0.0859905581317112
0.00146017805397035) 580.720301286552 581.2618104860386)
All the results are shown in the order: x y z xAngle yAngle zAngle
The Camera is located in:
Means: 360.560782713528 126.392293045199 892.924189572582 3.05707329326355
0.00438771457343922 6.278542452669
StdDev: 32.7325441605378 27.1600358792926 51.6317106029282 0.0325648735890721
0.0345225137419755 0.0163267814698297
The Camera has the following focal length:
Mean: 530.954097194911 524.319470113295
StdDev: 34.7356789642552 35.8975563667176
In process: estimation of the pose of the detected fiducials/objects
Calculation of object statistics

Object		fiducial		with	id:	22#
has		the		location:		
	184.3133		1.572837			
	-126.901		1.528304			
	4.280769		5.798324			
	6.005265		0.002345			
	0.563379		0.007606			
	6.221056		0.002033			
Object		fiducial		with	id:	30#
has		the		location:		
	252.8191		1.507692			
	-56.4609		1.534132			
	15.50112		5.815474			
	0.020029		0.005877			
	6.219329		0.007245			
	5.445684		2.53E-04			
Object		fiducial		with	id:	5#
has		the		location:		
	165.0884		1.563306			
	218.8365		1.554089			
	175.5144		4.944121			
	0.052021		0.005048			
	6.153179		0.004419			
	1.106241		9.34E-04			
Object		fiducial		with	id:	20#
has		the		location:		
	353.3293		1.385331			
	281.7323		1.705933			
	-5.56879		5.453797			
	6.212614		0.01011			
	6.275413		0.009125			
	3.56226		0.001683			

Table C. 5: Output when estimating the focal length with: Std Dev = 20 mm + 4 Ref Fid + All in Z = 0

ETSEIB

accepted = 3978 and rejected = 6021

acceptedMap = Map(IntrinsicProposal(15.0) -> 1151 CameraRProposal(0.1) -> 6 CameraTProposal(10.0) -> 574 CameraTProposal(1.0) -> 1801 CameraRProposal(0.01) -> 446)

rejectedMap = Map(IntrinsicProposal(15.0) -> 940 CameraRProposal(0.1) -> 1930 CameraTProposal(10.0) -> 1411 CameraTProposal(1.0) -> 193 CameraRProposal(0.01) -> 1547)

PoseWithFocalLength(Location(431.8985552723741 22.6133638468044 939.0624264563506) Orientation(-3.1133777424505915 0.0762599644188445 -0.0016349352848254973) 580.720301286552 581.2618104860386)

Initial focal length: 580.720301286552 581.261810486038

All the results are shown in the order: x y z xAngle yAngle zAngle

The Camera is located in:
Means: 352.391440396219 36.9961738412862 1174.2972388422 3.15335829182291 6.2806309779396 6.28049146567241
StdDev: 21.4832703099365 36.6666501002907 46.1170673864375 0.0309191069955526 0.0176959251298537 0.012795267524646

The Camera has the following focal length:
Mean: 702.064745789644 709.377270161852

StdDev: 30.5167713221455 28.737895006025

In process: estimation of the pose of the detected fiducials/objects

Calculation of object statistics

Object has	fiducial the		with location:	id:	30#
	252.3932	1.472671			
	-57.1311	1.539852			
	19.25823	5.824545			
	0.025483	0.00581			
	6.210879	0.007456			
	5.446041	2.34E-04			
Object has	fiducial the		with location:	id:	20#
	353.8142	1.356195			
	279.6841	1.675551			
	1.75966	5.452365			
	6.229351	0.007413			
	0.027472	0.010106			
	3.557469	0.001861			
Object has	fiducial the		with location:	id:	5#
	164.704	1.538576			
	217.8506	1.559226			
	180.1423	4.934037			
	0.049645	0.00533			
	6.13304	0.004163			
	1.101887	7.90E-04			

Table C. 6: Output when estimating the focal length with: Std Dev = 20 mm + 5 Ref Fid + All in Z = 0

```
accepted = 3861 and rejected = 6138
acceptedMap = Map(IntrinsicProposal(15.0) -> 1074 CameraRProposal(0.1) -> 1
CameraTProposal(10.0) -> 501 CameraTProposal(1.0) -> 1775
CameraRProposal(0.01) -> 510)
rejectedMap = Map(IntrinsicProposal(15.0) -> 978 CameraRProposal(0.1) -> 1973
CameraTProposal(10.0) -> 1481 CameraTProposal(1.0) -> 186
CameraRProposal(0.01) -> 1520)
PoseWithFocalLength(Location(429.49765191661646 26.2519754449971
940.3766572845713) Orientation(-3.1168005942766643 0.0737515115439825 -
0.0030381165125138955) 580.720301286552 581.2618104860386)
```

Initial focal length: 580.720301286552 581.261810486038

All the results are shown in the order: x y z xAngle yAngle zAngle

The Camera is located in:
Means: 453.127097166686 4.26615765090276 985.181780540424
3.18565210845514 0.0928098118055421 6.28086533176263
StdDev: 30.6149549630248 17.6309010660676 51.8833693887833
0.0149661423001495 0.0266119832769982 0.0139561512898468

The Camera has the following focal length:
Mean: 608.752620658664 604.048699167644
StdDev: 37.8234163416725 35.1707894875426

In process: estimation of the pose of the detected fiducials/objects
Calculation of object statistics

Object has		fiducial the		with location:	id:	30#
	251.8202		1.463105			
	-56.6633		1.545232			
	20.23059		5.824454			
	0.02576		0.005742			
	6.206922		0.007394			
	5.446023		2.38E-04			
Object has		fiducial the		with location:	id:	20#
	353.3749		1.347935			
	280.7673		1.694743			
	-0.80843		5.459835			
	6.231181		0.008313			
	0.018568		0.009956			
	3.559277		0.001776			
Object has		fiducial the		with location:	id:	5#
	163.2985		1.53172			
	219.4318		1.564296			
	178.4507		4.944405			
	0.044305		0.00526			
	6.138422		0.004231			
	1.101079		7.97E-04			

Table C. 7: Output when estimating the focal length with: Std Dev = 20 mm + 6 Ref Fid + All in Z = 0

ETSEIB

accepted = 5272 and rejected = 4727
acceptedMap = Map(IntrinsicProposal(15.0) -> 1258 CameraRProposal(0.1) -> 21
CameraTProposal(10.0) -> 1022 CameraTProposal(1.0) -> 1851 CameraRProposal(0.01) -> 1120)
rejectedMap = Map(IntrinsicProposal(15.0) -> 760 CameraRProposal(0.1) -> 1979
CameraTProposal(10.0) -> 1013 CameraTProposal(1.0) -> 109 CameraRProposal(0.01) -> 866)
PoseWithFocalLength(Location(473.59683257399513 13.6879950904812 923.4425790022817)
Orientation(-3.0989153928028994 0.119709438876544 0.009887490679135354)
580.720301286552 581.2618104860386)
Initial focal length: 580.720301286552 581.261810486038
All the results are shown in the order: x y z xAngle yAngle zAngle
The Camera is located in:
Means: 521.243905127163 311.21112642502 756.12116035131 2.74379898595863
0.174843368347535 6.16555089843833
StdDev: 47.6591670208004 38.4576977321971 57.5345820045342 0.0293745434903589
0.0524608685014522 0.0607959644979575
The Camera has the following focal length:
Mean: 579.236125579961 389.671814108533
StdDev: 63.5163505565109 44.3289666695236
In process: estimation of the pose of the detected fiducials/objects
Calculation of object statistics

Object has	fiducial the		with location:	id:	22#
	181.307	4.352118			
	-120.38	1.901228			
	-35.1381	20.25691			
	6.259479	0.08092			
	0.065854	0.096149			
	0.025619	0.013214			
Object has	fiducial the		with location:	id:	30#
	249.705	3.537863			
	-51.0948	1.594537			
	-31.175	20.00161			
	6.244297	0.029741			
	0.045461	0.082531			
	5.440941	0.010299			
Object has	fiducial the		with location:	id:	5#
	165.1511	4.687257			
	224.9231	0.670297			
	141.4931	17.6566			
	0.123741	0.030824			
	6.208952	0.039315			
	1.116074	0.012124			
Object has	fiducial the		with location:	id:	20#
	353.3835	1.726264			
	281.5702	3.240716			
	-32.3473	13.689			
	6.2718	0.044007			
	6.219083	0.03114			
	3.569995	0.00326			

Table C. 8: Output when estimating the focal length with: Std Dev = 20 mm + 2 Ref Fid + One in Z > 0

```
accepted = 4749 and rejected = 5250
acceptedMap = Map(IntrinsicProposal(15.0) -> 1172 CameraRProposal(0.1) -> 11
CameraTProposal(10.0) -> 845 CameraTProposal(1.0) -> 1846 CameraRProposal(0.01) -> 875)
rejectedMap = Map(IntrinsicProposal(15.0) -> 838 CameraRProposal(0.1) -> 1962
CameraTProposal(10.0) -> 1200 CameraTProposal(1.0) -> 132 CameraRProposal(0.01) ->
1118)
PoseWithFocalLength(Location(466.855955797015 10.3705676760992 921.3915513969216)
Orientation(-3.100789773774954 0.113129066109755 0.0013178826175287179)
580.720301286552 581.2618104860386)
Initial focal length: 580.720301286552 581.261810486038
All the results are shown in the order: x y z xAngle yAngle zAngle
The Camera is located in:
Means: 409.197375797343 176.540600982797 1041.73640839681 3.02400342050588
0.0551179549588737 0.0476945763739302
StdDev: 26.4575228047526 26.134161855672 50.5098652329661 0.025727230801744
0.0272715085132481 0.0272300942714535
The Camera has the following focal length:
Mean: 653.606372739736 576.097595024732
StdDev: 33.7349084901181 28.7745496580734
In process: estimation of the pose of the detected fiducials/objects
```

Object has	fiducial the		with location:	id:	22#
	187.1424	3.409207			
	-132.565	0.844991			
	-14.2765	17.73056			
	6.012438	0.015787			
	0.52505	0.027162			
	6.242908	0.009686			
Object has	fiducial the		with location:	id:	30#
	256.2051	2.880157			
	-61.9678	0.690479			
	-5.7292	17.48944			
	6.242694	0.021125			
	0.011355	0.041396			
	5.448817	0.009319			
Object has	fiducial the		with location:	id:	5#
	169.3391	2.688825			
	214.0183	0.843752			
	162.2122	14.70614			
	0.106283	0.017662			
	6.181707	0.018641			
	1.11353	0.007891			
Object has	fiducial the		with location:	id:	20#
	357.7531	2.165155			
	273.3562	2.397527			
	-11.7369	17.70033			
	6.260307	0.022606			
	6.248762	0.018733			
	3.568837	0.006899			

Table C. 9: Output when estimating the focal length with: Std Dev = 20 mm + 3 Ref Fid + One in Z > 0

ETSEIB

accepted = 4339 and rejected = 5660
acceptedMap = Map(IntrinsicProposal(15.0) -> 1214 CameraRProposal(0.1) -> 3
CameraTProposal(10.0) -> 732 CameraTProposal(1.0) -> 1769 CameraRProposal(0.01) -> 621)
rejectedMap = Map(IntrinsicProposal(15.0) -> 840 CameraRProposal(0.1) -> 1912
CameraTProposal(10.0) -> 1344 CameraTProposal(1.0) -> 149 CameraRProposal(0.01) -> 1415)
PoseWithFocalLength(Location(446.4390689731874 3.20492126778201 924.8817513480653)
Orientation(-3.0922565348557334 0.0920615037754657 0.0043529332058538095)
580.720301286552 581.2618104860386)
Initial focal length: 580.720301286552 581.261810486038
All the results are shown in the order: x y z xAngle yAngle zAngle
The Camera is located in:
Means: 491.727698133061 72.6214747775872 1166.98116266333 3.12050813623768
0.10964565983331 0.00719888185993831
StdDev: 36.9142462451948 20.715424959943 40.093797724985 0.0182060964237596
0.027670809807116 0.0167224207999578
The Camera has the following focal length:
Mean: 731.233616562933 703.5602612476
StdDev: 30.7617955118425 32.7074961941577
In process: estimation of the pose of the detected fiducials/objects
Calculation of object statistics

Object has	fiducial the		with location:	id:	22#
	185.5319	2.814376			
	-131.616	0.748363			
	-13.6011	6.156243			
	6.26794	0.009718			
	0.072047	0.020137			
	0.03041	0.006984			
Object has	fiducial the		with location:	id:	30#
	255.2419	2.297952			
	-61.0293	0.52064			
	-2.64421	6.3098			
	6.239892	0.012471			
	0.055874	0.027304			
	5.44516	0.007032			
Object has	fiducial the		with location:	id:	5#
	163.4266	0.669578			
	212.1242	1.162503			
	164.6559	5.015055			
	0.11677	0.010799			
	6.198706	0.012514			
	1.125353	0.008585			
Object has	fiducial the		with location:	id:	20#
	358.3169	0.882791			
	271.2651	1.633496			
	5.740185	9.139148			
	0.012313	0.013508			
	6.242682	0.010119			
	3.572771	0.007452			

Table C. 10: Output when estimating the focal length with: Std Dev = 20 mm + 4 Ref Fid + One in Z > 0

accepted = 4058 and rejected = 5941
acceptedMap = Map(IntrinsicProposal(15.0) -> 1154 CameraTProposal(10.0) -> 588
CameraTProposal(1.0) -> 1794 CameraRProposal(0.01) -> 522)
rejectedMap = Map(IntrinsicProposal(15.0) -> 850 CameraRProposal(0.1) -> 2012
CameraTProposal(10.0) -> 1422 CameraTProposal(1.0) -> 184 CameraRProposal(0.01) ->
1473)
PoseWithFocalLength(Location(438.04971166677285 7.82115622154152
932.9354223642625) Orientation(-3.0981919867093324 0.0816382635757172 -
1.1815564530209846E-4) 580.720301286552 581.2618104860386)
Initial focal length: 580.720301286552 581.261810486038

All the results are shown in the order: x y z xAngle yAngle zAngle

The Camera is located in:
Means: 459.104188662242 -2.2164237484791 1093.31169542355 3.18763621696372
0.0891409909278017 6.28160654031882
StdDev: 19.5433164282963 51.9440207315169 31.3164740891756 0.0460161502813599
0.0172272015399265 0.0136367116642992

The Camera has the following focal length:

Mean: 681.253885726074 673.510739109293

StdDev: 25.98201091968 28.4873003622704

In process: estimation of the pose of the detected fiducials/objects

Calculation of object statistics

Object has		fiducial the		with location:	id:	30#
	253.0103		0.471963			
	-61.8566		0.512798			
	10.32427		5.697445			
	6.273238		0.011741			
	0.031006		0.024752			
	5.438364		0.002274			
Object has		fiducial the		with location:	id:	20#
	357.9655		0.742803			
	268.7921		1.48818			
	10.97999		8.83702			
	6.277547		0.013805			
	6.271672		0.013075			
	3.562276		0.001714			
Object has		fiducial the		with location:	id:	5#
	162.579		0.928086			
	210.1784		0.539244			
	171.7976		4.700269			
	0.113072		0.012668			
	6.171869		0.011942			
	1.110481		0.002874			

Table C. 11: Output when estimating the focal length with: Std Dev = 20 mm + 5 Ref Fid + One in Z > 0

accepted = 3827 and rejected = 6172
acceptedMap = Map(IntrinsicProposal(15.0) -> 980 CameraRProposal(0.1) -> 3 CameraTProposal(10.0) -> 497 CameraTProposal(1.0) -> 1739 CameraRProposal(0.01) -> 608)
rejectedMap = Map(IntrinsicProposal(15.0) -> 999 CameraRProposal(0.1) -> 1974 CameraTProposal(10.0) -> 1565 CameraTProposal(1.0) -> 197 CameraRProposal(0.01) -> 1437)
PoseWithFocalLength(Location(438.886221464816 4.29689946330672 929.3237164710116) Orientation(-3.0953035679662193 0.0850088063745822 -6.307635845169578E-5) 580.720301286552 581.2618104860386)
Initial focal length: 580.720301286552 581.261810486038
All the results are shown in the order: x y z xAngle yAngle zAngle
The Camera is located in:
Means: 448.836765913808 -3.18294522751601 939.438556847308 3.19487561969737 0.0942331718917391 0.00172652094564046
StdDev: 28.2907180146605 34.4861991929635 37.6238822881778 0.0339885693268769 0.0269023399076068 0.0135713815994233
The Camera has the following focal length:
Mean: 583.625611148603 582.59235920435
StdDev: 28.6866287767627 28.866381925157
In process: estimation of the pose of the detected fiducials/objects
Calculation of object statistics

Object has		fiducial the		with location:		id:	30#
	251.0598		0.454552				
	-62.0514		0.523326				
	0.808774		5.763837				
	6.239819		0.014148				
	0.030455		0.025991				
	5.436524		0.002588				
Object has		fiducial the		with location:		id:	20#
	357.8619		0.794493				
	269.3296		1.605097				
	7.963592		9.133572				
	0.015451		0.013789				
	6.246764		0.010574				
	3.563158		0.001042				
Object has		fiducial the		with location:		id:	5#
	161.9616		0.873135				
	211.9182		0.563608				
	167.7739		4.819343				
	0.106879		0.011731				
	6.181512		0.012142				
	1.110723		0.00303				

Table C. 12: Output when estimating the focal length with: Std Dev = 20 mm + 6 Ref Fid + One in Z > 0

ETSEIB

Inlier size 24
accepted = 3923 and rejected = 6076
acceptedMap = Map(IntrinsicProposal(15.0) -> 1074 CameraRProposal(0.1) -> 4
CameraTProposal(10.0) -> 513 CameraTProposal(1.0) -> 1804
CameraRProposal(0.01) -> 528)
rejectedMap = Map(IntrinsicProposal(15.0) -> 1023 CameraRProposal(0.1) -> 1882
CameraTProposal(10.0) -> 1563 CameraTProposal(1.0) -> 182
CameraRProposal(0.01) -> 1426)
PoseWithFocalLength(Location(436.58953750650664 9.34985221371669
933.6758069388287) Orientation(-3.0997473609584483 0.0811633692033235 -
9.649076316729406E-4) 580.720301286552 581.2618104860386)
Initial focal length: 580.720301286552 581.261810486038
All the results are shown in the order: x y z xAngle yAngle zAngle
The Camera is located in:
Means: 382.979889616498 -5.75660274475765 1045.42295132669
3.19507816000386 0.023683778748912 6.27990205611389
StdDev: 23.7507155437271 29.4582206397028 51.8963787674677
0.0289253749674521 0.0234470086352874 0.0157277664844321
The Camera has the following focal length:
Mean: 642.680388633629 641.525714689009
StdDev: 35.3004597429518 31.6765828707343
In process: estimation of the pose of the detected fiducials/objects
Calculation of object statistics

Object has	fiducial the	with location:	id:	30#
251.8129	0.495452			
-61.8053	0.505901			
8.926377	5.879855			
6.260795	0.011906			
0.031312	0.025232			
5.435693	0.002347			
Object has	fiducial the	with location:	id:	20#
357.5297	0.759756			
269.084	1.5601			
10.44992	9.141013			
6.278347	0.015052			
6.251505	0.012012			
3.564684	0.001358			
Object has	fiducial the	with location:	id:	5#
162.2177	0.938526			
210.5004	0.531254			
172.505	4.665378			
0.10034	0.012461			
6.166193	0.011571			
1.109552	0.002658			

Table C. 13: Output when applying the robust estimation algorithm and estimating focal length with: Std Dev = 20 mm + 6 Ref Fid + One in Z > 0

ETSEIB

accepted = 1678 and rejected = 8321
acceptedMap = Map(IntrinsicProposal(15.0) -> 231 CameraTProposal(10.0) ->
53 CameraTProposal(1.0) -> 1345 CameraRProposal(0.01) -> 49)
rejectedMap = Map(IntrinsicProposal(15.0) -> 1790 CameraRProposal(0.1) ->
1923 CameraTProposal(10.0) -> 2034 CameraTProposal(1.0) -> 624
CameraRProposal(0.01) -> 1950)
PoseWithFocalLength(Location(442.9260071766578 8.85140872776292
930.7340762421055) Orientation(-3.0974166146429196 0.0870119813125029
0.003115946352317159) 580.720301286552 581.2618104860386)
Initial focal length: 580.720301286552 581.261810486038
All the results are shown in the order: x y z xAngle yAngle zAngle
The Camera is located in:
Means: 448.089761597889 12.9813527758052 919.609527295389
3.18151983734245 0.0931720444253914 0.00396492488820101
StdDev: 4.26989001058385 3.42172994649986 10.3184945247022
0.00340305418676987 0.00406362364121468 0.0028216809086771
The Camera has the following focal length:
Mean: 574.041382125458 572.179123907099
StdDev: 7.52311162635733 7.5857621890317
In process: estimation of the pose of the detected fiducials/objects
Calculation of object statistics

Object has	fiducial the	with location:	id:	30#
251.3852	0.867433			
-62.9339	0.323266			
0.339798	3.718054			
0.005018	0.014657			
6.271336	0.022482			
5.443199	0.00141			

Object has	fiducial the	with location:	id:	5#
162.6721	1.395301			
209.6169	0.201117			
164.2153	3.064068			
0.081191	0.013027			
6.153359	0.011484			
1.104844	0.002603			

Object has	fiducial the	with location:	id:	20#
354.029	0.373196			
271.4355	1.346093			
-6.91875	1.398382			
6.236574	0.021295			
6.260602	0.016392			
3.566603	0.002414			

Table C. 14: Output when estimating the focal length with: Std Dev = 5 mm + 4 Ref Fid + One in Z > 0