A literature survey

Forest Management with Neural Network & Artificial Intelligence

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In forrest management
lots of unpredictables should be predicted

(1) Forest Wildfire (of most vital importance)

E.g.

Big wildfires in US just in 2013

- Tres Lagunas fire, Thompson Ridge fire, Silver fire, Jaroso fire in New Mexico;
- Black Forest fire, Royal Gorge fire in Colorado;
- Yarnell Hill fire in Arizona (where 19 firefighters were killed);
- Quebec fire in Quebec;
- Mount Charleston fire, Bison fire in Nevada;
- Idaho Little Queens fire in Idaho;
- Silver fire, Beaver Creek fire, Rim fire, Morgan fire, Clover fire in California.

E.g.

Wildfires happened just in California as of 16 May in 2014

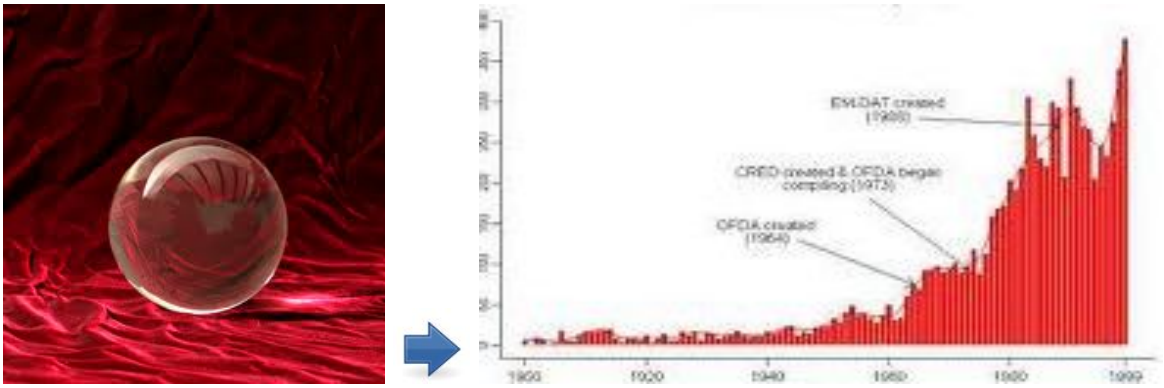
1400 wildfires have already been battled

(twice the number in the same period in a normal year!)

Events happened in forests are sometimes mysterious

We used to depend on fortune telling

Crystal-ball to Statistics



Logistic Regression (LR)

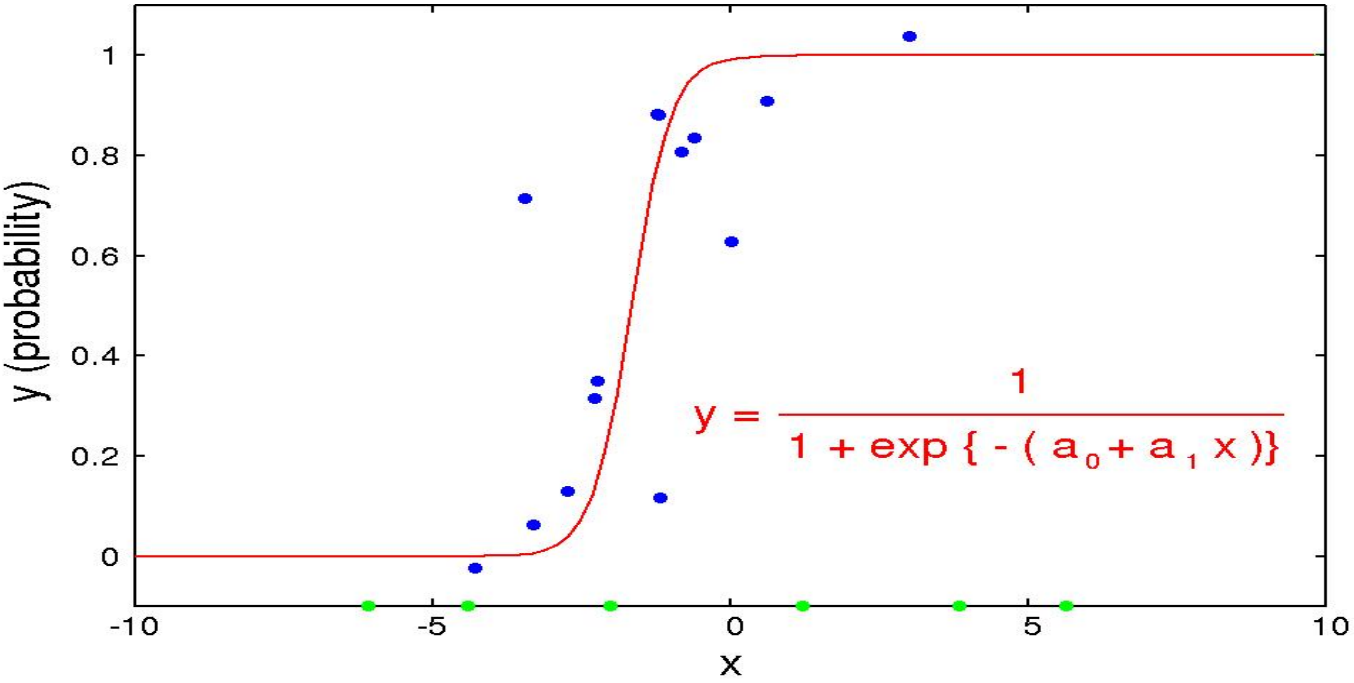
A model of prediction of stochastic events

Logistic Regression

estimates the probability of a binary independent variable from a set of independent continuous variables

$$y = p(x_1, x_2, x_3, x_4, x_5, \cdots)$$

1-D Logistic Regression



multi-D Logistic Regression

$$y = \frac{1}{1 + exp\{-(a_0 + a_1 x_1 + a_2 x_2 + \cdots + a_n x_n)\}}$$

Chou et al. (1995)

Forrestfire danger prediction by LR

A model in San Jacinto Mountain California
with x_i being
environmental factors: vegitation, temperature, precipitation, etc.
and
human factors: distance to urban areas, nearby transportation, etc.

$\Downarrow$

neighborhood effects are of great importance in wildland fires

Mohammadi et al. (2013)

sought what trigers wildfire using LR

In Sarvabad forests in Kurdistan province of western Iran

They identify the factors influencing the occurrence of a wildfire

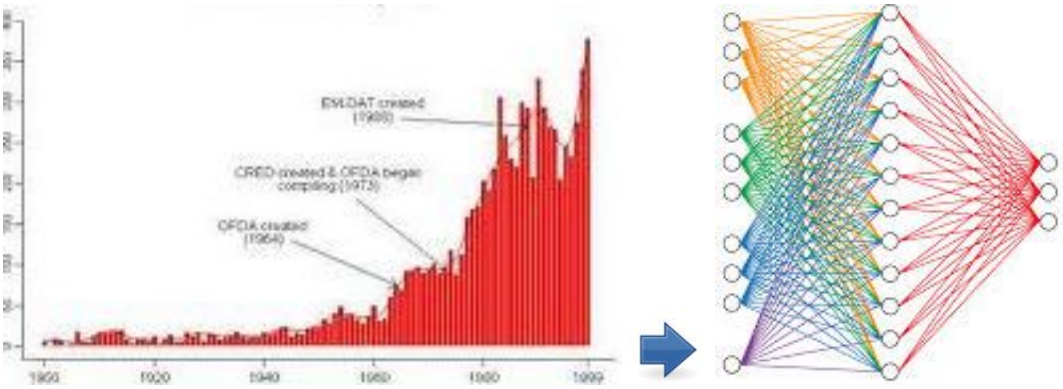
$\Downarrow$

land slope, altitude, distance from farmland $\Rightarrow$ negatively related

annual precipitation $\Rightarrow$ positively related

Statistics to Neural Networks

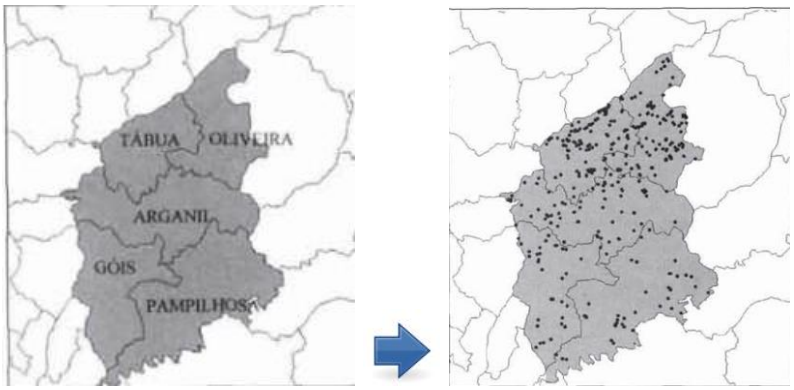
which are good at treating such non-linearity



Maria Jose et al. (2001)

Compared LR & NN on fire location

in the 5 municipalities in Portugal



Maria Jose et al. (2001)

A result of comparison

⇓

LR is better in the training phase

while

NN shows higher classification accuracies.

I. Approaches using Artificial Neural Networks (ANN)

Events unpredictable to be predicted

(1) Forest Fire

(2) Forest cover type

(3) Growth of individual tree

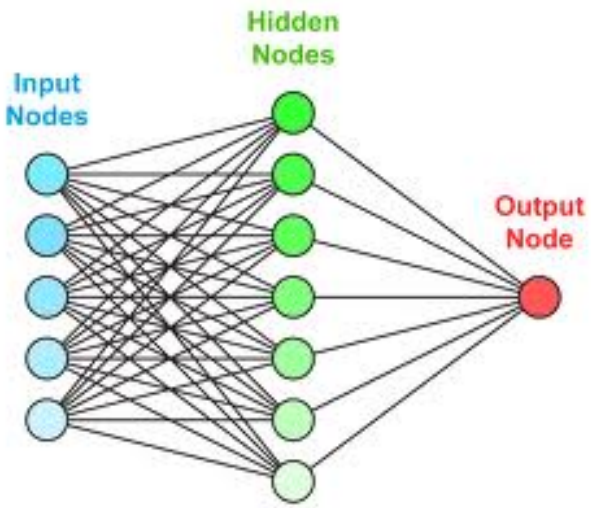
(4) Growth of forest

(5) Biodiversity

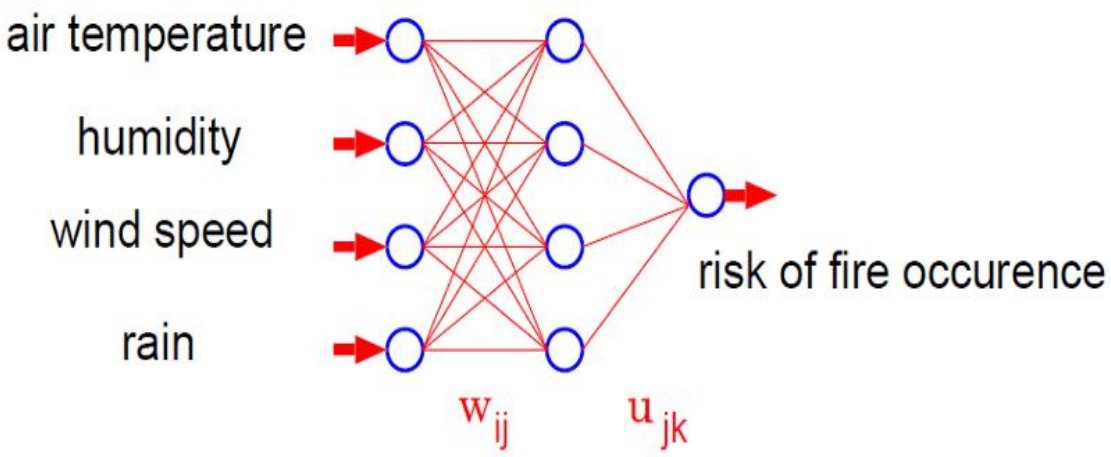
(6) Tree mortality

(7) Common pool resources

Multilayer perceptron (Feedforward NN) with backpropagation



An Example


air temperature
humidity
wind speed
rain
risk of fire occurence
w_{ij}
u_{jk}

Garson's Method

Degree of influence Q_{ik} of the i-th input to the k-th output

$$Q_{ik} = \frac{\sum_{j=1}^{L} \left(\frac{w_{ij}}{W_j} u_{jk} \right)}{\sum_{i=1}^{N} \left(\sum_{j=1}^{L} \left(\frac{w_{ij}}{W_j} \right) \right)}$$

where

$$W_j = \sum_{r=1}^{N} w_{rj}$$

for normalization

To open the black-box of NN: importance of input for output

Gevrey et al. (2003) "Review and comparison of methods to study the contribution of variables in artificial neural network models." Ecological Modeling

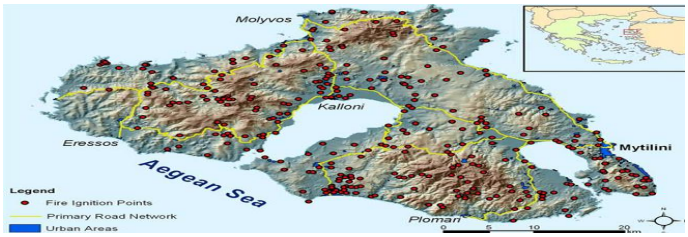
Thrush et al. (2008) "Complex positive connections between functional groups are revealed by neural network analysis of ecological time series." American Naturalist

Yeh et al. (2010) "First and second order sensitivity analysis of MLP." Neurocomputing

Vasilakos et al. (2008)

Fire ignition risk by Garson's method

in Lesvos Island, Greece



The degree of importance to the risk of fire occurrence

air temperature ⇒ 28.7%; wind speed ⇒ 28.9%; humidity ⇒ 14.5%; and amount of rainfall ⇒ 35.9%

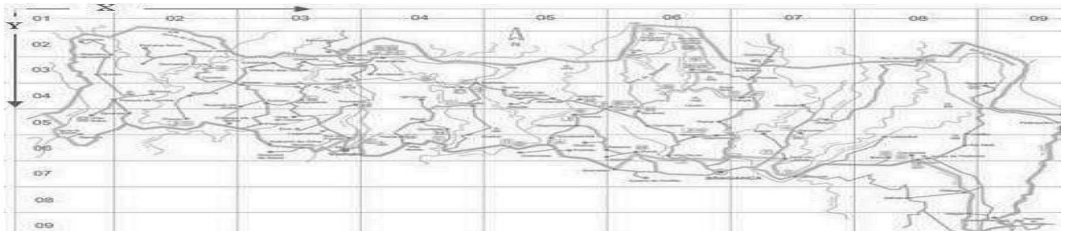
Safi et al. (2013)

Map the past wildfire data to burned area

of the ancient oak forests in Portuguese Montesinho Natural Park
by ANN

Inputs: location, month of the year, day of the week, air temperature, humidity, wind speed, amount of rain, etc.

Output: total burned area (in ha)



Sakr et al. (2010)

Fire hazard level of the day from previous weather condition

in the forests in Lebanon

using Support Vector Machine

Support Vector Machine (SVM)

also a feedforward NN to classify objects in a high-dimensional space with hopefully by a hyperplane

$$d(\vec{x}) = \sum_{i=1}^{n} w_i x_i + b$$

or otherwise by a hypersurface

$$d(\vec{x}) = \sum_{i=1}^{l} y_i \alpha_i K(x_i, \vec{x})$$

where $K(x_i, x_j)$ is a kernel function, e.g., Gaussian kernel is

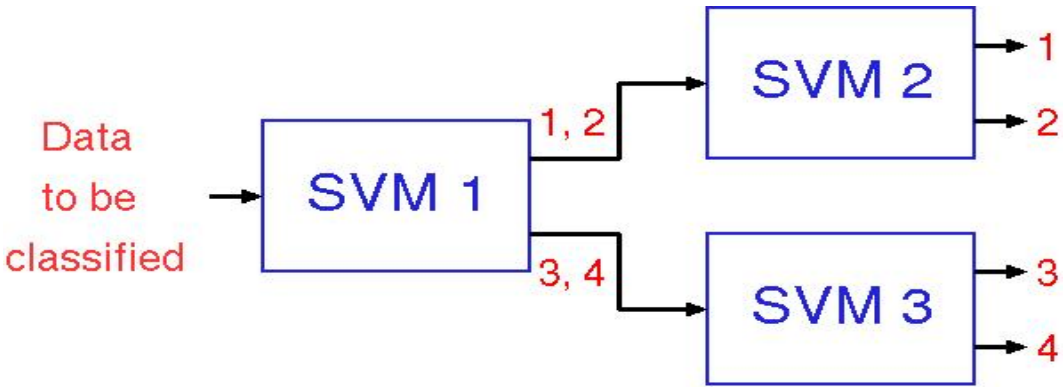
$$K(x_i, x_j) = \exp(-\Gamma \|x_i - x_j\|^2)$$

Sakr et al. (2010)

Weather data from 2000 to 2008 in Lebanon such as
daily minimum and maximum temperature, average humidity, average wind speed, solar radiation, cumulative annual precipitation
predicted
number of fires in a day over the nine years with four scales of danger from 1 (lowest) to 4 (highest)
⇓
each of a two-class prediction of fire risk with high accuracy of up to 96%

Sakr et al. (2010)

Four classes prediction by three SVMs



(2) Forest cover type

A classification system based on trees that dominate in a particular area.

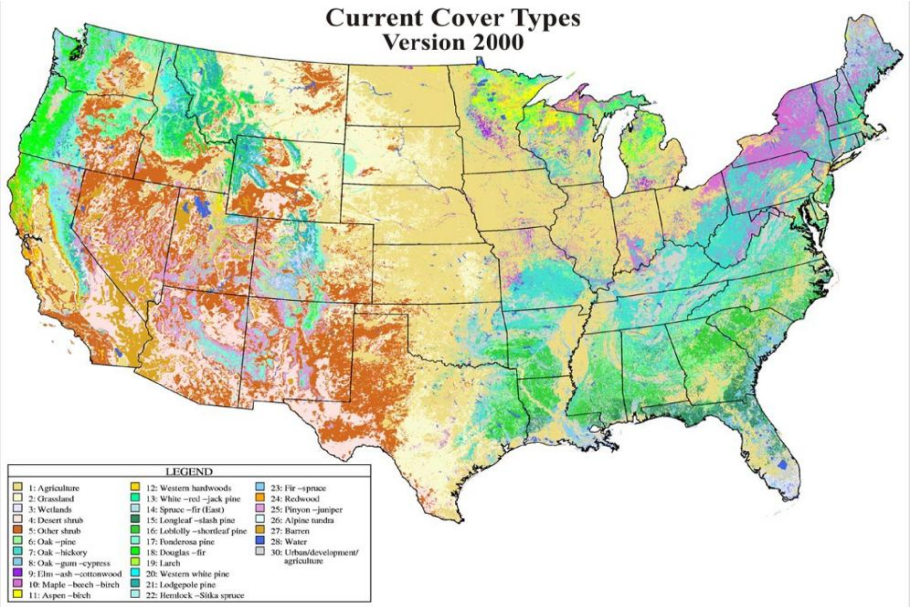
A species of tree that dominates the forest

such as

pine, ceder, white birch, acacia, linden, etc.

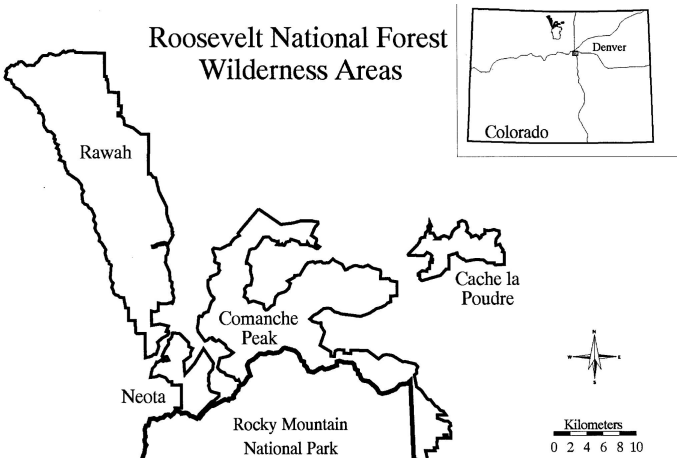
26 forest cover types in US in 2000

Forest cover types change from one year to the next



Blackard (1999)

studied forest cover types from cartographic variables



Blackard (1999)

predicted the change of forest cover types in the four wilderness areas of
Roosevelt National Forest in northern Colorado, US
(Rawah, Comanche Peak, Neota, and Cache la Poudre)

⇓

NN predicted changes of forest cover type more accurately
than

a statistical model based on Gaussian Discriminant Analysis

(3) Growth of individual tree

An individual-tree growth model to predict,
e.g.,
the annual growth of hight and diameter (at breast height)
are necessary to predict

future of the entire forest

Guan et al. (1991)

Predicts red pine tree survival

ANN trained with a proportional coding scheme based on Gaussian distributions

⇓

actual diameter (at breast height) and estimated diameter growth as its predictors

The data not only fit better than a statistical model,

but also performed better on future data.

Carlos (2013)

Tree Growth Model for Eucalyptus

to predict tree height, diameter and mortality probability

in northern Brazil by NN.

Carlos (2013)

Comparison of ANN to LR

with the same data

to estimate diameter and height in future ages

⇓

ANN is effective in individual tree modeling and provides superior results than

regression models

particularly in generalization or validation stage.

(4) Forest growth

A complicated non-linear system

The model should describe forest growth
from factors such as
location, age, density of trees, etc.
then dynamics of these factors should be used to predict its future
and
should assess functions of these factors under changing environment

Fuang et al. (2011)

Forest Growth model by ANN with backpropagation

pinus massoniana plantation in Guizhou province, China

Predicting precision of the model

⇓

mean breast height diameter 87%; mean volume 92%

(5) Biodiversity

a high diversity of tree species has a positive influence on a number of ecosystem

Gamfeldt et al. (2012)

More tree species for better ecosystems

(NN not related)

Number of tree species positively relates to
(i) tree growth , (ii) carbon storage , (iii) berry production, (iv) food for wild lives , (v) presence of dead wood and (vi) biodiversity in vegetation

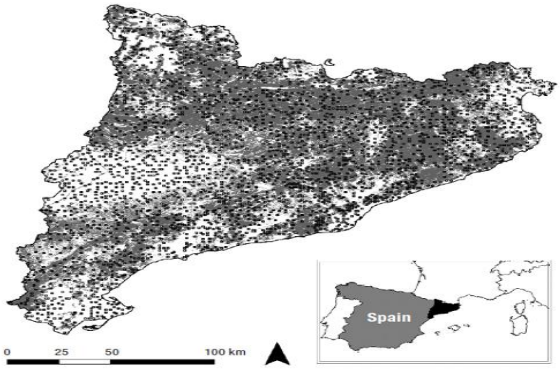
Necessity: no single tree species cannot promote all services
but
some services were negatively correlated to each other
$\Downarrow$
management is complicated

Gil-Tena (2010)

bird species richness

as a function of environment and forest structure in Catalonia, Spain
using Cascade Correlation Networks

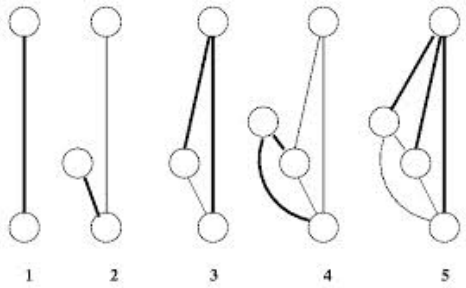
"birds play a key role in ecosystems ⇒ good biodiversity indicators"



Cascade Correlation Network

begins with a minimal network adding new hidden units one by one
instead of just adjusting the weights of fixed topology

(developed by Fahlman & Lebiere)



Gil-Tena (2010)

models relationships between 53 bird species & 25 environmental variables
such as topography, climate and human pressure

⇓

landscape variables & climate were the best predictors
positively correlated with a wide breadth of canopy closure
and
negatively associated with

high annual temperatures and low summer precipitations.

forest canopy

refers to
forest's upper layer formed by mature trees' aboveground parts
playing a roll as shade trees blocking sun light for lower plants
⇓
Canopy closure is a percentage of canopy overlying forest floor

(6) Tree mortality

- Background mortality
  - ⋆ aging, competition, root disease, insect attack, presence of herbivores, nutrients deficiency, etc.
- Catastrophic mortality
  - ⋆ by an external force like: fire, hurricanes, epidemic attacks of insects, etc. ⇒ unpredictable.

Weingartener et al. (2000)

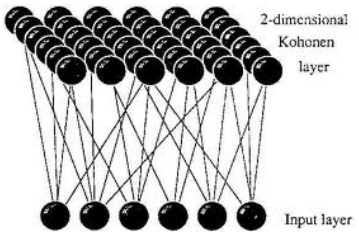
Prediction of Individual Tree Mortality

by Learning Vector Quantization

Training data set from Austrian National Forest Inventory applied to Litschau forest in Austria as test data

Learning Vector Quantization (LVQ)

A kind of feed forward network to classify n-D input points to m classes each of which has p sub-classes.



Hidden layer is made up of m set of p arrays of n neurons.
One array represents a center of a sub-class (voronoi tessellation)

Training is by winner-take-all learning approach

Learning Vector Quantization (LVQ)

m outputs represent the class that the input belongs to

Unlike the widespread binary classifiers
LVQ can classify any set of input vectors

not just linearly separable sets of input vectors.

(7) Common pool resource

a resource that benefits a group of people

but

a fewer benefits to everyone if pursued from self-interest

e.g.

fishery, river, irrigation, etc.

Frey (2000)

Why do some communities fail while others succeed?

Numerous factors have proposed so far but no comprehensive model to integrate these factors to explain success

⇓

tried ANN

with inputs being 24 such success factors so far reported

and

output being ecological success

Frey (2000)

simulated the impact of changes in the success factors
on the predicted sucess or failure
of the Common Pool Resourse systems analyzed.
i.e.
which factors in which combinations are likely to be influential?

using data on the irrigation systems in Nepal
⇓
The mean squared error of the best predicting network reached 0.033

II. Approaches using Artificial Intelligence

Papers which claim machine intelligence

- **Artificial intelligence: a new tool for forest management.**
- **An intelligent system for false alarm reduction in infrared forest-fire detection.**
- **An intelligent system for effective forest fire detection using spatial data.**
- **Artificial intelligence for forest fire prediction.**

Not-matured concept of AI in papers 1990's

ANN is an artificial intelligence system similar to human brain

or

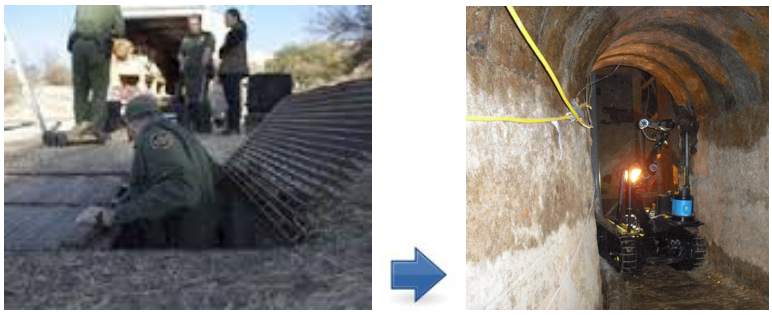
ANN is an information processing method imitating biological brain

Nowadays no one is so optimistic

Intelligent robot, if any, might do human dangerous jobs

E.g.
Borders new agents are robots
penetrating sewage - deepest drug routes

(from the article in New York Times on 22 February 2013)



19 firefigters were killed in Forestfire in Arizona (2013)

Toward more human-like intelligence on forest fire fighting

Stepanicev (2011)

Intelligent Forest Fire Monitoring System iForestFire from idea to realization

Croatia belongs to countries with high wildfire risk in Europe
(4851 wildfires from 1992 to 2007)

⇓

whole Istria region, Croatia

is covered by iForestFire network

Stepanicev (2011)

The region have 29 monitoring stations and 7 operational centers

Before

Human observers equipped only with binoculars and communication equipment covering only area within sight of view.

⇓ Then

Monitoring with remotely controlled video cameras at many monitoring spots with human observer located in the observation center.

⇓ Now

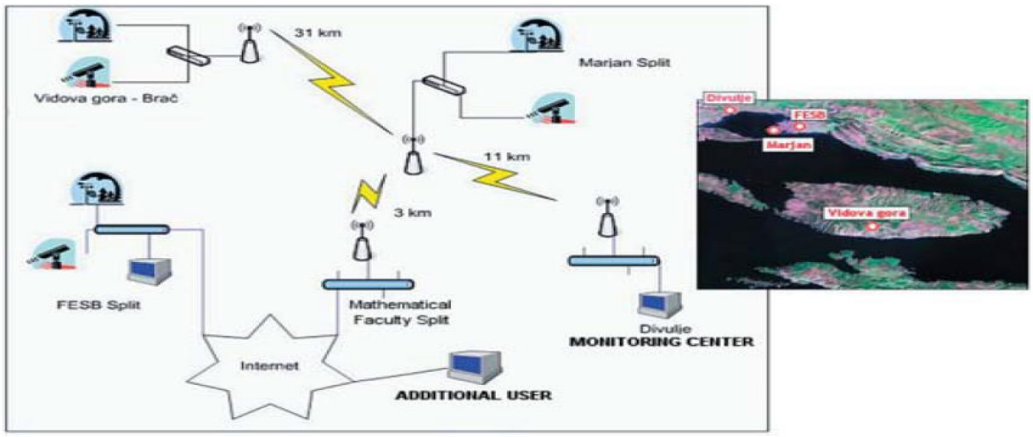
Advanced automatic wildfire surveillance

Stepanicev (2011)

Sensors sense:

smoke recognition during the day and
fire flames recognition during the night by video cameras
heat flux from the fire by infrared thermal imaging cameras
spectral characteristics of smoke by spectrometer
laser light backscattered by smoke particles
air temperature
acoustic emission from fire
chemical detection

iForestFire in Istria region, Croatia



Stepanicev (2011)

claims the system is intelligent because it has:

Environmental Intelligence (EI)

operators are on any location with broadband IP based Internet connection with a Web browser

Distributed Intelligence (DI)

Multiagent system are responsible for sensors testing, data collecting, image and data validation and storing, image pre- and post-processing and alarms generation. Agents share the same ontology and language

besides

Artificial Intelligence (AI) & Computatioanl Intelligence (CI)

Is iForestFire intelligent like human?

"The task of a human operator is not to monitor camera all the time, but only to confirm or discard possible fire alarms"

⇓

False positive would be O.K. but what about false negative?

To be intelligent like human

(1) Not programed but a real flexible action to unknown situation
(2) A learnig mechanism from previous success or failure

Smart firefighter project is ongoing in US

Smart vs. Intelligence

⇓

Intelligence is something with which you are born

while

Smart is an earned status

⇓

Intelligence is the measurement of your ability to become smarter through learning.

Forrest in Belarus

Belovezhskaya Pushcha National Park

"the home to 900 plants and 250 animals and birds, including several rare species."

⇓

Forest management using IT should be more prevalent

Thank you!