Anomly detection with isolation forests

Which elements are few and different?

Terence Parr
University of San Francisco

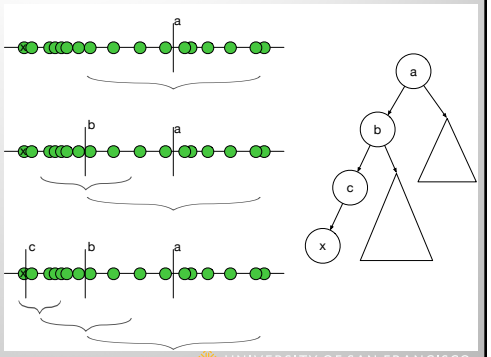
Project link:
https://github.com/parrt/msds689/blob/master/projects/iforest/iforest.md

Anomaly detection

- Applications include detecting network attacks, financial fraud, unusual changes in stock prices or other timeseries / signals
- Either focus on what's normal and look for "nonnormal" e.g., use kernel density estimates and look for elements > 4 sigma
- Or, focus on the unusual, which is what isolation forests do

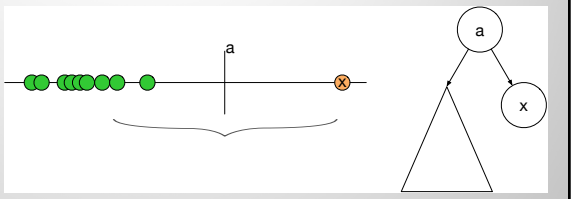
Random-split isolation in 1D

- To isolate x takes many partitions (splits at a, b, c)
- This leads to path length 3

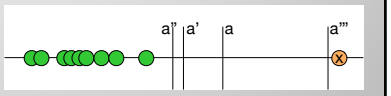


Random split on feature w/high kurtosis

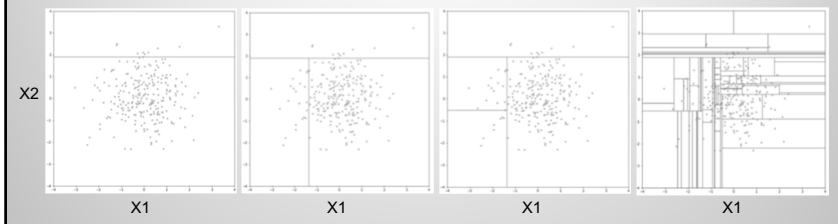
x has path length 1



"Anomalies are more susceptible to isolation and hence have short path lengths." – Liu *et al*

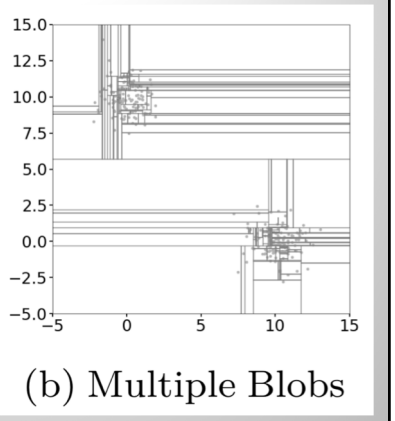


Random split isolation in 2D: [X1 X2]



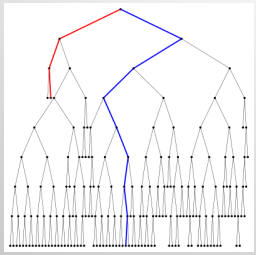
Images: http://www.ncsa.illinois.edu/Conferences/LSST18/assets/pdfs/hariri_forest.pdf

Works for multimodal data too

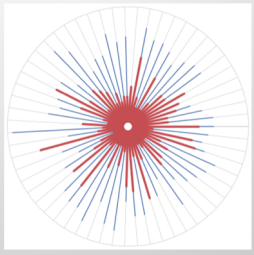


Forest of isolation trees

- Score for x is inversely related to depth of leaf containing x
- Average score across forest to get anomaly score



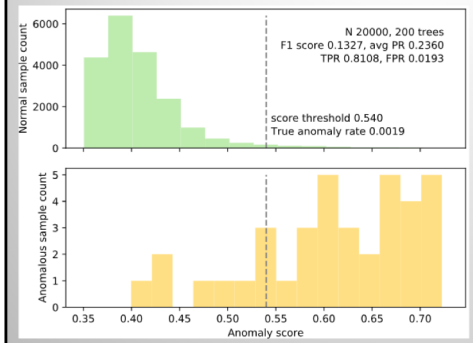
Tree



Forest

Images from Hariri et al: https://arxiv.org/abs/1811.02141

Scoring: sigmoid on normalized path length



Credit card data

$$s(x,\psi) = 2^{-\frac{E(h(x))}{c(\psi)}}$$

$$c(\psi) = \begin{cases} 2H(\psi-1) - 2(\psi-1)/n & \text{for } \psi > 2, \\ 1 & \text{for } \psi = 2, \\ 0 & \text{otherwise.} \end{cases}$$

h(i) ~= ln(i) + 0.5772156649

Tree construction

- From tiny subsample of all X training data, partition based upon random Xi feature and random split point between min(Xi) and max(Xi)

Algorithm 2 : $iTree(X, e, l)$

Inputs: X - input data, e - current tree height, l - height limit

Output: an iTree

if $e \geq l$ or $|X| \leq 1$ **then**
  return *exNode*$\{Size \leftarrow |X|\}$
else
  let Q be a list of attributes in X
  randomly select an attribute $q \in Q$
  randomly select a split point p from max and min values of attribute q in X
  $X_l \leftarrow filter(X, q < p)$
  $X_r \leftarrow filter(X, q \geq p)$
  return *inNode*$\{Left \leftarrow iTree(X_l, e+1, l)$,
    $Right \leftarrow iTree(X_r, e+1, l)$,
    $SplitAtt \leftarrow q$,
    $SplitValue \leftarrow p\}$
end if

Computing path length

- Recursively count levels, *e*, to node containing *x*
- If |X|>1 for leaf, we need to estimate depth using c(|X|) for samples X in leaf

Algorithm 3 : $PathLength(x, T, e)$

Inputs : x - an instance, T - an iTree, e - current path length; to be initialized to zero when first called

Output: path length of x

if T is an external node **then**
  return $e + c(T.size)$ {$c(.)$ is defined in Equation 1}
end if
$a \leftarrow T.splitAtt$
if $x_a < T.splitValue$ **then**
  return $PathLength(x, T.left, e+1)$
else $\{x_a \geq T.splitValue\}$
  return $PathLength(x, T.right, e+1)$
end if