How Many Parachutists will be Needed to Find a Needle in a Pastoral?

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Intrusion Detection by Soft-computing

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- Assuming *Supervised Learning*
  - ⋆ We need samples for *Training* & *Testing*
    - · *Iris-flower*
    - · *KDD-cup-99*

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  "Intrusion is like a-needle-in-a-hay-stack
  not like an iris family."

- *Conjecture 2*
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  to efficiently find a needle in a haystack."

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  - ⋆ *Training should be only with normal samples!*
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How to design an intrusion detection system intelligently, if any?

- Two categories
  - ⋆ Detection of *known attack.*
  - ⋆ Detection of *unknown no-normal.*

To detect known-attacks, intelligence is not necessary but a lookup-table is enough

$$\Downarrow$$

Our interest is on detecting *unknown no-normal.*

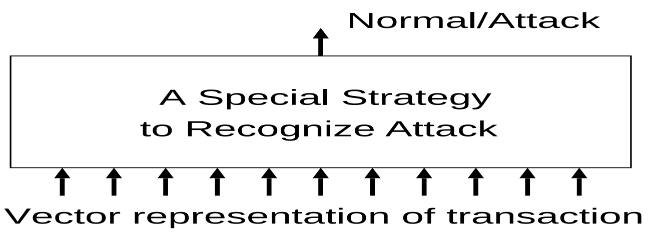
General assumption:

- TCP/IP connection to a network

  $\Rightarrow$ can be represented by an n-dimensional vector

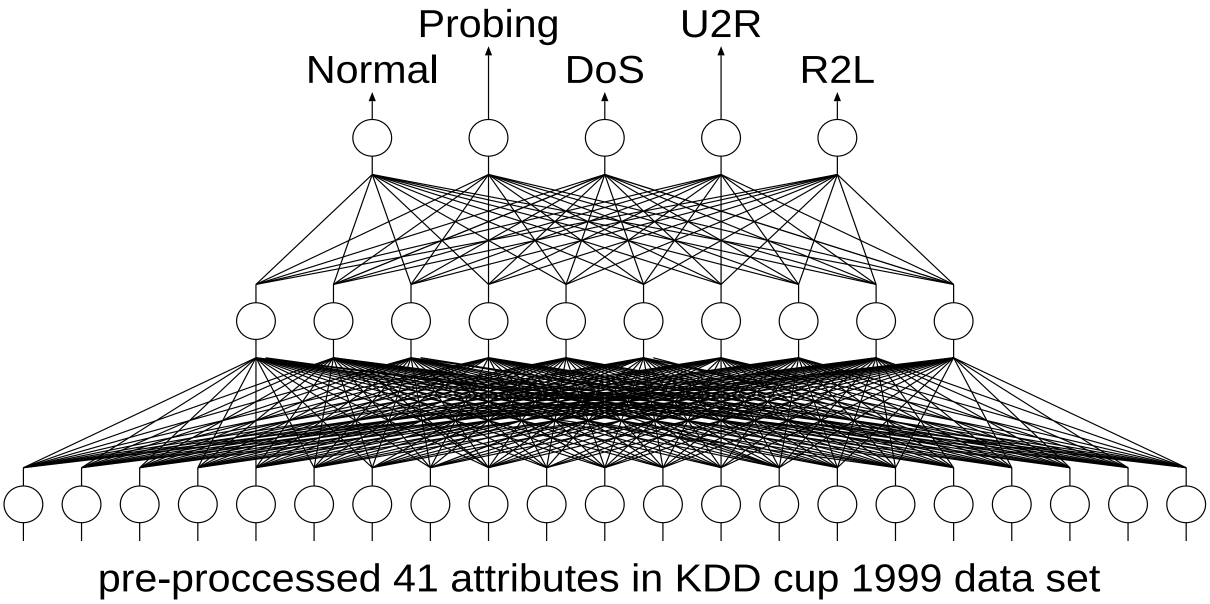
Our Goal

To design a machine which tells
the input is a *normal* or an *attack*.



Hopefully with
Detection Rate $> 90\%$ & *False Alarm Rate* $< 10\%$

An example of NN implementation



A question

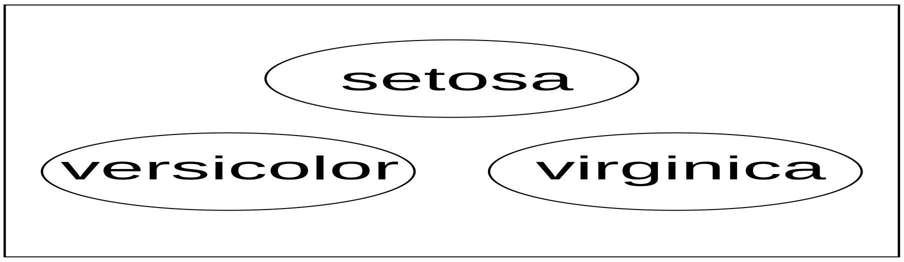
"Is it possible or not?"

Training & Testing

- Frequently used two public domain datasets.
  - ⋆ Iris-flower dataset.
  - ⋆ KDD-cup-1999 dataset

I. What is iris flower dataset

- 3 families of iris flower ⇒ 150 samples in total;
- Each family ⇒ 50 samples; Each sample ⇒ 4 features.



IRIS flower

Lots of successes have reported so far

Castellano et al. (2000)
assumed one to be normal while the other two abnormal.

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(by Fuzzy-NN with T-S model)

- abnormal detection rate = 96%
- false alarm rate = 0.6%

(cont'd)

But can we be so optimistic?

$\Downarrow$

When a family of iris is normal then are others abnormal?

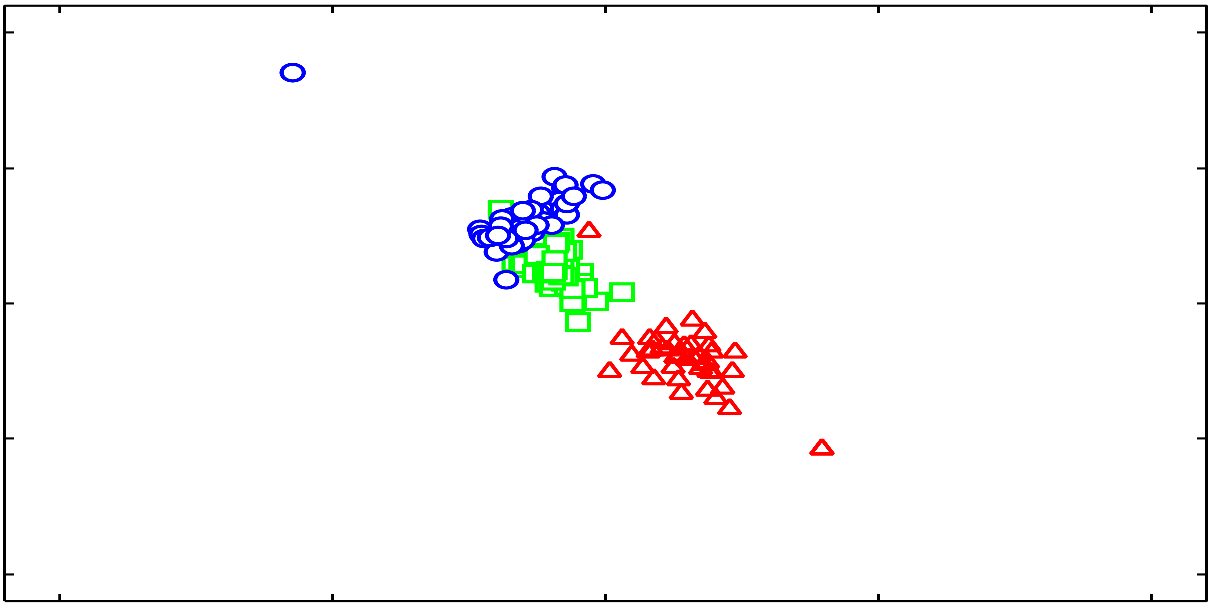
Let's visualize iris families — Sammon mapping

Sammon mapping maps points in a high-D space to 2-D

by

keeping distance relation preserved as much as possible
or
approximating distances in the n-D space
by distances in 2-D space with a minimal error.

A Sammon mapping of iris families



Where do outliers lie?

Not in the domain for the other families!!

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Not at the point at random, either.

$\Downarrow$

But outlier usually hides behind Normal.

□ Challenge 1

Attacks by Mutant

(1) Assume one family as {Normal}

(2) Mutate the normal samples and take them as {Attack}.

(3) Train with half of the {Normal + Mutant}

(4) Test with remaining {Normal + Mutant}

$\Rightarrow$ Will a successful result be possible?

The 1st warning

Iris is good to start with, but not of so useful.

II. What is the KDD-cup-1999 dataset?

- *Normal*
- *Attack* $\Rightarrow$ 32 attack types of the 4 categories:

(cont'd)

- *Attack* $\Rightarrow$ 32 attack types of the 4 categories:
  - ⋆ *Probing*

    by proving a vulnerability of the network;
  - ⋆ *Denial-of-Service (DoS)*

    by denying legitimate requests to a system;
  - ⋆ *User-to-Root (U2R)*

    an unauthorized access to local super-user or root;
  - ⋆ *Remote-to-Local (R2L)*

    an unauthorized local access from a remote machine.

KDD-cup-99 winner's result

Detection rate for 4 attack types

Probe	*DoS*	*U2R*	*R2L*
83.3%	*97.1%*	*13.2%*	*8.4%*

Detection rate by Sabhnani et al. (2003)

	Probe	DoS	U2R	R2L
Multi-layer Perceptron	88.7	97.2	13.2	5.6
Gaussian Classifier	90.2	82.4	22.8	9.6
K-mean Clustering	87.6	97.3	29.8	6.4
Nearest Cluster Algorithm	88.8	97.1	2.2	3.4
Radial Basis Function	93.2	73.0	6.1	5.9
Leader Algorithm	83.8	97.2	6.6	1.0
Hypersphere Algorithm	84.8	97.2	8.3	1.0
Fuzzy Art Map	77.2	97.0	6.1	3.7
C4.5 Decision Tree	80.8	97.0	1.8	4.6

We doubt some sort of the reported success

- Dimension Reduction by PCA – by Kuchimanchi et al.
  - ⋆ 41-D to 19-D
    - · (detection accuracy, false positive) = (99.92%, 0.26%)
  - ⋆ while the original being
    - · (detection accuracy, false positive) = (99.94%, 0.23%)

Yet another interesting claim (cont'd)

- Joshi et al. (2005)
  - ⋆ 41-D to 5-D (taking the first five from above)
    - · (detection accuracy, false positive) = (79%, 21%) (using Hidden Markov Process)

Let's not go into detail here, but rather focus on

Why U2R and R2L attacks resist to be detected?

How big is the KDD-cup-1999 dataset?

Labeled 4,898,430 records ⇒ *Training*
Un-labeled 311,029 records ⇒ *Testing*
and
Each record is 41-dimensional vector

$\Downarrow$
Sammon Mapping wouldn't work any more!

Ratios in the samples for testing

Normal	*Probe*	*DoS*	*U2R*	*R2L*
19.5%	1.3%	73.9%	5.2%	0.1%

Let's try a thought experiment!

- *always-return-random-answer-strategy*

  which returns either Normal, Probe, DoS, U2R, or R2L at random regardless of the input.

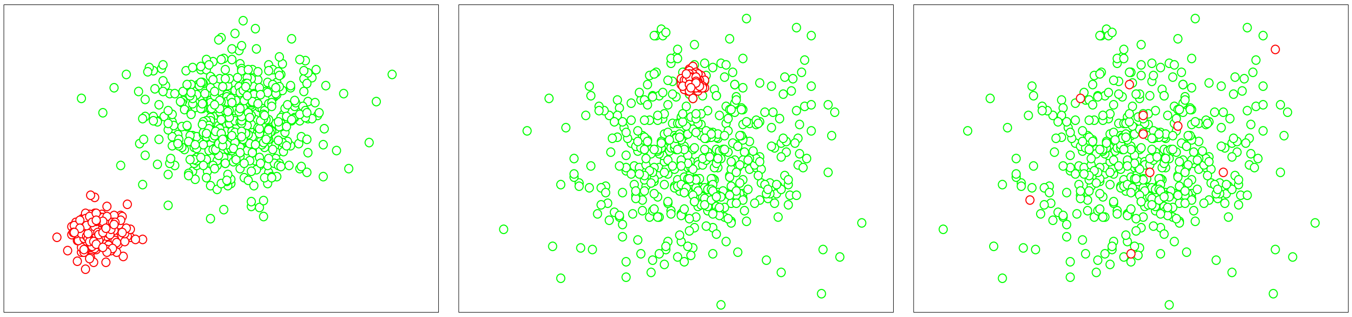
$\Rightarrow$ a high score to detect DoS attacks, like

Normal	*Probe*	*DoS*	*U2R*	*R2L*
19.5%	*1.3%*	*73.9%*	*5.2%*	*0.1%*

A-tiny-set-of-R2L vs. a-huge-set-of-normal

	Total	Normal	Probe	DoS	U2R	R2L
Labeled for Training	4,898,430	19.9%	0.8%	79.3%	≈ 0.0%	≈0.0%
Non-labeled for Testing	311,029	19.5%	1.3%	73.9%	5.2%	0.1%

Fictitious but possible distributions



□ Conjecture 1

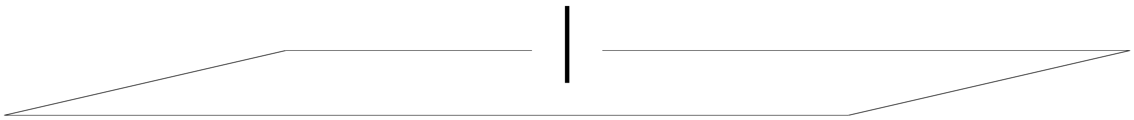
- *U2R, R2L and most of real attacks are like needles in a huge haystack of normals.*

What does a needle look like in a haystack?

The original Hinton & Nowlan's Needle:

- A-needle $\Rightarrow$ Only one configuration of 20-bit binary string.
  like (11000 11010 11101 0100)
- Haystack $\Rightarrow$ $2^{20} - 1$ search points

A fictitious needle in a haystack in 2D.



The reason of our title

a needle on pastoral & random fall of parachutists

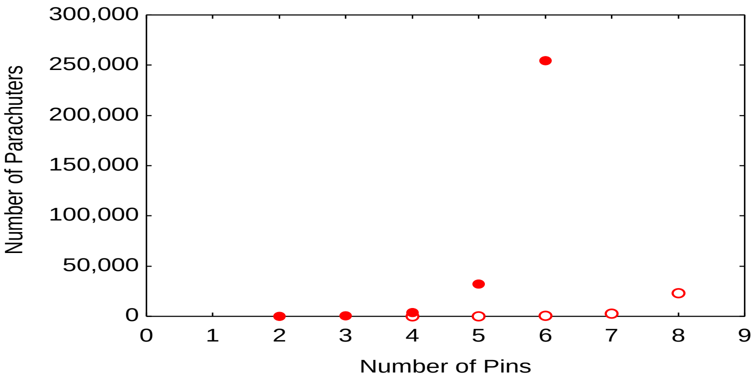
$$\Downarrow$$

How many parachutists will be needed to find
a needle in a pastoral?

Four experiments to look for a needle in pastoral

1. Random fall – a criterion for comparison
2. What if we permit walks after fall?
3. Neutral mutation
4. Mutation on intron

Random Fall & Walks after Fall



9-digit octal (= 27-bit binary) never stops a run

□ Conjecture 2

- *No such effective algorithm to look for a needle*

Yet another difficulty: The 2nd warning

(2) **Don't assume any expectations a priori!**

(3) *Training should be only with normal samples!*

"Artificial immune system detects a virus attack!"

How fantastic it sounds!

Forrest, Perelson et al. (1994)
"Self Nonself Discrimination in a Computer"

But more than a decade has passed since then,
and still an open issue.
$\Downarrow$
We hope not, but isn't it just a fantasy?

□ Challenge 2

- *Always-return-random-answer-strategy*

vs.

- *An intelligently designed system*

Placebo Experiment

(1) Prepare a dataset uniformly from all attack data

(2) Test your intelligent system with dataset above

(2) Compare the result with the random-return-machine

The last warning

(2) *Don't assume any expectations a priori!*

(3) **Training should be only with normal samples!**

From papers

P. Laskov et al. (2005)

"In a real application, one can never be sure that a set of available labeled examples covers all possible attacks. If a new attack appears, examples of it may not have been seen in training data."

Colin M. Frayn (2006)

Real-world data are very rarely well-behaved in the sense required by conventional algorithms.

Me (2005)

"When we know the attack, it's too late"

Gomez et al. (2003)

"A set of fuzzy rules characterized abnormal space using only normal samples."

with

10% dataset of KDD-cup-1999

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"It detects attacks with the detection rate 98.30% and false alarm rate 2.0%."

$\Downarrow$

Really satisfactory, if it's really true.

□ Challenge 3

Attack by dummy

(1) Prepare {Normal} and {Attack} from KDD-cup-99.

(2) Create {Dummy} at random

(3) Train with only {Normal}

(4) Test with {Attack} and {Dummy} one by one

$$\Downarrow$$

Can a Sommelier be trained without bootlegs?

CONCLUSION

- *Neither IRIS nor KDD-cup-99 are useful.*
- *A hacker is a person who is extremely good at finding a pattern which is very close to the normal.*
- **So, we must regard attack as a mutant-of-normal.**

- *This is not to negate the possibility, but we hope this will be a start of debate for an emergence of innovation.*