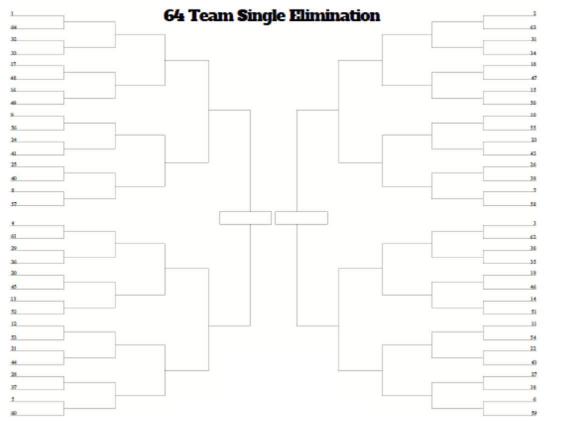
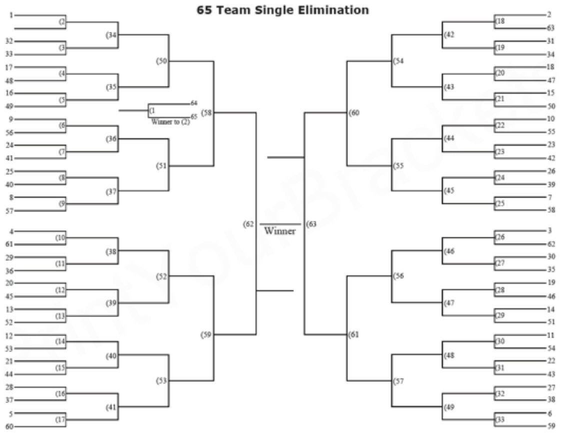
Upcoming

- Homework 3 due March 22
- Literature review due today March 20
- Project plan assignment posted, due April 10

- Paper presentation instructions: http://people.cs.umass.edu/~brun/class/2018Spring/CS621/paperPresentation/paperPresentation.pdf

Repairing Automated Repair





Generalizing

- How many games are there in a 78-team bracket?

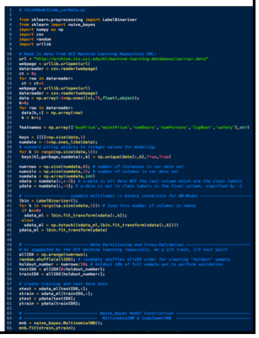
- What about an n-team bracket?

Repairing Automated Repair

Cobra effect

What do cobras have to do with automated program repair?

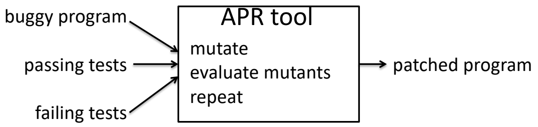
repairing python programs?



```
# thinkModelCode_carData.py

from sklearn.preprocessing import LabelBinarizer
from sklearn import naive_bayes
import numpy as np
import csv
import random
import urllib

# Read in data from UCI Machine Learning Repository URL:
url = "http://archive.ics.uci.edu/ml/machine-learning-databases/car/car.data"
webpage = urllib.urlopen(url)
datareader = csv.reader(webpage)
ct = 0;
for row in datareader:
 ct = ct+1
webpage = urllib.urlopen(url)
datareader = csv.reader(webpage)
data = np.array(-1*np.ones((ct,7),float),object);
k=0;
for row in datareader:
 data[k,:] = np.array(row)
 k = k+1;

featnames = np.array(['buyPrice','maintPrice','numDoors','numPersons','lugBoot','safety'],str)

keys = [[]]*np.size(data,1)
numdata = -1*np.ones_like(data);
# convert string objects to integer values for modeling:
for k in range(np.size(data,1)):
 keys[k],garbage,numdata[:,k] = np.unique(data[:,k],True,True)

numrows = np.size(numdata,0); # number of instances in car data set
numcols = np.size(numdata,1); # number of columns in car data set
numdata = np.array(numdata,int)
xdata = numdata[:,:-1]; # x-data is all data BUT the last column which are the class labels
ydata = numdata[:,-1]; # y-data is set to class labels in the final column, signified by -1

# ------------------ numdata multilabel -> binary conversion for NB-Model ---------------------
lbin = LabelBinarizer();
for k in range(np.size(xdata,1)): # loop thru number of columns in xdata
 if k==0:
  xdata_ml = lbin.fit_transform(xdata[:,k]);
 else:
  xdata_ml = np.hstack((xdata_ml,lbin.fit_transform(xdata[:,k])))
ydata_ml = lbin.fit_transform(ydata)


# -------------------------- Data Partitioning and Cross-Validation --------------------------
# As suggested by the UCI machine learning repository, do a 2/3 train, 1/3 test split
allIDX = np.arange(numrows);
random.shuffle(allIDX); # randomly shuffles allIDX order for creating 'holdout' sample
holdout_number = numrows/10; # holdout 10% of full sample set to perform validation
testIDX = allIDX[0:holdout_number];
trainIDX = allIDX[holdout_number:];

# create training and test data sets
xtest = xdata_ml[testIDX,:];
xtrain = xdata_ml[trainIDX,:];
ytest = ydata[testIDX];
ytrain = ydata[trainIDX];

# ---------------------------- Naive_Bayes Model Construction ----------------------------
# ----------------------------  MultinomialNB & ComplementNB  ----------------------------
mnb = naive_bayes.MultinomialNB();
mnb.fit(xtrain,ytrain);
```

Automated Program Repair

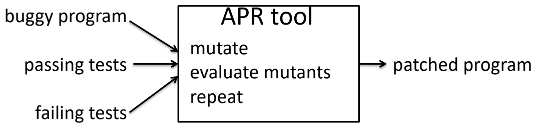
basic idea:



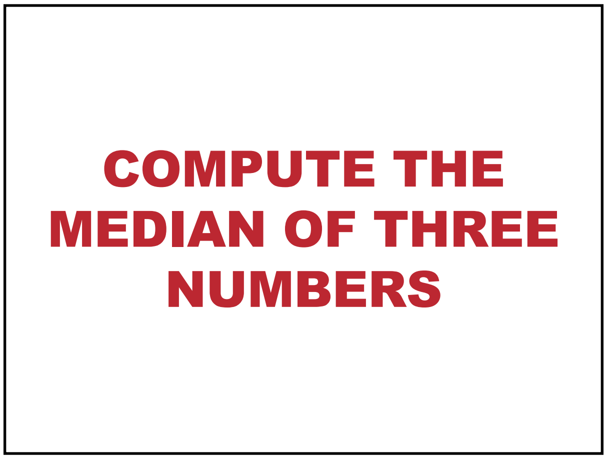
the many repair tools

ClearView [Perkinds et al. 2009] GenProg [Weimer et al. 2009]
Prophet [Long and Rinard 2015] SPR [Long and Rinard 2015]
TDS [Perelman et al. 2014]
Par [Kim et al. 2013] AE [Weimer et al. 2013]
SemFix [Nguyen et al. 2013] AutoFix-E [Wei et al. 2010]
[Carzaniga et al. 2010] [Carzaniga et al. 2013]
[Jin et al. 2011] Coker and Hafiz et al. 2013]
[Debroy and Wong et al. 2010] [Lin and Ernst et al. 2004]
[Forrest et al. 2009] [Novark et al. 2007] [Demsky et al. 2006]

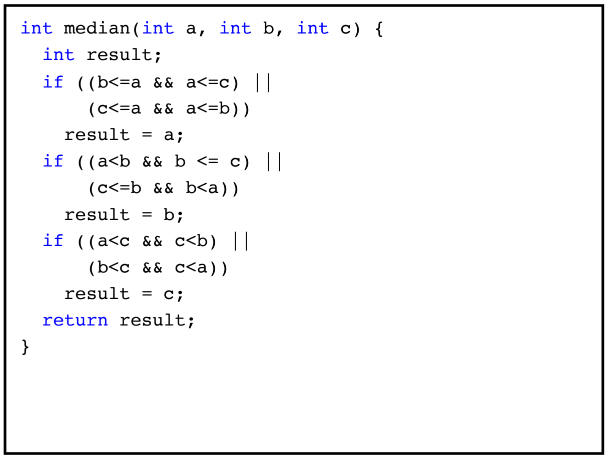
Potential problem



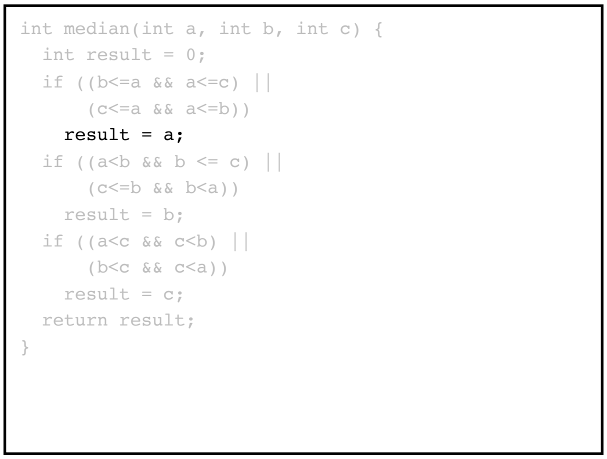
the patched program may pass all given tests, but break other functionality



COMPUTE THE MEDIAN OF THREE NUMBERS



```
int median(int a, int b, int c) {
  int result;
  if ((b<=a && a<=c) ||
      (c<=a && a<=b))
    result = a;
  if ((a<b && b <= c) ||
      (c<=b && b<a))
    result = b;
  if ((a<c && c<b) ||
      (b<c && c<a))
    result = c;
  return result;
}
```



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  int result = 0;
  if ((b<=a && a<=c) ||
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    result = a;
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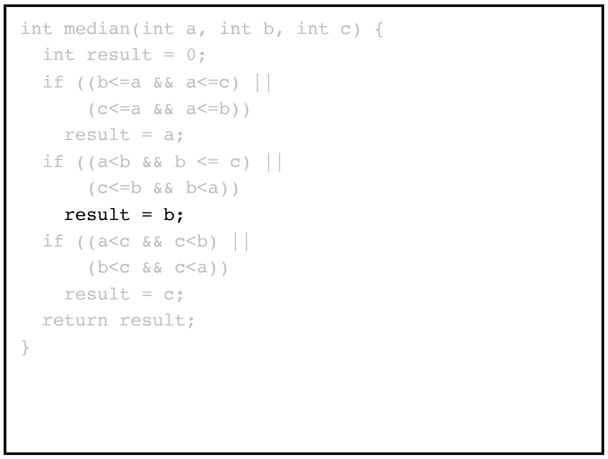
    result = c;
  return result;
}
```



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  int result = 0;
  if ((b<=a && a<=c) ||
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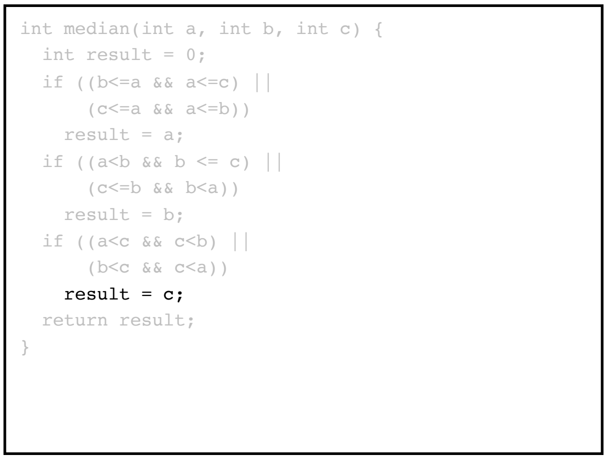

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  int result = 0;
  if ((b<=a && a<=c) ||
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    result = a;
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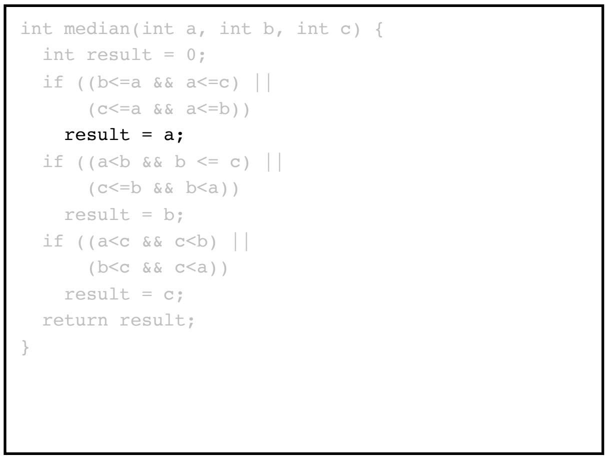

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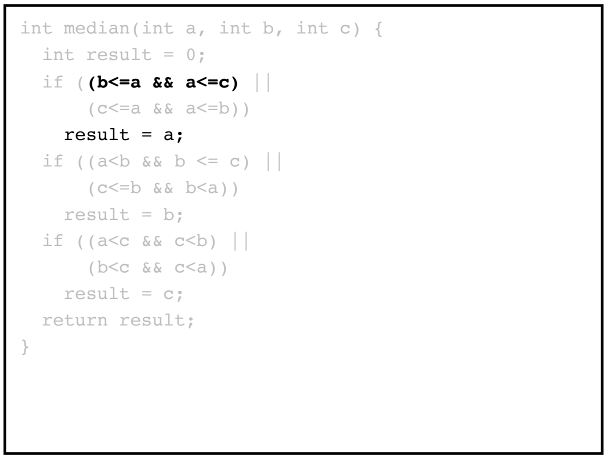

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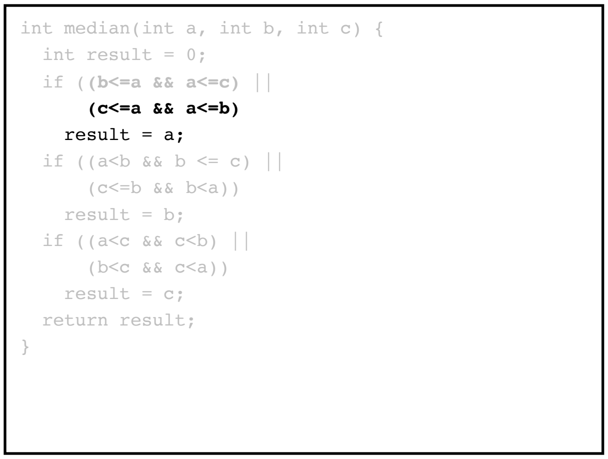

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      (b<c && c<a))
    result = c;
  return result;
}
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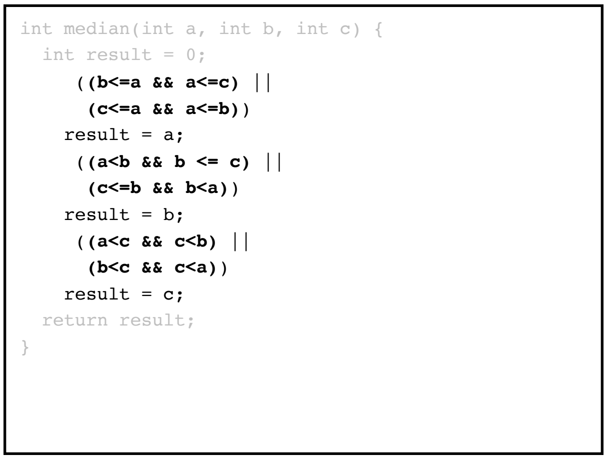

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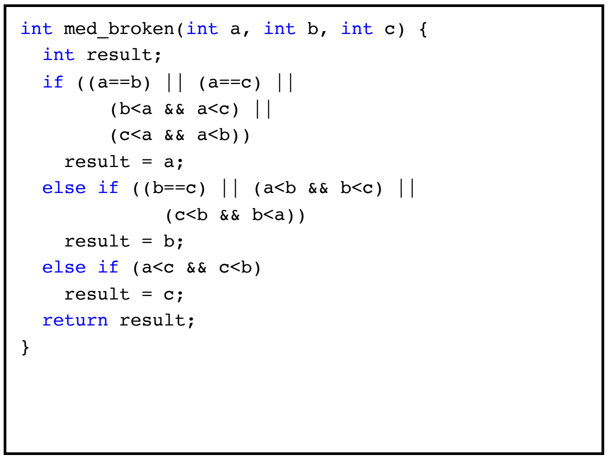
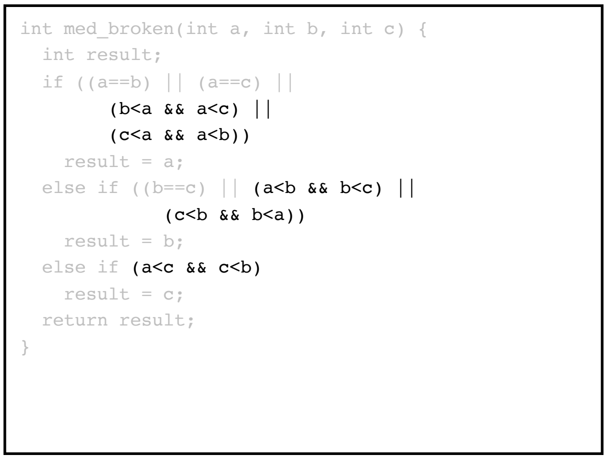


```
int med_broken(int a, int b, int c) {
  int result;
  if ((a==b) || (a==c) ||
        (b<a && a<c) ||
        (c<a && a<b))
    result = a;
  else if ((b==c) || (a<b && b<c) ||
             (c<b && b<a))
    result = b;
  else if (a<c && c<b)
    result = c;
  return result;
}
```



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    result = a;
  else if ((b==c) || (a<b && b<c) ||
             (c<b && b<a))
    result = b;
  else if (a<c && c<b)
    result = c;
  return result;
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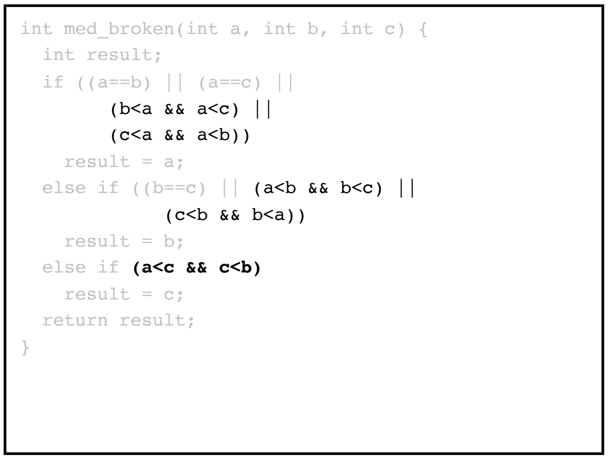

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  int result;
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        (c<a && a<b))
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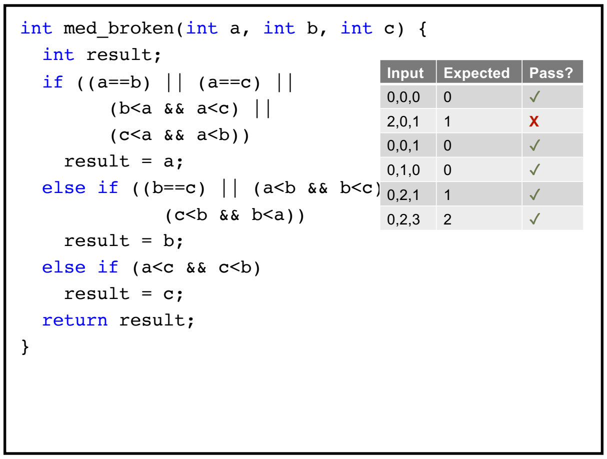

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    result = b;
  else if (a<c && c<b)
    result = c;
  return result;
}
```
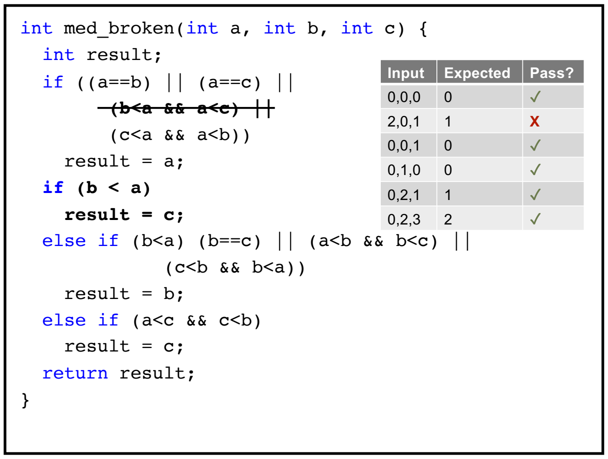

Input	Expected	Pass?
0,0,0	0	✓
2,0,1	1	X
0,0,1	0	✓
0,1,0	0	✓
0,2,1	1	✓
0,2,3	2	✓



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  int result;
  if ((a==b) || (a==c) ||
       ~~(b<a && a<c) ||~~
        (c<a && a<b))
    result = a;
  if (b < a)
    result = c;
  else if (b<a) (b==c) || (a<b && b<c) ||
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    result = b;
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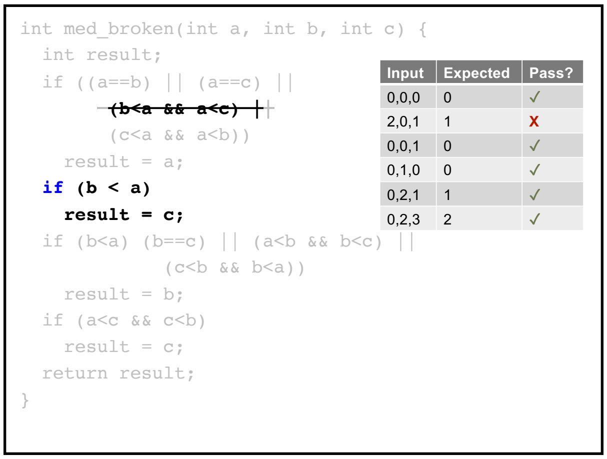
0,2,1	1	✓
0,2,3	2	✓



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    result = a;
  if (b < a)
    result = c;
  if (b<a) (b==c) || (a<b && b<c) ||
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  return result;
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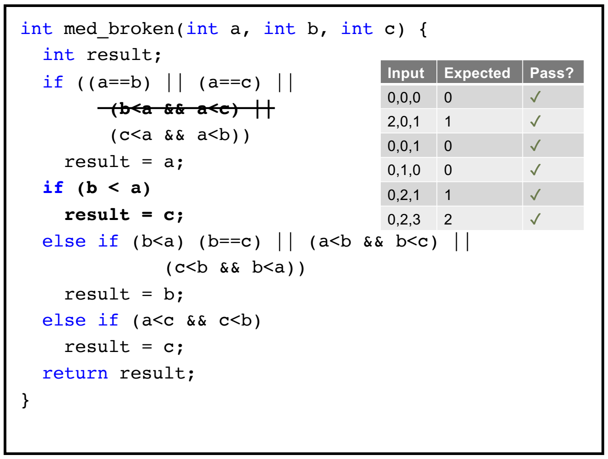
2,0,1	1	X
0,0,1	0	✓
0,1,0	0	✓
0,2,1	1	✓
0,2,3	2	✓



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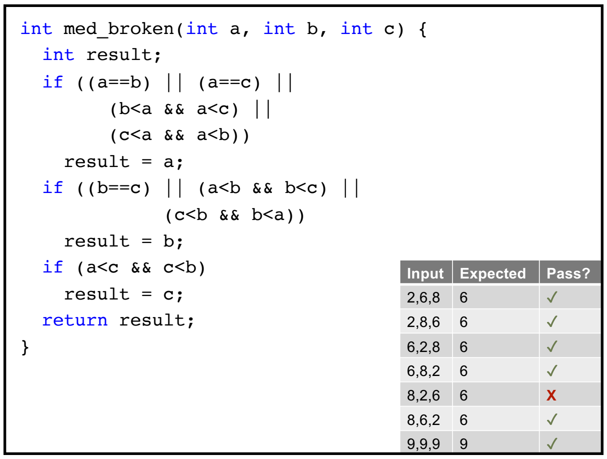
2,0,1	1	✓
0,0,1	0	✓
0,1,0	0	✓
0,2,1	1	✓
0,2,3	2	✓



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  int result;
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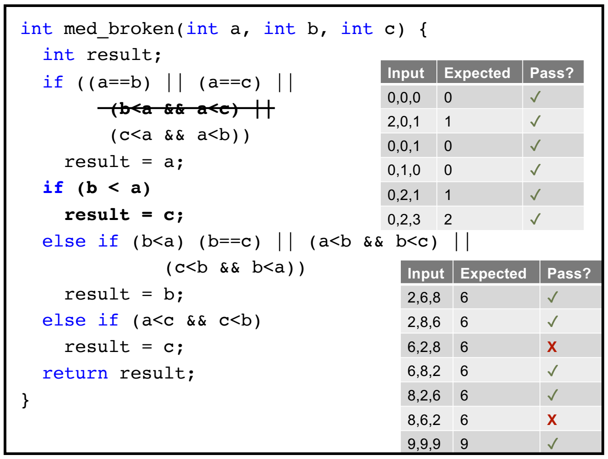
        (c<a && a<b))
    result = a;
  if ((b==c) || (a<b && b<c) ||
              (c<b && b<a))
    result = b;
  if (a<c && c<b)
    result = c;
  return result;
}
```

Input	Expected	Pass?
2,6,8	6	✓
2,8,6	6	✓
6,2,8	6	✓
6,8,2	6	✓
8,2,6	6	X
8,6,2	6	✓
9,9,9	9	✓



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    result = a;
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  else if (b<a) (b==c) || (a<b && b<c) ||
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```
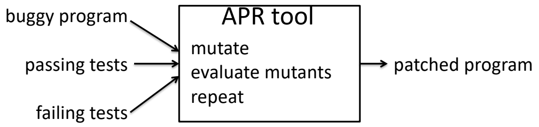

Input	Expected	Pass?
0,0,0	0	✓
2,0,1	1	✓
0,0,1	0	✓
0,1,0	0	✓
0,2,1	1	✓
0,2,3	2	✓

Input	Expected	Pass?
2,6,8	6	✓
2,8,6	6	✓
6,2,8	6	X
6,8,2	6	✓
8,2,6	6	✓
8,6,2	6	X
9,9,9	9	✓

Potential solution



Use an independent test suite to measure quality of the patch

Focus of prior evaluations

- Most evaluations are interested in whether tools work
  - produce patches
- Some interest in other factors
  - human acceptance of patches [Durieux et al. 2015] [Fry et al. 2012] [Kim et al. 2013]
  - plausibility [Qi et al. 2015]
  - ...but these don't fully assess functional correctness
- No evaluations test functional correctness of repair outputs independently of repair inputs

What do we need?

- We need bugs with 2 test suites
  - and the test suites need to be good

Why?

- it's hard enough to find one good test suite, good luck finding programs with two

Make your own!

http://repairbenchmarks.cs.umass.edu

998 student-written buggy C programs

- simple (very small)
- have 2 test suites
  - white-box (generated by KLEE)
  - black-box (written by instructor)

Some programs fail some wb tests, others bb tests, others, some of both

RQ1: What is the base incidence of overfitting?

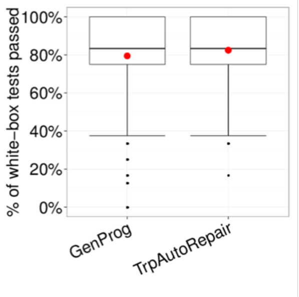
Give a repair tool the buggy program and the black-box test suite, try to repair it, see what fraction of the white-box tests the patches pass.

RQ1: What is the base incidence of overfitting?

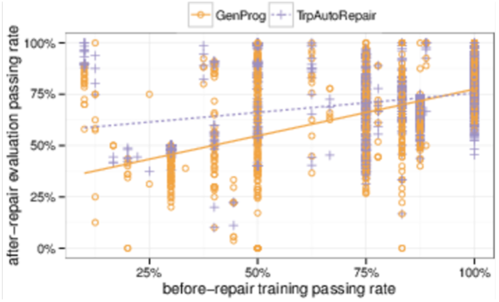
but first, how often can we actually generate patches?

repair tool	patch production %
GenProg	466/778 = 59.9%
TrpAutoRepair	444/778 = 57.1%

RQ1: What is the base incidence of overfitting?

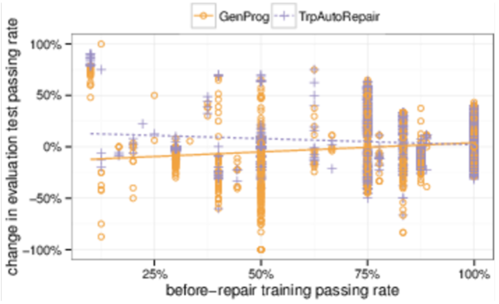


RQ2: What effect do pre-repair test failures have on overfitting?



Programs that fail more tests before repair still fail more tests after repair

RQ2: What effect do pre-repair test failures have on overfitting?

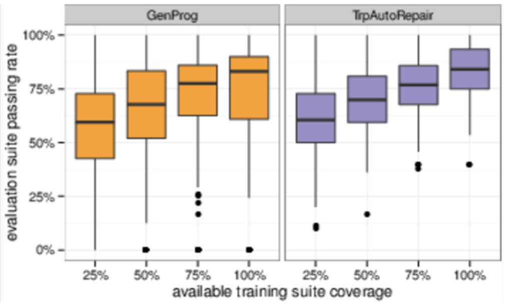


Repair is at best unlikely to improve correctness, at worst likely to worsen it

RQ3: What effect does test suite coverage have on overfitting?

- Randomly sample 25%, 50%, and 75% of passing and failing tests for each buggy program
- Attempt to repair programs
  - with each level of test coverage
- If a repair is found, measure correctness of repair

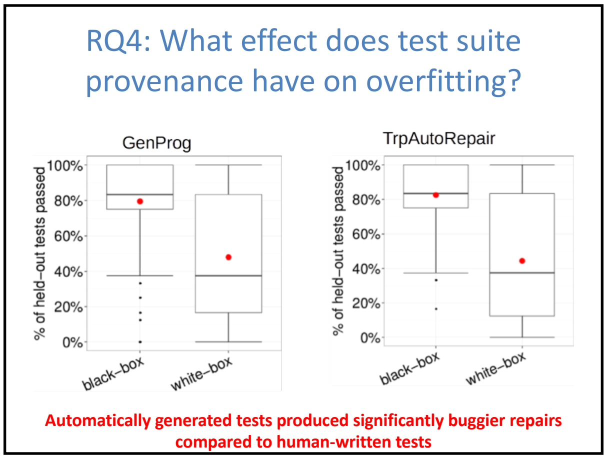
RQ3: What effect does test suite coverage have on overfitting?



Lower test suite coverage leads to more overfitting

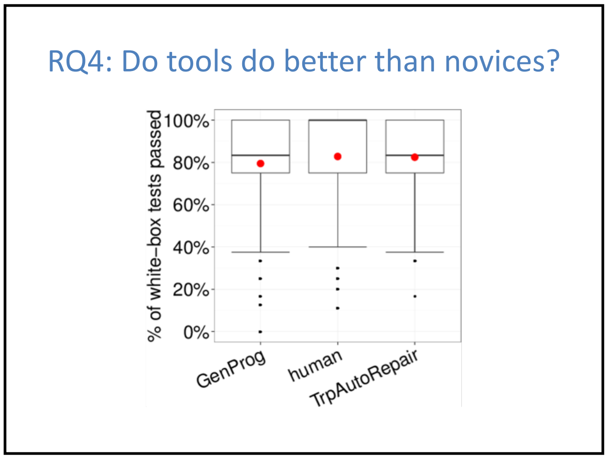
RQ4: What effect does test suite provenance have on overfitting?

- So far, all experiments have used human-written *black-box* tests to build repairs
- Switch to using KLEE-generated *white-box* tests
- Attempt to repair programs
- If a repair is found, measure correctness of repair
  - this time with *black-box* tests



RQ4: What effect does test suite provenance have on overfitting?

Automatically generated tests produced significantly buggier repairs compared to human-written tests



RQ4: Do tools do better than novices?

Summary

- Overfitting is a real concern
  - median patch for either tool passed only 75% of evaluation suite
- Overfitting is hard to avoid
  - minimization doesn't help on this dataset
  - N-version voting only works in extreme cases
- Program repair is harder for buggier programs, but likely to break more correct programs
- Novice developers don't significantly beat repair tools

So is there no hope?

- SearchRepair, a brand new technique, reduces overfitting to 97.2%.
- Most SearchRepair repairs pass 100% of the held-out test suite.
  (Select few poor repairs drop the overall rate.)

Read more about SearchRepair:

http://people.cs.umass.edu/~brun/pubs/pubs/Ke15ase.pdf