ISERM - INTELLIGENT DECISION SUPPORT SYSTEM FOR ENVIRONMENTAL RISK MANAGEMENT

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Motivation (1/4)

- During the last decades, forest fires have increased in numbers and intensity in the European Union and especially to the Mediterranean region member States
- Forest fires are considered natural phenomena but the magnitude of the problem can be attributed:
  - to poor forest management
  - to the increasing demand for land
  - to the extreme weather conditions (e.g. hot and dry periods in combination with strong winds).

Motivation (2/4)

- Regarding Greece, the abolishment of traditional activities related to forests has sent away people from the forests that they used to protect
- The results in annual destruction of
  - large forest areas,
  - agricultural cultivations,
  - industries,
  - animals
  - human lives.
- At the same time:
  - catastrophic floods entail the gradual desolation of the affected areas
  - large amounts of carbon dioxide along with smoke particles aggravate air quality.

Introduction (3/4)

- In order to confront forest fire phenomenon new methods and integrated models have been developed for fire management.
  - Fire Simulators,
  - Fire Danger Rating Indexes,
  - Many research activities are in progress
    - referred to remote surveillance and mapping of forests and forest fuels

Motivation (4/4)

- Ignition of a fire is related to
  - the prevailing atmospheric conditions
  - the local geomorphological structure
  - other anthropogenic factors that are not easily quantified
  - (proximity to roads, industrial activities, etc.).
- For the estimation of the risk of fire there exist in the literature many indices
  - Canadian Fire-Weather Index
  - McArthur Forest Fire-Danger Index
  - Fosberg Fire-Weather Index.

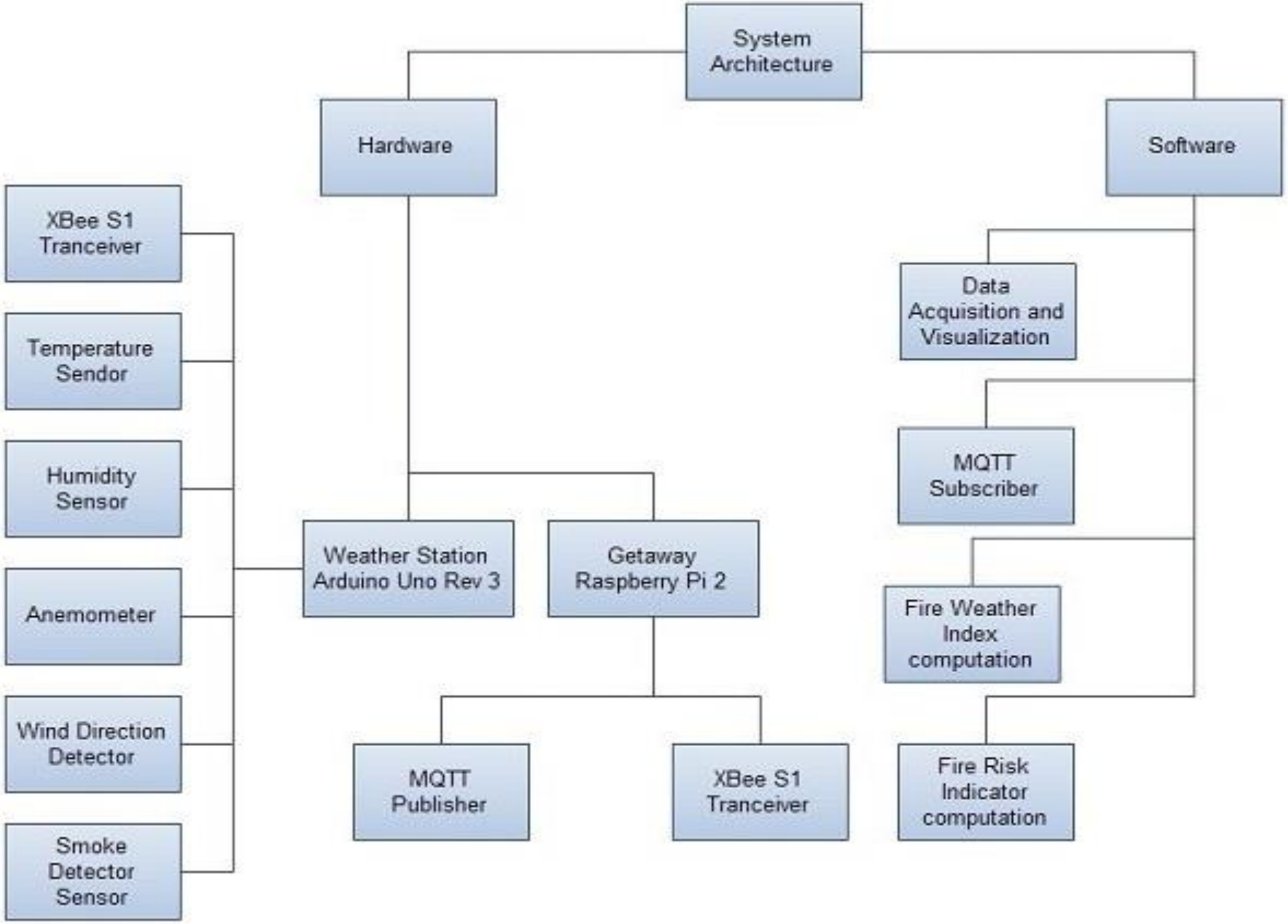
Objective (1/2)

- **In this work we have implemented an integrated hardware/software decision support system to counteract wildfires destruction danger in lowland forests**
- Uncertainty is present both in forest factors values and in forest functions modelling.
- Due to this, artificial intelligent methods are employed to handle uncertainty
  - Deep Learning techniques
  - Fuzzy Logic
- Based on these techniques and the calculation of the Fossberg Fire Weather Index (FFWI) the fire risk indicator is finally computed

Objective (2/2)

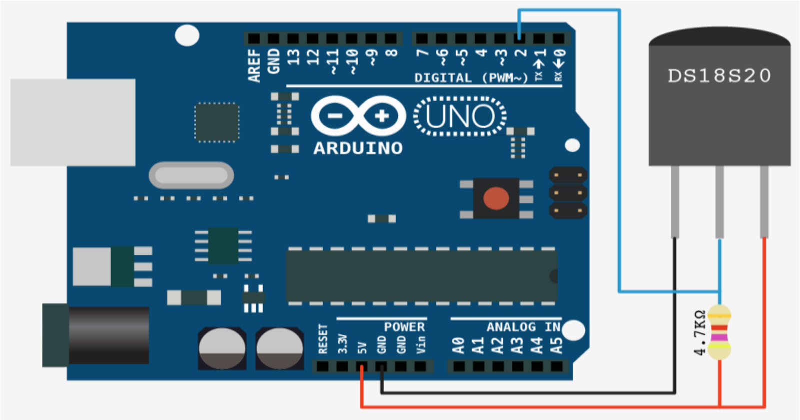
- The use of FFWI has been preferred in this work to any other index for the following reasons:
  - The FFWI has a very simple form comparing to other indices, since it depends only on temperature, relative humidity, and wind speed.
  - Its results have shown to be accurate in most cases for the discrimination of the fire-danger level.
  - Due to technical limitations, there is no information available about parameters which are required for other indices, since the corresponding meteorological stations do not provide such data
    - drought factor
    - fuel availability

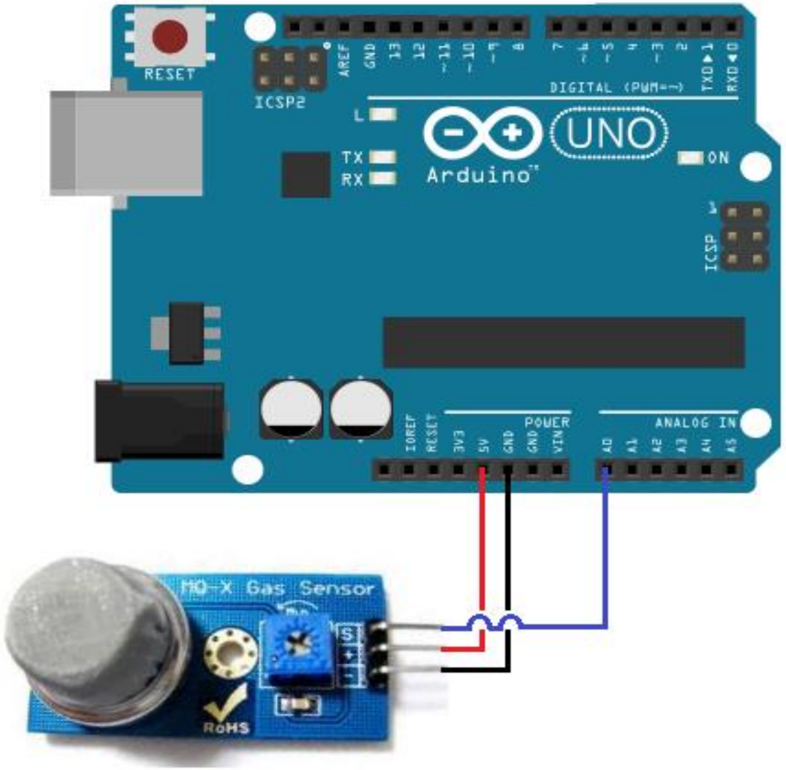
System Architecture

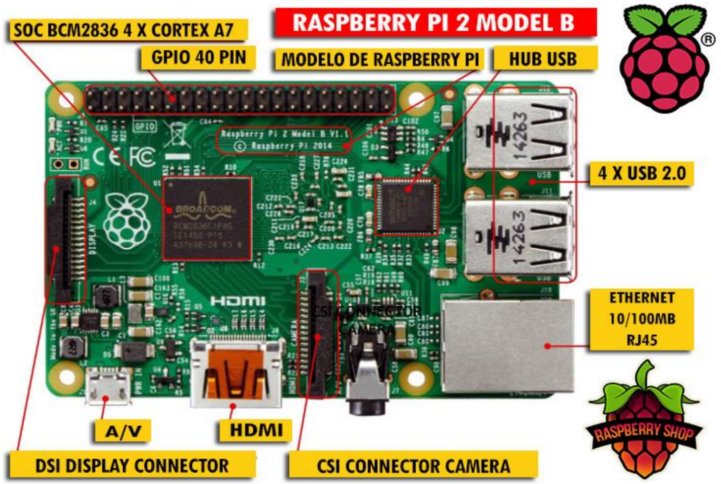


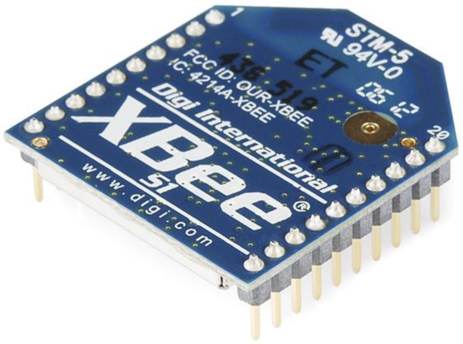
- The System architecture is divided into two parts.
- The Hardware part includes the weather station and the sensors.
- The software part includes the
  - data processing,
  - the computation of the fire risk indicator by employing Fuzzy Logic and Deep Learning
  - data visualization.

Hardware Components

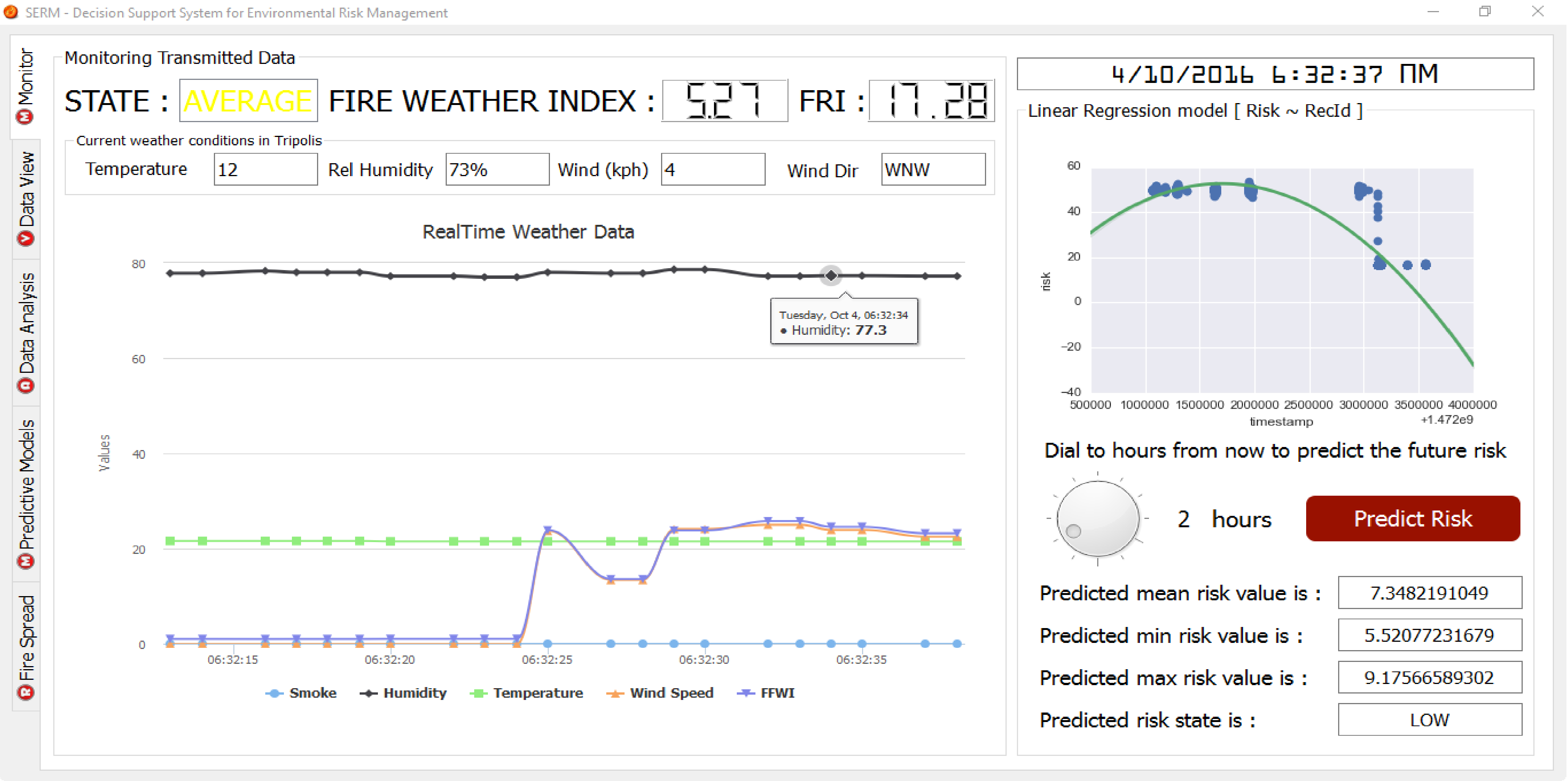








System GUI


SERM - Decision Support System for Environmental Risk Management
Monitor
Data View
Data Analysis
Predictive Models
Fire Spread
Monitoring Transmitted Data
STATE : AVERAGE
FIRE WEATHER INDEX : 5.27
FRI : 17.28
Current weather conditions in Tripolis
Temperature 12
Rel Humidity 73%
Wind (kph) 4
Wind Dir WNW
RealTime Weather Data
Values
Tuesday, Oct 4, 06:32:34
● Humidity: 77.3
06:32:15
06:32:20
06:32:25
06:32:30
06:32:35
Smoke
Humidity
Temperature
Wind Speed
FFWI
4/10/2016 6:32:37 ΠΜ
Linear Regression model [Risk ~ RecId]
risk
timestamp
+1.472e9
Dial to hours from now to predict the future risk
2 hours
Predict Risk
Predicted mean risk value is : 7.3482191049
Predicted min risk value is : 5.52077231679
Predicted max risk value is : 9.17566589302
Predicted risk state is : LOW

Uncertainty in Fire Management

- In all real world situations the available information is always imperfect, incomplete, vague and often erroneous.
- Such imprecisely defined classes play an important role in human thinking, particularly in the domains of
  - pattern recognition,
  - communication of information
  - abstraction (Zadeh, 1965).
- Working on environmental subjects, there are many manifestations of uncertainty and fuzziness due to natural phenomena.
  - For example, it is almost impossible using today's techniques to measure fuel humidity accurately over extended areas
  - conditions that affect it vary temporally and locally (understory, sunlight intensity - duration, wind velocity, atmospheric humidity etc.).
  - To monitor therefore fuel humidity over large areas, a prohibitively great number of measurements must be taken for a long period.
  - In practice, therefore, approximations of fuel humidity levels are accepted.

Uncertainty in Fire Management

- There are also other reasons of uncertainty
  - inability to predict the time and position of a future fire event
- It is also fuzziness, which is present in many situations related to space and time.
  - E.g., forest density changes gradually either from one position to another or in time.
- In many cases, therefore, it is rather impossible to define exactly where or when the forest changes from dense to thin.

Uncertainty in Fire Management

- Uncertainty in fire management can be attributed to:
  - The lack of data over extended forested areas, and/or long time intervals.
  - The errors in measurements of forest factors values.
  - The poor modeling of forest functions due to their complexity.
    - For example, forest stand structure is difficult to be modeled accurately.
    - Hence, future values of some forest factors are considered in approximation.
  - The inability to predict accurately the frequency, intensity, time and position of future fire events
- To be therefore realistically operational, Information Systems must contain mechanisms to
  - optimally exploit this inexact and eventually vague information
  - elicit it from the user or the domain expert.
- Methods to handle uncertainty: Fuzzy Logic, Deep Learning

Fuzzy Logic (1/2)

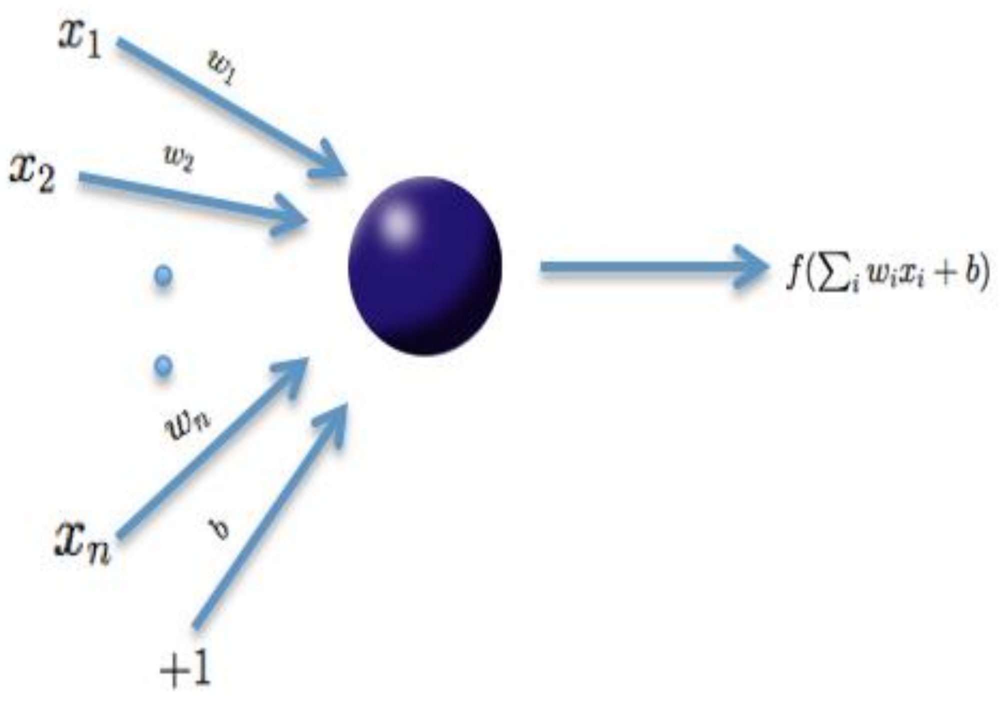
- **Fuzzy Logic**
  - "truthiness" of something can be expressed over a continuum. This is to say that something isn't *true* or *false* but instead *partially true* or *partially false*.
- **fuzzy variable**
  - has a **crisp value** which takes on some number over a pre-defined domain (in fuzzy logic terms, called a **universe**).
  - The crisp value is how we think of the variable using normal mathematics.
  - For example, if my fuzzy variable was how much to tip someone, it's universe would be 0 to 25% and it might take on a crisp value of 15

Fuzzy Logic (2/2)

- A fuzzy variable also has several **terms**
- The terms taken together are the **fuzzy set** which can be used to describe the “fuzzy value” of a fuzzy variable.
  - These terms are usually adjectives like “poor,” “mediocre,” and “good.”
  - Each term has a **membership function** that defines how a crisp value maps to the term on a scale of 0 to 1. In essence, it describes “how good” something is.
- A **fuzzy control system** links fuzzy variables using a set of **rules**.
  - These rules are simply mappings that describe how one or more fuzzy variables relates to another.
  - These are expressed in terms of an IF-THEN statement;
  - the IF part is called the **antecedent** and the THEN part is the **consequent**

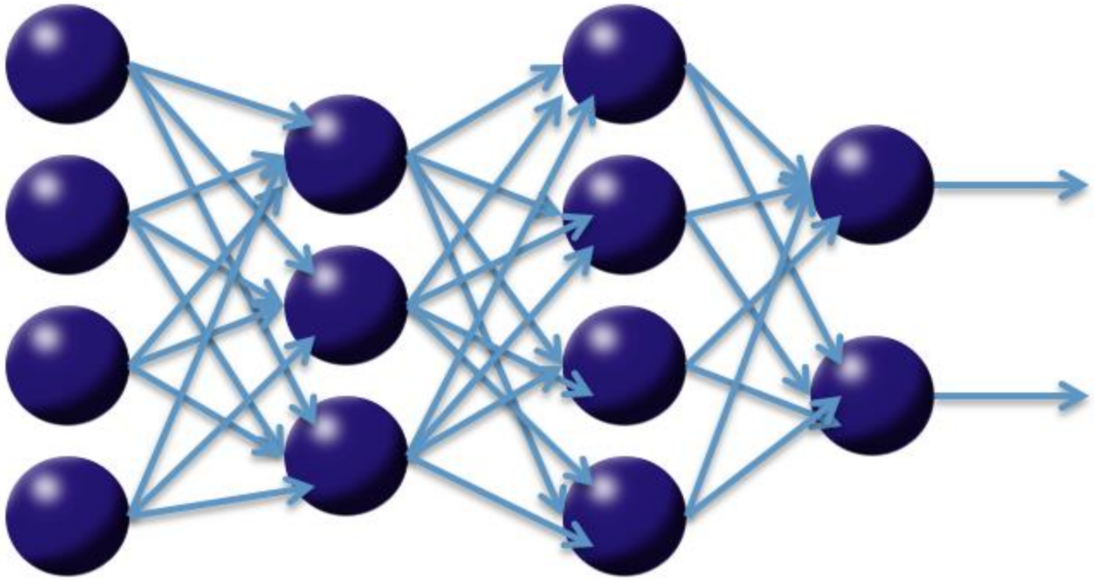
Deep Learning (1/2)

- The basic unit in the model (shown above) is the neuron
- For humans, varying strengths of neurons' output signals travel along the synaptic junctions and are then aggregated as input for a connected neuron's activation.
- In the model, the weighted combination of input signals is aggregated $a = \Sigma_{i=1}^{n} w_i x_i + b$
- An output signal transmitted by the connected neuron.
- The function f represents the nonlinear activation function used throughout the network,
- The bias *b* accounts for the neuron's activation threshold.



Deep Learning (2/2)

- Multi-layer, feedforward neural networks consist of many layers of interconnected neuron units
  - starting with an input layer to match the feature space,
  - followed by multiple layers of nonlinearity,
  - and ending with a linear regression or classification layer to match the output space.
- The inputs and outputs of the model's units follow the basic logic of the single neuron.
- The weights linking neurons and biases with other neurons fully determine the output of the entire network, and learning occurs when these weights are adapted to minimize the error on labeled training data.
- For each training example, the objective is to minimize a loss function
- Deep learning architectures are models of hierarchical feature extraction, typically involving multiple levels of nonlinearity.
- Deep learning models are able to learn useful representations of raw data and have exhibited high performance on complex data such as images, speech, and text



Discussion (1/2)

- Effective fire management planning can greatly be facilitated by integrated information systems.
- The advantages of such systems are that they:
  - Can store and retrieve tedious amount of data and perform various type calculations in a very sort time.
  - Exchange information with other systems or humans in real time.
- The practical advantage of such information is that preventive and suppressive measures can be taken according to the expected size of fire damages.
  - fuel modification for fire behaviour alternation,
  - construction of fuel brakes (e.g. between forest and residence places and public infrastructure),
  - establishment of fire detection networks and fire-fighting plans,
  - move forces to the areas with high risk.
- The majority of ecological knowledge incorporates a degree of fuzziness and uncertainty, which are difficult to be removed because they form inevitable or inherent parts of the ecosystem

Discussion (2/2)

- Fuzzy models and deep learning can be used for the representation and processing of non-linear relationships.
- These techniques use concepts similar to the human thought:
  - making easier the transformation of existing knowledge into models,
  - and reducing drastically the number of combinations of factors
- The proposed Intelligent Decision Support System uses fuzzy Logic and Deep Learning for the representation and management of uncertainty.
- It facilitates fire management planning by integrating various models and methodologies in one modular system.
- Its usefulness is profound, for short and long-term fire management planning,
  - since it provides information about the current and future level of fire risk and determines appropriate measures that should be applied.

Thank you for your attention!

- Questions?