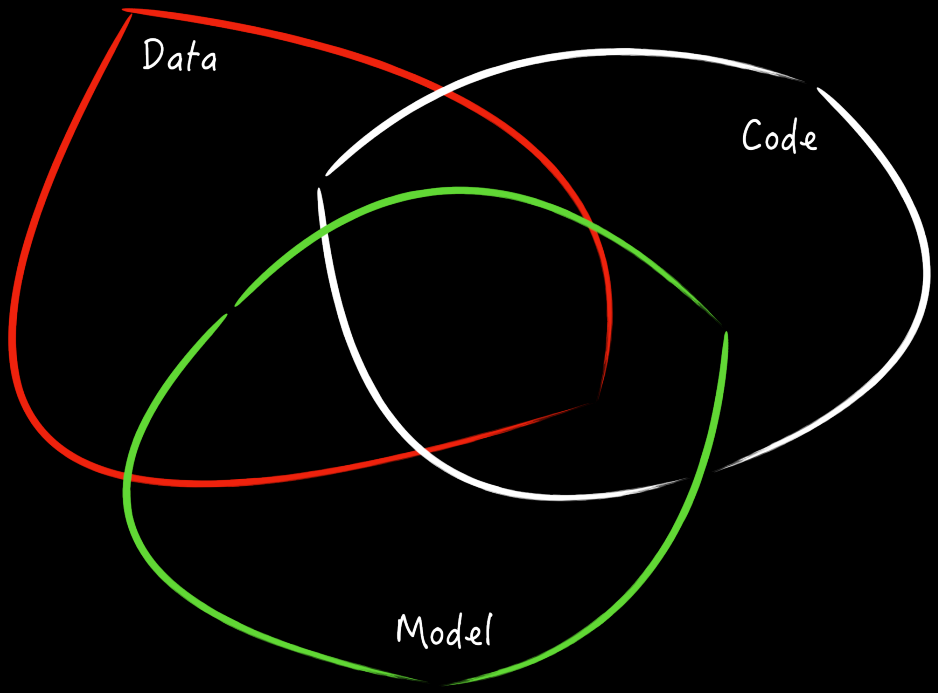
Quality Assessment

- Data Quality

Jin Guo
SOCS McGill University

Software Quality Management


Data
Code
Model

Data Quality

- What makes “good” data for machine learning?

Contains relevant features

Reflect real interactions

Good coverage

Few or no biases

Large enough

Data Quality

Dimensions	Elements
1) Availability	1) Accessibility
	2) Timeliness
2) Usability	1) Credibility
3) Reliability	1) Accuracy
	2) Consistency
	3) Integrity
	4) Completeness
4) Relevance	1) Fitness
5) Presentation Quality	1) Readability

Cai, L. and Zhu, Y., 2015. The Challenges of Data Quality and Data Quality Assessment in the Big Data Era. *Data Science Journal*, 14, p.2. DOI: http://doi.org/10.5334/dsj-2015-002

Data Quality

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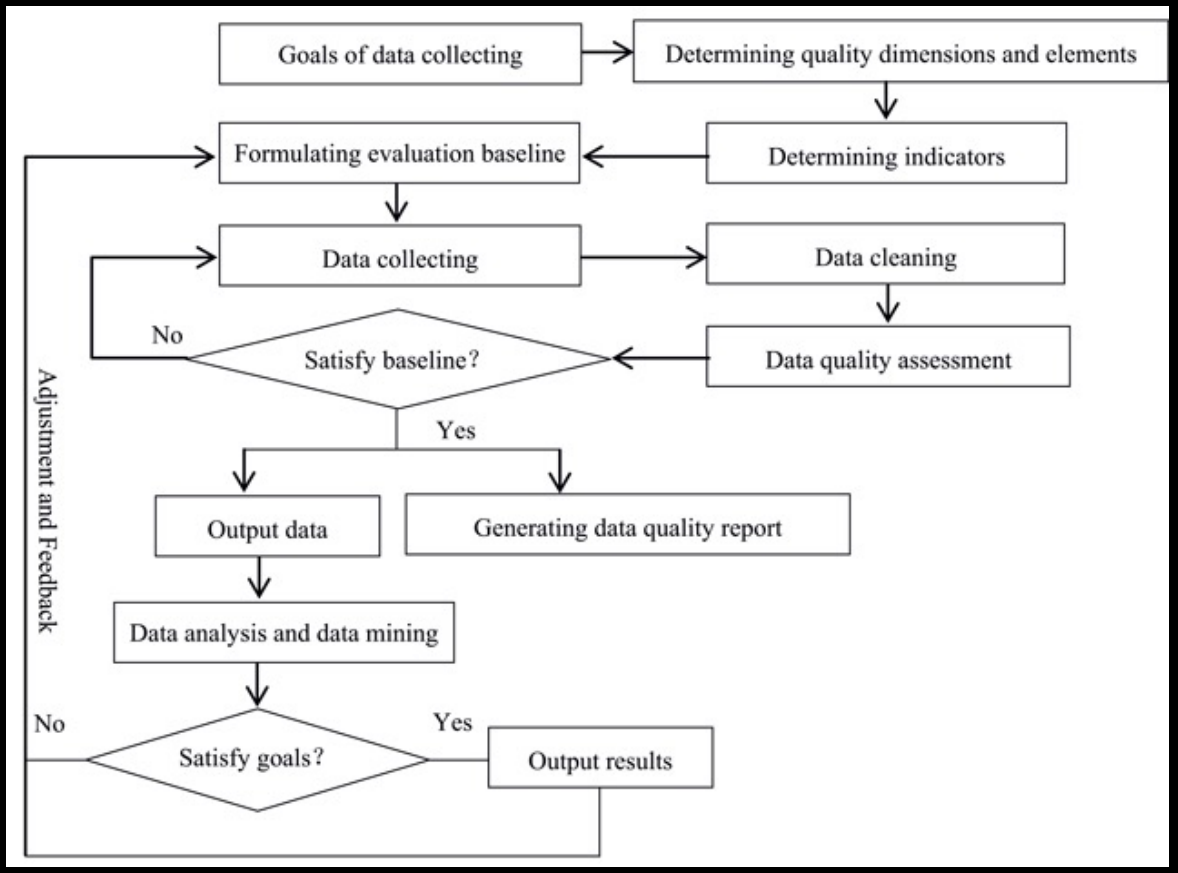
4) Relevance	1) Fitness
5) Presentation Quality	1) Readability

Indicators of accessibility:
- Whether a data access interface is provided
- Data can be easily made public or easy to purchase

Cai, L. and Zhu, Y., 2015. The Challenges of Data Quality and Data Quality Assessment in the Big Data Era. *Data Science Journal*, 14, p.2. DOI: http://doi.org/10.5334/dsj-2015-002

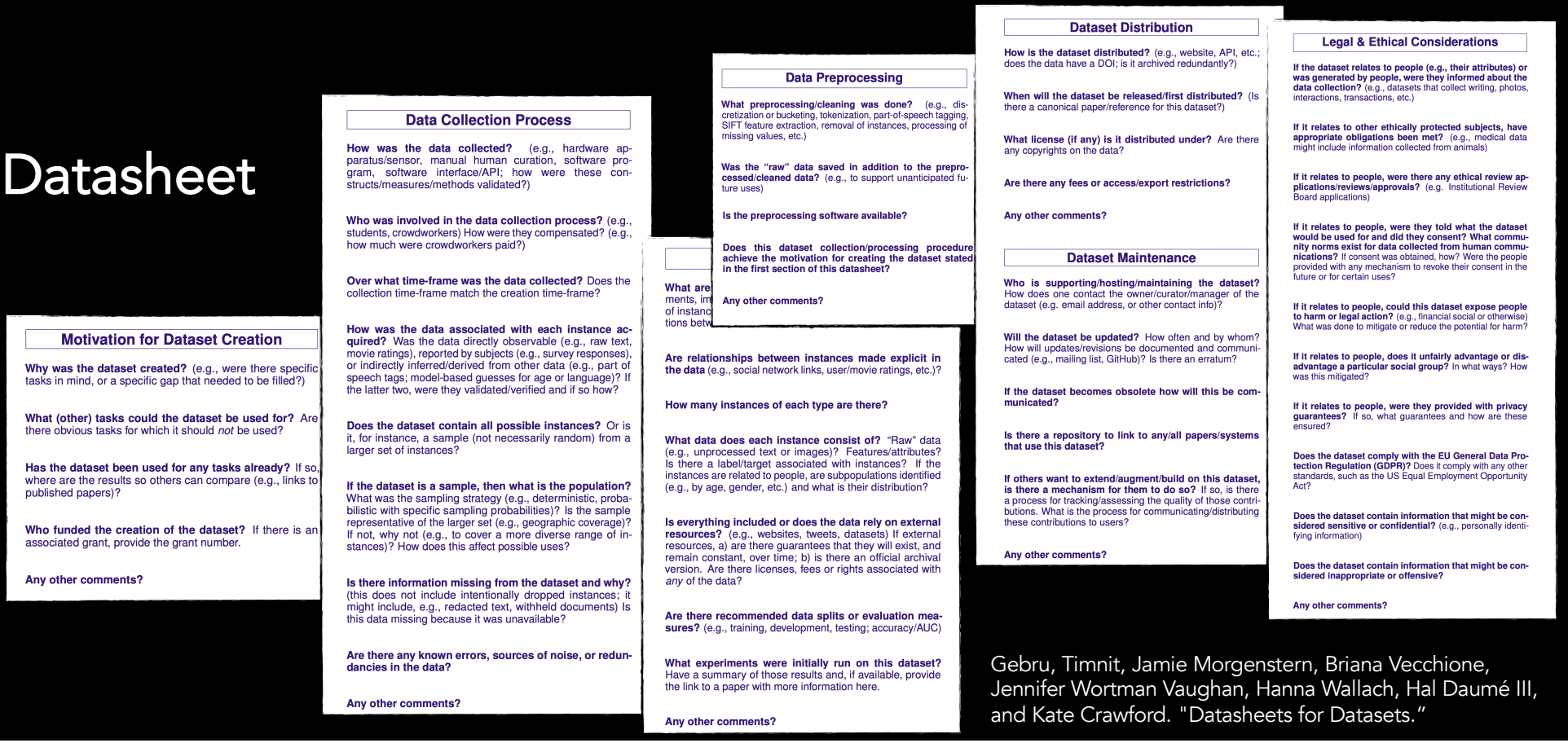
Data Quality Assessment Process



Cai, L. and Zhu, Y., 2015. The Challenges of Data Quality and Data Quality Assessment in the Big Data Era. *Data Science Journal*, 14, p.2. DOI: http://doi.org/10.5334/dsj-2015-002

Review Dataset documentation

Datasheet



Motivation for Dataset Creation

Why was the dataset created? (e.g., were there specific tasks in mind, or a specific gap that needed to be filled?)

What (other) tasks could the dataset be used for? Are there obvious tasks for which it should *not* be used?

Has the dataset been used for any tasks already? If so, where are the results so others can compare (e.g., links to published papers)?

Who funded the creation of the dataset? If there is an associated grant, provide the grant number.

Any other comments?

Data Collection Process

How was the data collected? (e.g., hardware apparatus/sensor, manual human curation, software program, software interface/API; how were these constructs/measures/methods validated?)

Who was involved in the data collection process? (e.g., students, crowdworkers) How were they compensated? (e.g., how much were crowdworkers paid?)

Over what time-frame was the data collected? Does the collection time-frame match the creation time-frame?

How was the data associated with each instance acquired? Was the data directly observable (e.g., raw text, movie ratings), reported by subjects (e.g., survey responses), or indirectly inferred/derived from other data (e.g., part of speech tags; model-based guesses for age or language)? If the latter two, were they validated/verified and if so how?

Does the dataset contain all possible instances? Or is it, for instance, a sample (not necessarily random) from a larger set of instances?

If the dataset is a sample, then what is the population? What was the sampling strategy (e.g., deterministic, probabilistic with specific sampling probabilities)? Is the sample representative of the larger set (e.g., geographic coverage)? If not, why not (e.g., to cover a more diverse range of instances)? How does this affect possible uses?

Is there information missing from the dataset and why? (this does not include intentionally dropped instances; it might include, e.g., redacted text, withheld documents) Is this data missing because it was unavailable?

Are there any known errors, sources of noise, or redundancies in the data?

Any other comments?

Data Preprocessing

What preprocessing/cleaning was done? (e.g., discretization or bucketing, tokenization, part-of-speech tagging, SIFT feature extraction, removal of instances, processing of missing values, etc.)

Was the "raw" data saved in addition to the preprocessed/cleaned data? (e.g., to support unanticipated future uses)

Is the preprocessing software available?

Does this dataset collection/processing procedure achieve the motivation for creating the dataset stated in the first section of this datasheet?

Any other comments?

What are
ments, im
of instanc
tions betw

Are relationships between instances made explicit in the data (e.g., social network links, user/movie ratings, etc.)?

How many instances of each type are there?

What data does each instance consist of? "Raw" data (e.g., unprocessed text or images)? Features/attributes? Is there a label/target associated with instances? If the instances are related to people, are subpopulations identified (e.g., by age, gender, etc.) and what is their distribution?

Is everything included or does the data rely on external resources? (e.g., websites, tweets, datasets) If external resources, a) are there guarantees that they will exist, and remain constant, over time; b) is there an official archival version. Are there licenses, fees or rights associated with *any* of the data?

Are there recommended data splits or evaluation measures? (e.g., training, development, testing; accuracy/AUC)

What experiments were initially run on this dataset? Have a summary of those results and, if available, provide the link to a paper with more information here.

Any other comments?

Dataset Distribution

How is the dataset distributed? (e.g., website, API, etc.; does the data have a DOI; is it archived redundantly?)

When will the dataset be released/first distributed? (Is there a canonical paper/reference for this dataset?)

What license (if any) is it distributed under? Are there any copyrights on the data?

Are there any fees or access/export restrictions?

Any other comments?

Dataset Maintenance

Who is supporting/hosting/maintaining the dataset? How does one contact the owner/curator/manager of the dataset (e.g. email address, or other contact info)?

Will the dataset be updated? How often and by whom? How will updates/revisions be documented and communicated (e.g., mailing list, GitHub)? Is there an erratum?

If the dataset becomes obsolete how will this be communicated?

Is there a repository to link to any/all papers/systems that use this dataset?

If others want to extend/augment/build on this dataset, is there a mechanism for them to do so? If so, is there a process for tracking/assessing the quality of those contributions. What is the process for communicating/distributing these contributions to users?

Any other comments?

Legal & Ethical Considerations

If the dataset relates to people (e.g., their attributes) or was generated by people, were they informed about the data collection? (e.g., datasets that collect writing, photos, interactions, transactions, etc.)

If it relates to other ethically protected subjects, have appropriate obligations been met? (e.g., medical data might include information collected from animals)

If it relates to people, were there any ethical review applications/reviews/approvals? (e.g. Institutional Review Board applications)

If it relates to people, were they told what the dataset would be used for and did they consent? What community norms exist for data collected from human communications? If consent was obtained, how? Were the people provided with any mechanism to revoke their consent in the future or for certain uses?

If it relates to people, could this dataset expose people to harm or legal action? (e.g., financial social or otherwise) What was done to mitigate or reduce the potential for harm?

If it relates to people, does it unfairly advantage or disadvantage a particular social group? In what ways? How was this mitigated?

If it relates to people, were they provided with privacy guarantees? If so, what guarantees and how are these ensured?

Does the dataset comply with the EU General Data Protection Regulation (GDPR)? Does it comply with any other standards, such as the US Equal Employment Opportunity Act?

Does the dataset contain information that might be considered sensitive or confidential? (e.g., personally identifying information)

Does the dataset contain information that might be considered inappropriate or offensive?

Any other comments?

Gebru, Timnit, Jamie Morgenstern, Briana Vecchione, Jennifer Wortman Vaughan, Hanna Wallach, Hal Daumé III, and Kate Crawford. "Datasheets for Datasets."

Data Profiling

Adult Data Set

Predict whether income exceeds $50K/yr based on census data. Also known as "Census Income" dataset.

Data Set Characteristics:	Multivariate	Number of Instances:	48842	Area:	Social
Attribute Characteristics:	Categorical, Integer	Number of Attributes:	14	Date Donated	1996-05-01
Associated Tasks:	Classification	Missing Values?	Yes	Number of Web Hits:	1953013

https://archive.ics.uci.edu/ml/datasets/adult

Data Profiling

Adult Data Set

Source:
Donor:
Ronny Kohavi and Barry Becker
Data Mining and Visualization
Silicon Graphics.
e-mail: ronnyk '@' live.com for questions.

Data Set Information:
Extraction was done by Barry Becker from the 1994 Census database. A set of reasonably clean records was extracted using the following conditions: ((AAGE>16) && (AGI>100) && (AFNLWGT>1)&& (HRSWK>0))

Prediction task is to determine whether a person makes over 50K a year.

https://archive.ics.uci.edu/ml/datasets/adult

Data Profiling

Adult Data Set

Listing of attributes:
>50K, <=50K.

age: continuous.
workclass: Private, Self-emp-not-inc, Self-emp-inc, Federal-gov, Local-gov, State-gov, Without-pay, Never-worked.
fnlwgt: continuous.
education: Bachelors, Some-college, 11th, HS-grad, Prof-school, Assoc-acdm, Assoc-voc, 9th, 7th-8th, 12th, Masters, 1st-4th, 10th, Doctorate, 5th-6th, Preschool.
education-num: continuous.
marital-status: Married-civ-spouse, Divorced, Never-married, Separated, Widowed, Married-spouse-absent, Married-AF-spouse.
occupation: Tech-support, Craft-repair, Other-service, Sales, Exec-managerial, Prof-specialty, Handlers-cleaners, Machine-op-inspct, Adm-clerical, Farming-fishing, Transport-moving, Priv-house-serv, Protective-serv, Armed-Forces.
relationship: Wife, Own-child, Husband, Not-in-family, Other-relative, Unmarried.
race: White, Asian-Pac-Islander, Amer-Indian-Eskimo, Other, Black.
sex: Female, Male.
capital-gain: continuous.
capital-loss: continuous.
hours-per-week: continuous.
native-country: United-States, Cambodia, England, Puerto-Rico, Canada, Germany, Outlying-US(Guam-USVI-etc), India, Japan, Greece, South, China, Cuba, Iran, Honduras, Philippines, Italy, Poland, Jamaica, Vietnam, Mexico, Portugal, Ireland, France, Dominican-Republic, Laos, Ecuador, Taiwan, Haiti, Columbia, Hungary, Guatemala, Nicaragua, Scotland, Thailand, Yugoslavia, El-Salvador, Trinadad&Tobago, Peru, Hong, Holand-Netherlands.

https://archive.ics.uci.edu/ml/datasets/adult

Data Profiling

Overview

Overview | Dataset | Variables | Warnings 6 | Reproduction

Warnings

Dataset has 25 (0.1%) duplicate rows	Duplicates
`workclass` has 1836 (5.6%) missing values	Missing
`occupation` has 1843 (5.7%) missing values	Missing
`native-country` has 583 (1.8%) missing values	Missing
`capital-gain` has 29849 (91.7%) zeros	Zeros
`capital-loss` has 31042 (95.3%) zeros	Zeros

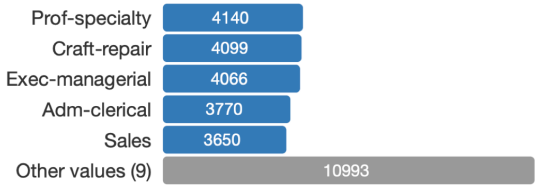
https://pandas-profiling.github.io/pandas-profiling/examples/master/census/census_report.html

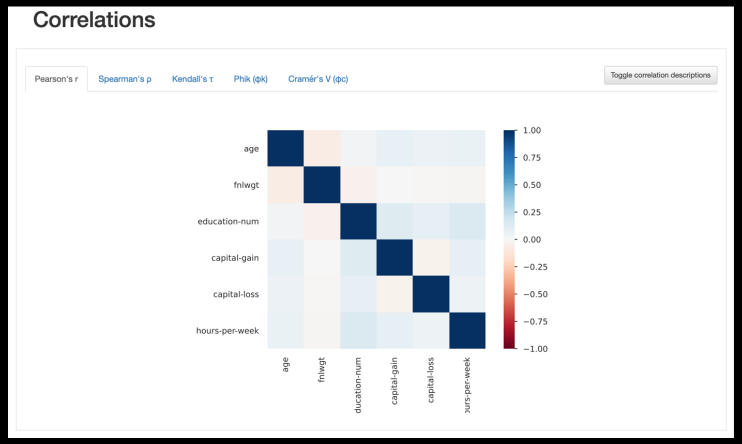
Data Profiling

occupation
Categorical

`MISSING`

Distinct	14
Distinct (%)	< 0.1%
Missing	1843
Missing (%)	5.7%
Memory size	254.5 KiB





https://pandas-profiling.github.io/pandas-profiling/examples/master/census/census_report.html

Dataset Inspection Schema

Scope/Problem		Dirty Data	Reasons/Remarks
Attribute	Illegal values	bdate=30.13.70	values outside of domain range
Record	Violated attribute dependencies	age=22, bdate=12.02.70	age = current year - birth year should hold
Record type	Uniqueness violation	emp_1=(name="John Smith", SSN="123456"); emp_2=(name="Peter Miller", SSN="123456")	uniqueness for SSN (social security number) violated
Source	Referential integrity violation	emp=(name="John Smith", deptno=127)	referenced department (127) not defined

Rahm, Erhard, and Hong Hai Do. "Data cleaning: Problems and current approaches." IEEE Data Eng. Bull. 23, no. 4 (2000): 3-13.

Dataset Inspection Instance Constraints

Scope/Problem		Dirty Data	Reasons/Remarks
Attribute	Missing values	phone=9999-999999	unavailable values during data entry (dummy values or null)
	Misspellings	city=”Liipzig”	usually typos, phonetic errors
	Cryptic values, Abbreviations	experience=”B”; occupation=”DB Prog.”	
	Embedded values	name=”J. Smith 12.02.70 New York”	multiple values entered in one attribute (e.g. in a free-form field)
	Misfielded values	city=”Germany”	
Record	Violated attribute dependencies	city=”Redmond”, zip=77777	city and zip code should correspond
Record type	Word transpositions	$name_1$= ”J. Smith”, $name_2$=”Miller P.”	usually in a free-form field
	Duplicated records	emp_1=(name=”John Smith”,. . .); emp_2=(name=”J. Smith”,. . .)	same employee represented twice due to some data entry errors
	Contradicting records	emp_1=(name=”John Smith”, bdate=12.02.70); emp_2=(name=”John Smith”, bdate=12.12.70)	the same real world entity is described by different values
Source	Wrong references	emp=(name=”John Smith”, deptno=17)	referenced department (17) is defined but wrong

Rahm, Erhard, and Hong Hai Do. "Data cleaning: Problems and current approaches." IEEE Data Eng. Bull. 23, no. 4 (2000): 3-13.

Dataset Verification Tools

constraint	semantic
statistics	
`hasSize`	custom validation of the number of records
`hasTypeConsistency`	custom validation of the maximum fraction of values of the same data type
`hasCountDistinct`	custom validation of the number of distinct non-null values in a column
`hasApproxCountDistinct`	custom validation of the approx. number of distinct non-null values
`hasMin`	custom validation of a column's minimum value
`hasMax`	custom validation of a column's maximum value
`hasMean`	custom validation of a column's mean value
`hasStandardDeviation`	custom validation of a column's standard deviation
`hasApproxQuantile`	custom validation of a particular quantile of a column (approx.)
`hasEntropy`	custom validation of a column's entropy
`hasMutualInformation`	custom validation of a column pair's mutual information
`hasHistogramValues`	custom validation of column histogram
`hasCorrelation`	custom validation of a column pair's correlation
time	
`hasNoAnomalies`	validation of anomalies in time series of metric values

Schelter, Sebastian, Dustin Lange, Philipp Schmidt, Meltem Celikel, Felix Biessmann, and Andreas Grafberger. "Automating large-scale data quality verification." Proceedings of the VLDB Endowment 11, no. 12 (2018): 1781-1794.

Dataset Verification Tools


```scala
import com.amazon.deequ.{VerificationSuite, VerificationResult}
import com.amazon.deequ.VerificationResult.checkResultsAsDataFrame
import com.amazon.deequ.checks.{Check, CheckLevel}

val verificationResult: VerificationResult = { VerificationSuite()
  // data to run the verification on
  .onData(dataset)
  // define a data quality check
  .addCheck(
    Check(CheckLevel.Error, "Review Check")
      .hasSize(_ >= 3000000) // at least 3 million rows
      .hasMin("star_rating", _ == 1.0) // min is 1.0
      .hasMax("star_rating", _ == 5.0) // max is 5.0
      .isComplete("review_id") // should never be NULL
      .isUnique("review_id") // should not contain duplicates
      .isComplete("marketplace") // should never be NULL
      // contains only the listed values
      .isContainedIn("marketplace", Array("US", "UK", "DE", "JP", "FR"))
      .isNonNegative("year")) // should not contain negative values
  // compute metrics and verify check conditions
  .run()
}

// convert check results to a Spark data frame
val resultDataFrame = checkResultsAsDataFrame(spark, verificationResult)
```

constraint	constraint status	constraint_message
SizeConstraint(Size(None))	Success	
MinimumConstraint(Minimum(star_rating,None))	Success	
MaximumConstraint(Maximum(star_rating,None))	Success	
CompletenessConstraint(Completeness(review_id,None))	Success	
UniquenessConstraint(Uniqueness(List(review_id)))	Failure	Value: 0.9926566948782706 does not meet the constraint requirement!
CompletenessConstraint(Completeness(marketplace,None))	Success	
ComplianceConstraint(Compliance(marketplace contained in US,UK,DE,JP,FR,marketplace IS NULL OR marketplace IN ('US','UK','DE','JP','FR'),None))	Success	
ComplianceConstraint(Compliance(year is non-negative,COALESCE(year, 0.0) >= 0,None))	Success	

https://aws.amazon.com/blogs/big-data/test-data-quality-at-scale-with-deequ/

Dataset Verification Tools

```
expect_column_values_to_not_be_null
expect_column_values_to_match_regex
expect_column_values_to_be_unique
expect_column_values_to_match_strftime_format
expect_table_row_count_to_be_between
expect_column_median_to_be_between
```

```
[49]: my_df.expect_column_values_to_be_in_set("PClass", ["1st", "2nd", "3rd"], mostly=.99)
```


```
[49]: {
  "success": true,
  "meta": {},
  "result": {
    "element_count": 1313,
    "missing_count": 0,
    "missing_percent": 0.0,
    "unexpected_count": 1,
    "unexpected_percent": 0.07616146230007616,
    "unexpected_percent_nonmissing": 0.07616146230007616,
    "partial_unexpected_list": [
      "*"
    ]
  },
  "exception_info": null
}
```

```
{
  "data_asset_type": "Dataset",
  "expectation_suite_name": "taxi.demo",
  "expectations": [
  …
    {
      "expectation_type": "expect_column_values_to_not_be_null",
      "kwargs": {
        "column": "passenger_count"
      },
      "meta": {
        "BasicSuiteBuilderProfiler": {
          "confidence": "very low"
        }
      }
    },
    {
      "expectation_type": "expect_column_distinct_values_to_be_in_set",
      "kwargs": {
        "column": "passenger_count",
        "value_set": [
          1.0,
          2.0,
          3.0,
          4.0,
          5.0,
          6.0
        ]
      },
      "meta": {
        "BasicSuiteBuilderProfiler": {
          "confidence": "very low"
        }
      }
    },
   …
```


Expectation Suite

Dataset Verification Tools

great_expectations Home / taxi.demo / 20200819T024609.241003Z / 2020-08-19T02:46:09.241003+00:00 / cbb8bd044ccaa28d4db5e3d59c0be748

Expectation Validation Result

Evaluates whether a batch of data matches expectations.

Actions

Validation Filter:

Show All | Failed Only

How to Edit This Suite

Show Walkthrough

Table of Contents

- Overview
- Table-Level Expectations
- passenger_count

Overview

Expectation Suite: taxi.demo

Status: Succeeded

Statistics

Evaluated Expectations	6
Successful Expectations	6
Unsuccessful Expectations	0
Success Percent	100%

Show more info...

Table-Level Expectations

Search

Status	Expectation	Observed Value
✓	Must have between 9000 and 11000 rows.	10000
✓	Must have exactly 18 columns.	18
✓	Must have these columns in this order: vendor_id, pickup_datetime, dropoff_datetime, passenger_count, trip_distance, rate_code_id, store_and_fwd_flag, pickup_location_id, dropoff_location_id, payment_type, fare_amount, extra, mta_tax, tip_amount, tolls_amount, improvement_surcharge, total_amount, congestion_surcharge	['vendor_id', 'pickup_datetime', 'dropoff_datetime', 'passenger_count', 'trip_distance', 'rate_code_id', 'store_and_fwd_flag', 'pickup_location_id', 'dropoff_location_id', 'payment_type', 'fare_amount', 'extra', 'mta_tax', 'tip_amount', 'tolls_amount', 'improvement_surcharge', 'total_amount', 'congestion_surcharge']

passenger_count

Data integration from Multiple Sources

Customer (source 1)

CID	*Name*	*Street*	*City*	*Sex*
11	Kristen Smith	2 Hurley Pl	South Fork, MN 48503	0
24	Christian Smith	Hurley St 2	S Fork MN	1

Client (source 2)

Cno	*LastName*	*FirstName*	*Gender*	*Address*	*Phone/Fax*
24	Smith	Christoph	M	23 Harley St, Chicago IL, 60633-2394	333-222-6542 / 333-222-6599
493	Smith	Kris L.	F	2 Hurley Place, South Fork MN, 48503-5998	444-555-6666

Customers (integrated target with cleaned data)

No	*LName*	*FName*	*Gender*	*Street*	*City*	*State*	*ZIP*	*Phone*	*Fax*	*CID*	*Cno*
1	Smith	Kristen L.	F	2 Hurley Place	South Fork	MN	48503-5998	444-555-6666		11	493
2	Smith	Christian	M	2 Hurley Place	South Fork	MN	48503-5998			24	
3	Smith	Christoph	M	23 Harley Street	Chicago	IL	60633-2394	333-222-6542	333-222-6599		24

OpenRefine

TRIFACTA

Rahm, Erhard, and Hong Hai Do. "Data cleaning: Problems and current approaches." IEEE Data Eng. Bull. 23, no. 4 (2000): 3-13.

Data Drifting

- The change in model input data that leads to model performance degradation.

- Causes
  - Upstream process changes, such as a sensor being replaced that changes the units of measurement from inches to centimeters.
  - Data quality issues, such as a broken sensor always reading 0.
  - Natural drift in the data, such as mean temperature changing with the seasons.
  - Change in relation between features, or covariate shift.

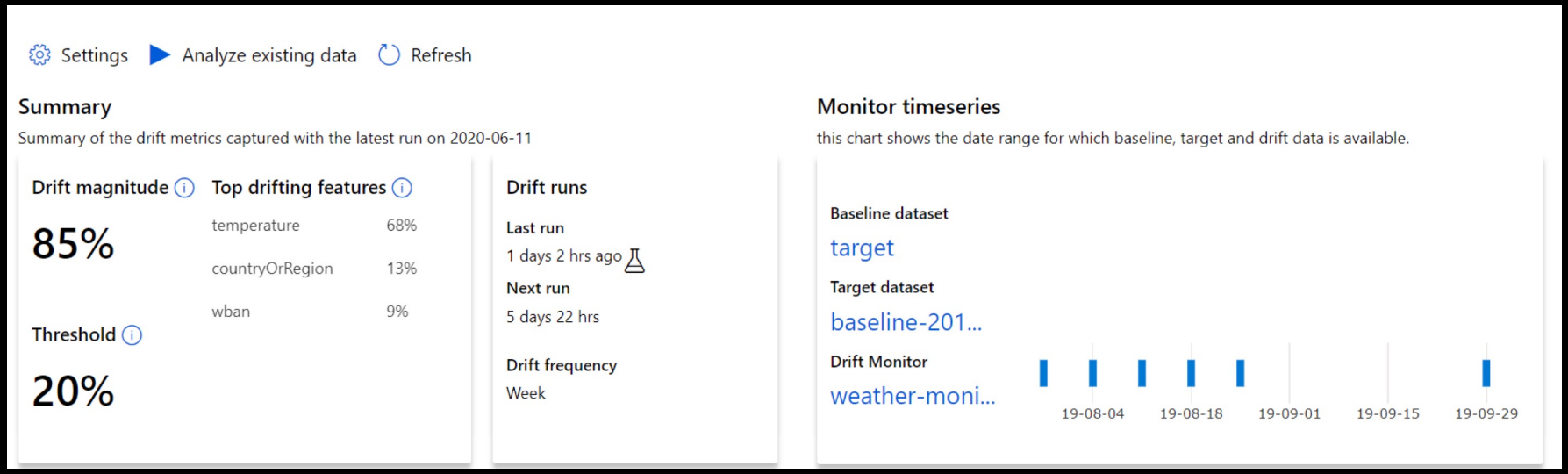
https://docs.microsoft.com/en-us/azure/machine-learning/how-to-monitor-datasets

Data Monitoring

- Detect and alert to data drift on new data in a dataset.
- Analyze historical data for drift.
- Profile new data over time.
- Monitor model performance

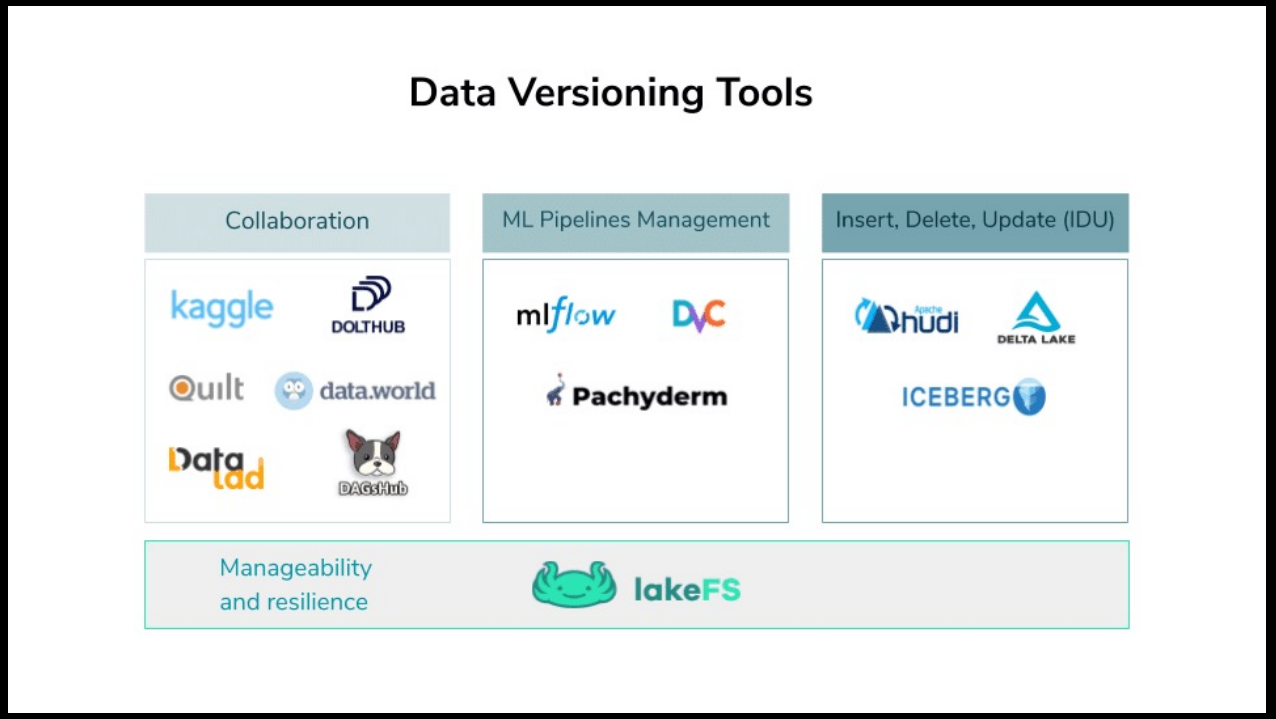
https://docs.microsoft.com/en-us/azure/machine-learning/how-to-monitor-datasets

Data Monitoring



https://docs.microsoft.com/en-us/azure/machine-learning/how-to-monitor-datasets

Data/Experiment Version Control



https://lakefs.io/data-versioning/

On next Tuesday:

Quality Assessment

Infrastructure by Avinash