Data Fusion Research

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Techniques for Data Fusion

A Review of Data Fusion Techniques

Terms

Data: Raw, unprocessed info collected from diff sources (ex: sensor readings)

Feature: Specific measurable traits or characteristics extracted from the data (ex: shape of an object)

Decision: Final outcome/conclusion derived after analyzing features/combining multiple data inputs (ex: identifying an object based on features)

Track: continuous estimation of an objects state over time as it moves

Dasarathy's Classification

1. data in-data out: process inputs and outputs raw data.
    - Reliable
    - conducted immediatly
    - based on signal and image processing algos
2. data in-feature out: process raw data to extract features.
    - extract characteristics that describe entities or the enviorment.
3. feature in-feature out: both input and output are features
    - used to improve/refine features or to obtain a new feature.
4. feature in-decision out: input a set of features and outputs a set of decisions

- most classification systems that perform a decision based on a sensor's input fall into this category

5. Decision In-Decision Out: fuses input decisions to obtain better/new decisions

Abstraction Levels

Signal Level

directly addresses data from sensors

LiDAR in it's raw form is considered this

Pixel Level

fusion at the level of individual pixels/raw data points

happens before any higher-level feature extraction

common in: satellite imagery, medical imaging, fields that rely on raw visual data

Once processed LiDAR can be visualized as point clouds/3D maps making it visual data.

Characteristic

Fusing the characterstics derived from raw data (patterns, shapes, statistical properties)

Fused to improved pattern recognition/classification.

provieds more meaningful data for decision-making

Often used in object recognition or sensor fusion

Symbol

information combined at semantic level

works with high-level, abstract representations of data (recognized objects, words, or symbols)

used in applications requiring complex paterns, relationships, or events like natural language processing

Alt Abstraction Levels

low level

Raw data provided as input directly

medium level

characters or features are fused

high level

decision fusing, combining symbolic represtaions

Bayesian methods typically used at this level

multiple level fusion

using multiple levels of abstraction

Data Association Techniques

Linking/matching related atapoints from multiple sources.

Make sure right data is combined to make accurate decisions or inferences.

Nearest Neighbors (NN)

Assigns measurements to closest predicted target based on proximity.

Assumes nearest target is correct in multi-target instances.

Simple and efficient but struggles in crowded environments

K-means

A modification of the NN algo.

divides data into clusters

finds best localization of the center of cluster

1. obtain input and # of clusters
2. randomly assign center of cluster
3. match data point with a center
4. move the cluster center to a better center of the cluster
5. if alo does not converge return to step 3

Doesn't always find best solution for centers

number of clusters must be already known and we assume is optimal

assumes dataset is normalized/ignores covariance

Join Probabilistic Data Association

not good for tracking multiple targets in cluttered environments

consideres all possible associations simultaneously

manages uncertaintiy in cluttered situations

common usage: radar/sonar

a measurement cannot come from more than one target

two measurements cannot orinate from the same target at an instant

sum of all measurements probabilities that are assigned to one target must be 1

requires explicit mechanism for track initialization

cannot make new tracks or remove tracks out of observable area

computationally expensive

best in situations where density of false measurements is high

Multiple Hypothesis Testing

generates and evaluates several potenetial hypotheses about new observations as they correspond to existing tracks.

Does not commit to a single data association at each step, keeps multiple hypotheses alive and updates their likelihood as more data arrives.

Prunes less likeley hypotheses as time goes -> converges on most probable associations

Useful in complex enviornments with high uncertainty and clutter.

State Estimation Methods

Predicting the position/velocity of an object over time.

Decision Fusion Methods

Fusing the decisions multiple systems come to on there own after independently processing data.

Vote Averageing or Weighted Combination

Data Sets

ONCE Dataset (One millioN sCenEs)- Huawei Corp

- Lidar + Camera
- 1mil lidar scense + 7mil corresponding images
- 144hrs driving hours
- 15k scenes
  - fully annotated
  - 5 classes (car, bus, truck, pedestrian, cyclist)
  - 3 weather conditions (sunny, cloudy, rainy)
  - 4 time periods (morning, noon, afternoon, night)

All-in-One Drive (AIODrive)

- Camera + Lidar + Radar
- largescale perception dataset
- high density long-range point clouds
- large scale **Synthetic** dataset
- 8 sensor modalities

Ford Multi-AV Seasonal dataset

- Camara, LiDAR
- collected by a fleet of Ford autonomous vehicles on different days and times during 2017–18
- mix of driving scenarios, including the Detroit Airport, freeways, city-centers, university campus, and suburban neighborhood
- logs annotated with freeway, overpass, bridge, cloudy, construction, tunnel, airport, residential,vegetation, overpass

Dense Depth for Autonomous Driving (DDAD)

- Camera, LiDAR
- monocular video
- grout-truth depth
- 360 degrees

PandaSet

- Camera, LiDar
- forward facing LiDAR + spinning LiDAR