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- Luca Carlone: Certifiable perception for Robots and autonomous vehicles: from robust algorithms to robust systems.
- Certifiable perception algorithms:
  - Image-based object localization

    feature detection → Model fitting / estimation (3D registration)

    RGB: Yang CVPR'20

    PCL: PointNetLk CVPR'19, SmoothNet CVPR'19

    Teaser RSS'19, TRO'20

    Issues: 1. front-end (feature detection) has many outliers.

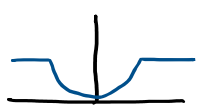
    2. back-end may fail if there are many outliers

- Why does the back-end fail?

$$\min_{x} \sum_{i \in \mathcal{M}} \| r(x, y_i) \|^2$$

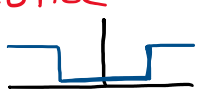
residual ← r; x → estimate; y_i → feature from front-end

a. L2-norm is not robust to outliers

b. M-estimator robust loss function 

(local solvers; needs initial guess)

fails without notice

c. Consensus maximization 

RANSAC (fails with many outliers, non-deteministic)

fails without notice

- Certifiable algorithms: fast algorithms that solve outlier rejection to optimality in virtually all problem instances or detect failure in worst-case problems.

  Robust estimation → optimization over the ring of polynomials → Semidefinite relaxation (Lasserre hierarchy)

  This enables: Robust solvers (no initial guess, deterministic, tolerate extreme outliers, global optimality, detect failures)

  TEASER++: Certifiable object localization in point clouds.

  runs in 20 ms

  Shape#: Certifiable object localization in images

- Towards system-level guarantees & real-time high-level understanding:
  - kimera: real-time 3D metric-semantic understanding
  - 3D Dynamic Scene Graph.

    "One Ring to Rule Them All"