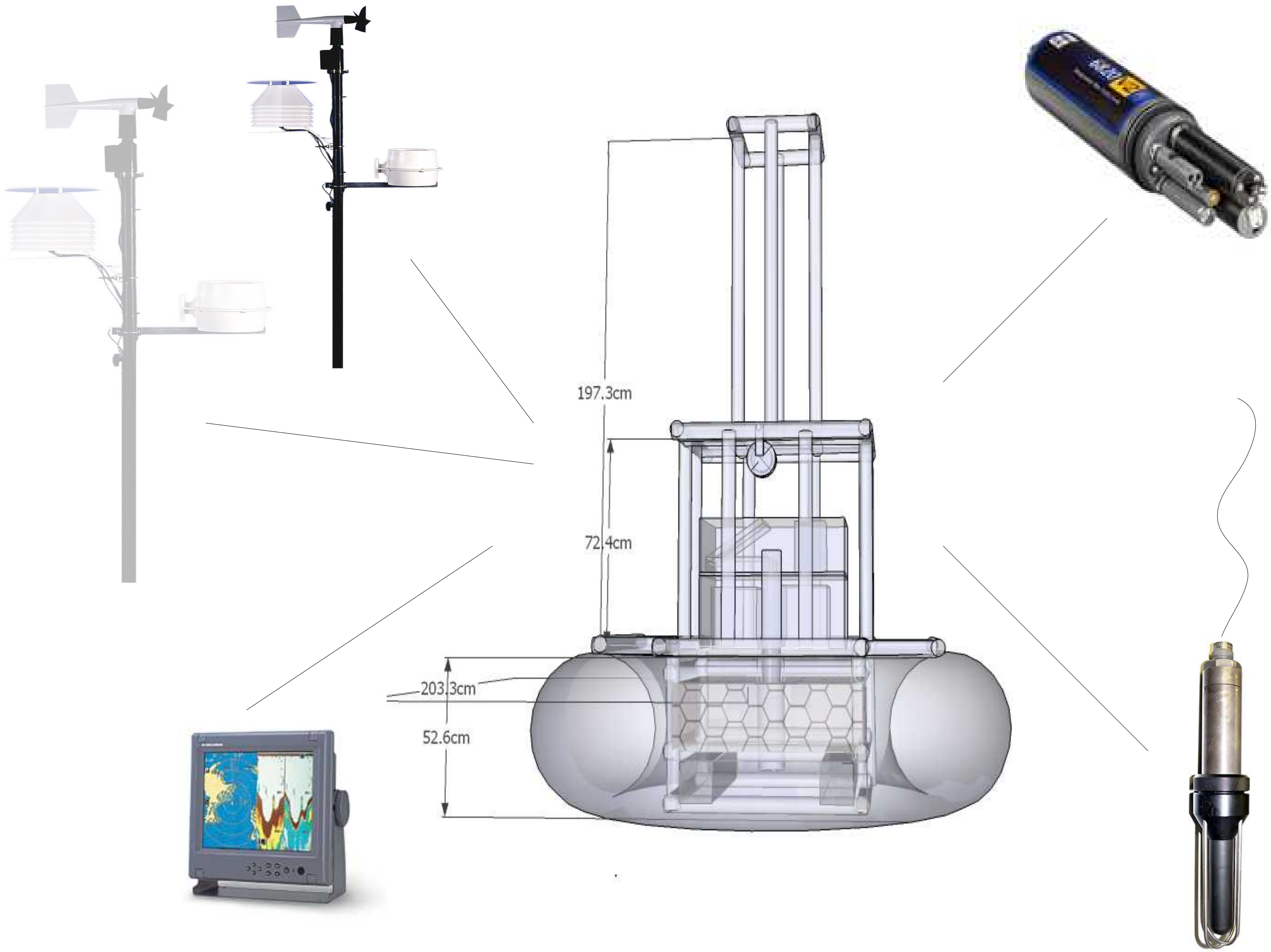
What is special about GBF ?

Expanded water quality concept
> water chemistry + aquatic life + water appreciation

Broadcasting
> site specific realtime data available on any mobile computer

Mobility
>maps out paths of least contamination and greatest swimming pleasure

-> the swimming pleasure measure (SPM)


197.3cm
72.4cm
203.3cm
52.6cm

water quality (YSI)

> dissolved oxygen
> turbidity
> dissolved solids
> chlorophyll
> conductivity
> salinity
> pH
> water temperature

real-time local weather

> air temperature
> wind speed
> wind direction
> barometric pressure
> rainfall (1hr, 24 hr)

NOAA weather

> current 5km grid (today)
> forecast on a grid (space: 5km, time: today + tomorrow)

hydrophone

> 20hz – 40khz data
> mp3 audio (15 sec) segments

sonar-based fish detector

> gps location
> water depth -> wave height
> heading (degrees)
> presence of fish (small and large)

Tiered approach to establish the *swimming pleasure measure*

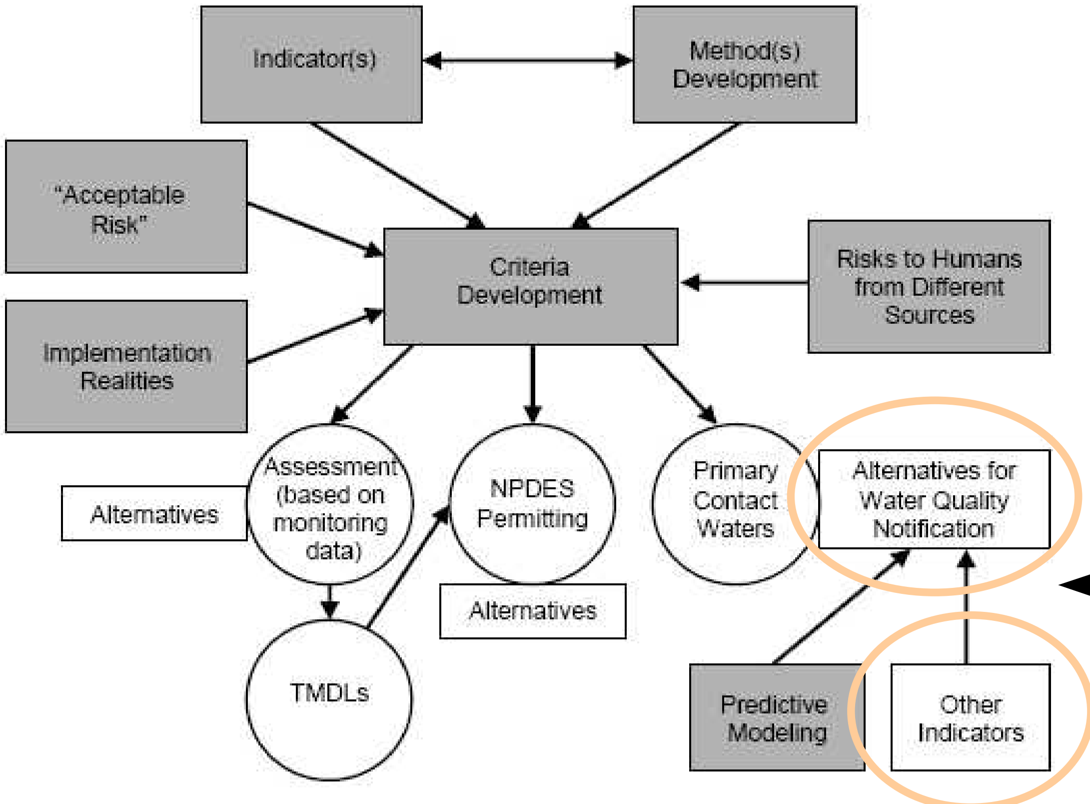
established
day of year, time of day, conductivity, water and air temperature, pH, dissolved oxygen, dissolved solids, chlorophyll, turbidity, ammonium-nitrogen

narrative-accepted
wave motion, micro-climate and macro-climate, insolation

numeric-experimental
realtime direct e-coli, real time caffeine (invited research)

second order narrative-experimental
presence of fish, crustaceans, presence of human artifacts (motorboats) audio and sonar, antidepressants

post experience survey
how was the water?



swimming pleasure measure

(SPM)

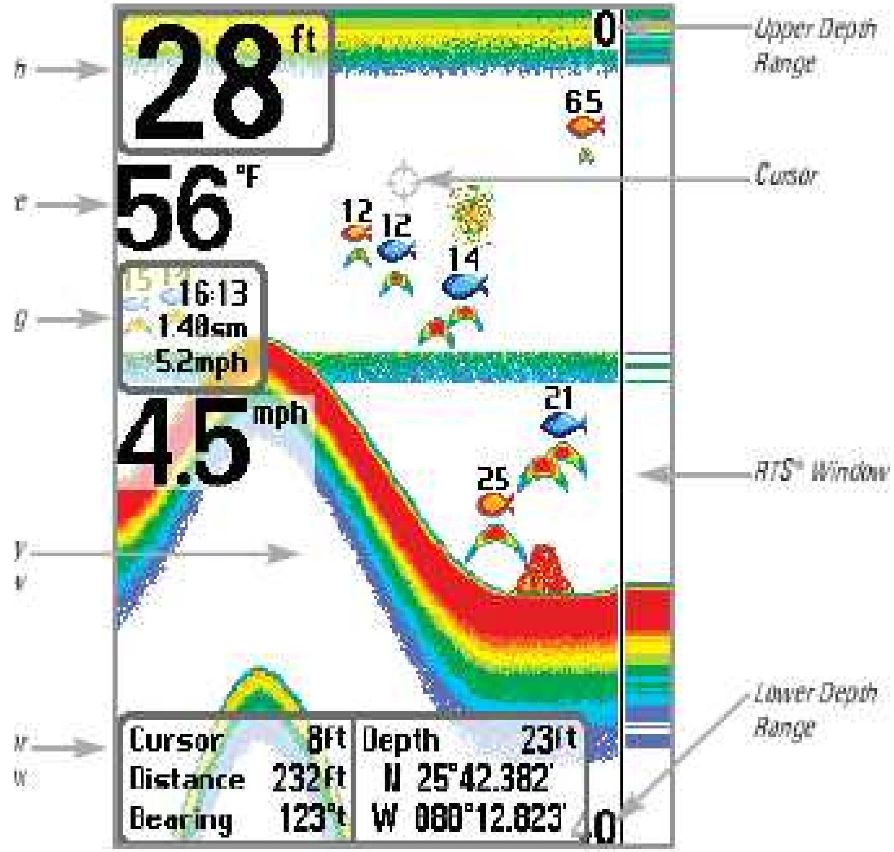
Source: http://www.epa.gov/waterscience/criteria/recreation/experts/

Typical performance specifications

	Range	Resolution	Accuracy
Rapid Pulse dissolved oxygen % air saturation	0 to 500%	0.1%	0 to 200%: ±2% of reading or 2% air saturation, whichever is greater; 200 to 500%: ±6% of reading
Rapid Pulse dissolved oxygen mg/L	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ±2% of reading or 0.2 mg/L, whichever is greater; 20 to 50 mg/L: ±6% of reading
ROX optical dissolved oxygen# % air saturation	0 to 500%	0.1%	0 to 200%: ±1% of reading or 1% air saturation, whichever is greater; 200 to 500%: ±15% of reading; relative to calibration gases
ROX optical dissolved oxygen# mg/L	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ±1% of reading or 0.1 mg/L, whichever is greater; 20 to 50 mg/L: ±15% of reading; relative to calibration gases
Conductivity+	0 to 100 mS/cm	0.001 to 0.1 mS/cm (range-dependent)	±0.5% of reading + 0.001 mS/cm
Temperature	-5 to 50°C	0.01°C	±0.15°C
pH	0 to 14 units	0.01 unit	±0.2 unit
Shallow depth	0 to 9.1 m (0 to 30 ft)	0.001 m (0.001 ft)	±0.018 m (±0.06 ft)
Medium depth	0 to 61 m (0 to 200 ft)	0.001 m (0.001 ft)	±0.12 m (±0.4 ft)
Deep depth	0 to 200 m (0 to 656 ft)	0.001 m (0.001 ft)	±0.3 m (±1 ft)
Vented level	0 to 9.1 m (0 to 30 ft)	0.001 m (0.001 ft)	±0.003 m (±0.01 ft)
Open-channel flow	Calculated measurement, requires vented level		
Free chlorine	0 to 3 mg/L	0.01 mg/L	±15% of reading or 0.05 mg/L, whichever is greater
ORP	-999 to +999 mV	0.1 mV	±20 mV in Redox standard solutions
Salinity	0 to 70 ppt	0.01 ppt	±1% of reading or 0.1 ppt, whichever is greater
Nitrate/nitrogen*	0 to 200 mg/L-N	0.001 to 1 mg/L-N (range dependent)	±10% of reading or 2 mg/L, whichever is greater
Ammonium/ammonia/ nitrogen*	0 to 200 mg/L-N	0.001 to 1 mg/L-N (range dependent)	±10% of reading or 2 mg/L, whichever is greater
Chloride*	0 to 1000 mg/L	0.001 to 1 mg/L (range dependent)	±15% of reading or 5 mg/L, whichever is greater
Turbidity#	0 to 1,000 NTU	0.1 NTU	±2% of reading or 0.3 NTU, whichever is greater in YSI AMCO-AEPA Polymer Standards
Rhodamine WT#	0-200 µg/L	0.1 µg/L	±5% of reading or ±1 µg/L, whichever is greater
	Range	**Resolution**	**Linearity**
Chlorophyll# ++	0 to 400 µg/L chl *a* 0 to 100 RFU	0.1 µg/L chl *a* 0.1% FS; 0.1 RFU	R^2 > 0.9999 for serial dilution of Rhodamine WT solution from 0 to 500 µg/L
	Range	**Detection limit**	**Linearity**
Blue-green algae# phycocyanin	0-280,000 cells/mL	220 cells/mL§	R^2 = 0.9999 for serial dilution of Rhodamine WT from 0 to 400 µg/L
Blue-green algae# phycoerythrin	0-200,000 cells/mL	450 cells/mL§§	R^2 = 0.9999 for serial dilution of Rhodamine WT from 0 to 8 µg/L
	Range	**Calibration**	**Stability**
PAR	400-700 nm waveband	±5%	<±2% change over 1 year
	Linearity	**Sensitivity**	
	Max. deviation of 1%	Typically 3µA per 1000 µmol s-1 m-2 in water	


HUMMINBIRD
ZOOM
VIEW
INFO
MENU
MARK
EXIT
34.4 ft
100 Left
Right 100
68.4 °F
2.4 mph
103 °t
797c2
GPS
Fishing
System

Sonar View


28 ft
0
Upper Depth Range
65
Cursor
56 °F
12
12
14
16:13
1.40sm
5.2mph
21
4.5 mph
25
RTS® Window
Lower Depth Range
Cursor 8ft
Distance 232ft
Bearing 123°t
Depth 23ft
N 25°42.382'
W 080°12.823'
40

water quality analysis: standard EPA approach:
measure fecal contaminants (e-coli and other fecal coliforms)

water sample → membrane filtration techniques → incubation (18 - 48hrs) → E-coli on threshold (235 CFU/ml)

water quality analysis:
alternate approaches for fecal contaminant assessment

- nowcasting / mathematical modeling
- photochemistry based methods
- antibody based methods
- others ...

nowcasting: prediction model based approach

wave height
rainfall
turbidity

→

multiple
linear
regression

→

probabilistic
e-coli

→

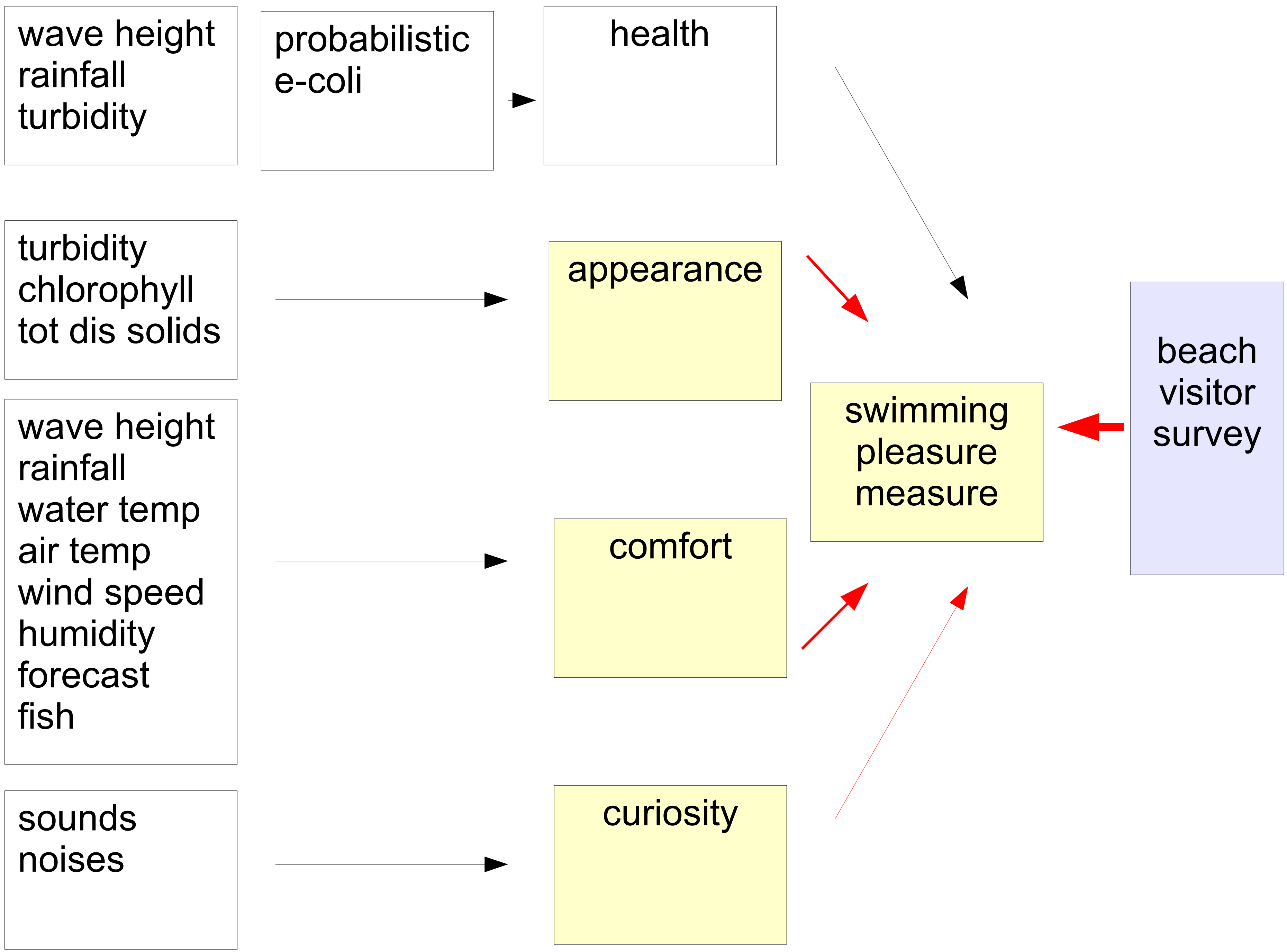
>
<
235 CFU/ml

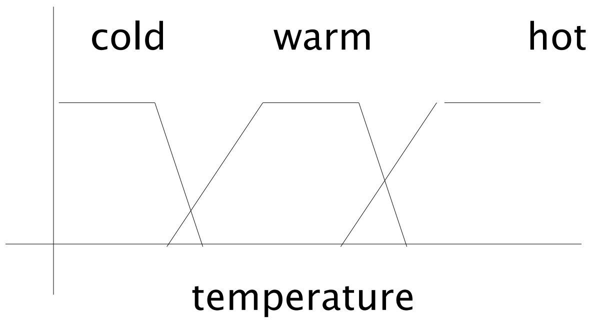
Francy et al, 2006

	FIS	ANN	EA	Symbolic Logic	Control Theory
mathematical model	SG	B	B	SB	G
learning ability	**B**	**G**	**G**	B	B
knowledge representation	**G**	**B**	**SB**	G	SB
expert knowledge	G	B	B	G	SB
nonlinearity	G	G	G	SB	B
optimization ability	B	G	G	B	SB
fault tolerance	G	G	G	B	B
uncertainty tolerance	G	G	G	B	B
realtime operation	G	SG	SB	B	G

KEY:
good: G slightly good: SG slightly bad: SB bad: B

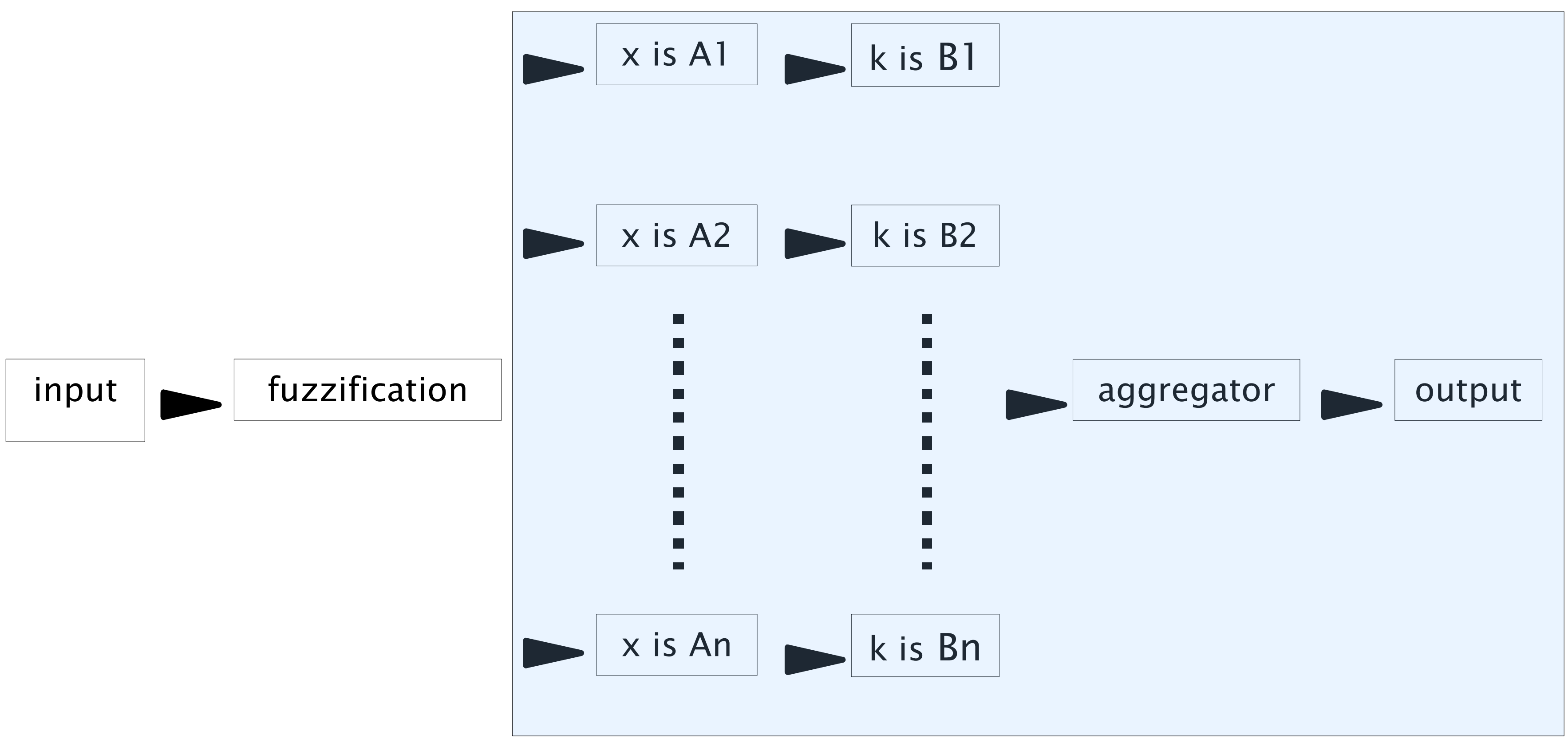
Source: Evolutionary Design of Neuro-Fuzzy Systems - A Generic Framework,
Ajith Abraham et al


wave height
rainfall
turbidity
probabilistic
e-coli
health
turbidity
chlorophyll
tot dis solids
appearance
wave height
rainfall
water temp
air temp
wind speed
humidity
forecast
fish
comfort
swimming
pleasure
measure
beach
visitor
survey
sounds
noises
curiosity



Version A

Fuzzy System




wave height
rainfall
turbidity
probabilistic
e-coli
If > 235 CFU -> 0
else > 0 1
health
turbidity
chlorophyll
tot dis solids
turbidity:
0.1 .... 1.0
Chlorophyll
0.1 .... 1.0
tot dis solids
0 .... 1.0
appearance
swimming
pleasure
measure
wave height
rainfall
water temp
air temp
wind chill
forecast
wave height
0 .... 1.0
rainfall
0.1 ... 1.0
water temp
0.1 .... 1.0
air temp
0.1 .... 1.0
wind chill
0.1 ... 1.0
forecast
0.2 ... 1.0
comfort
fish pres
sounds
noises
fish
0.2 ... 1.0
noises
0.2 ... 1.0
curiosity

fuzzy logic modeling

prob e-coli

turbidity
chlorophyll
tot dis solids

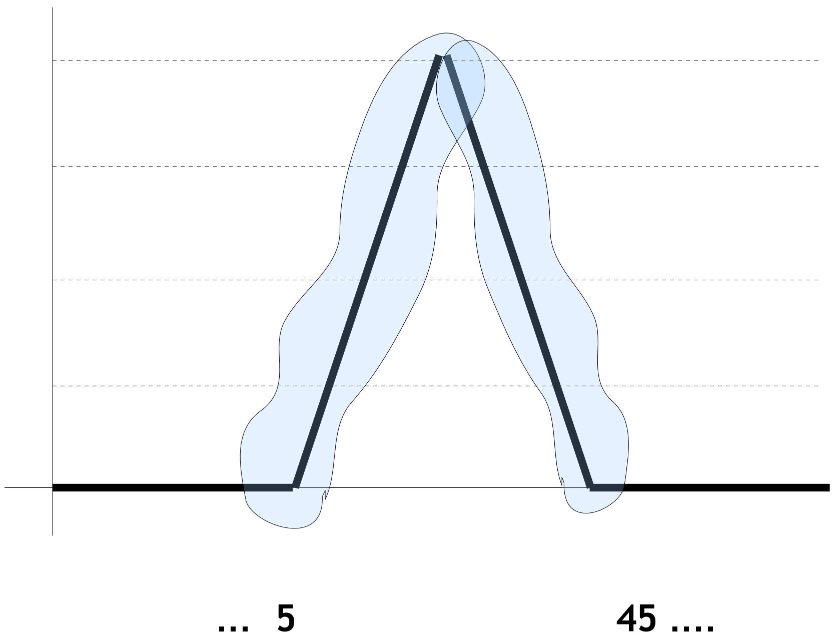
wave height
rainfall
water temp
air temp
wind speed
forecast

fish pres
sounds
noises

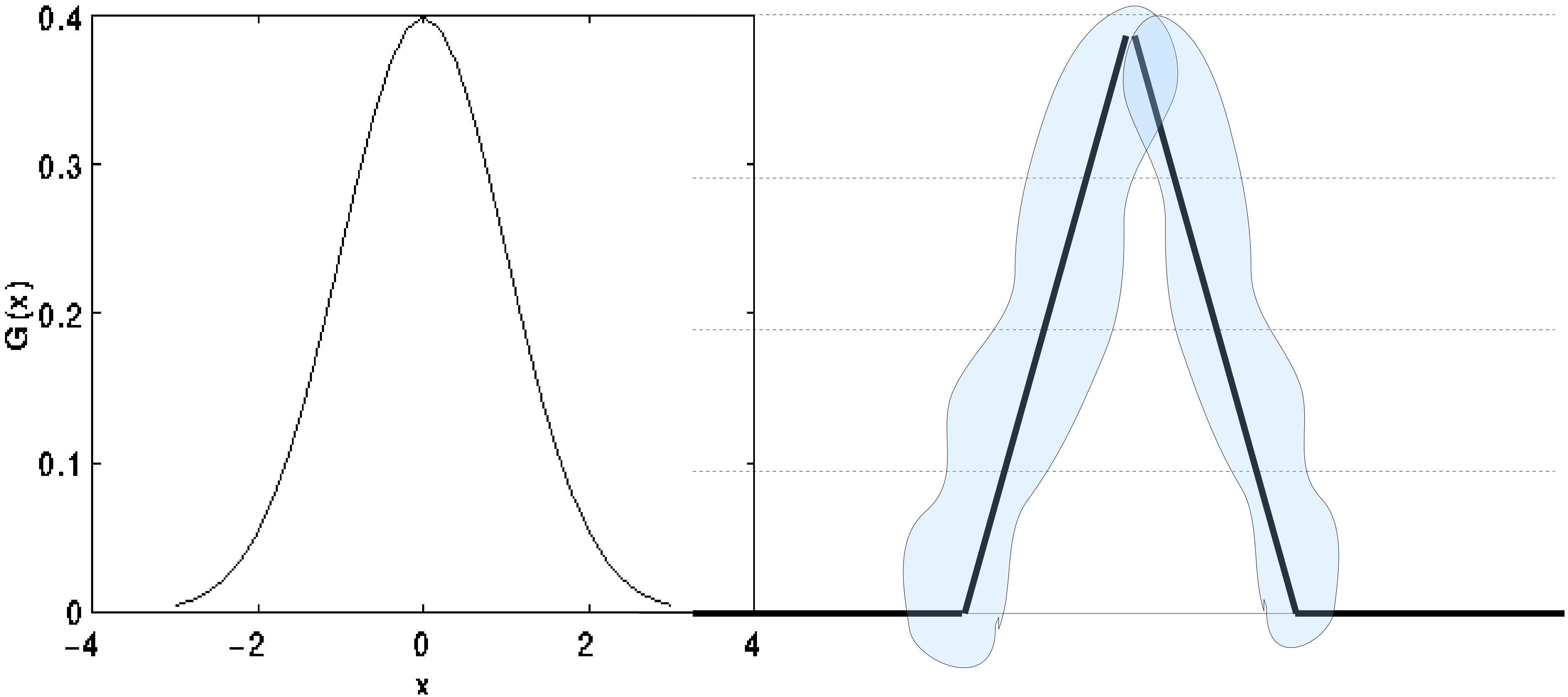
no	air temp lower limit	air temp upper limit	quantative value	fuzzy value
1	-20	0	0	very low
2	0	10	0.25	low
3	10	15	0.5	medium
4	15	20	0.75	high
5	20	25	1	veryhigh
6	25	28	0.75	high
7	28	34	0.5	medium
8	34	36	0.25	low
9	36	100	0	very low

fuzzy logic modeling

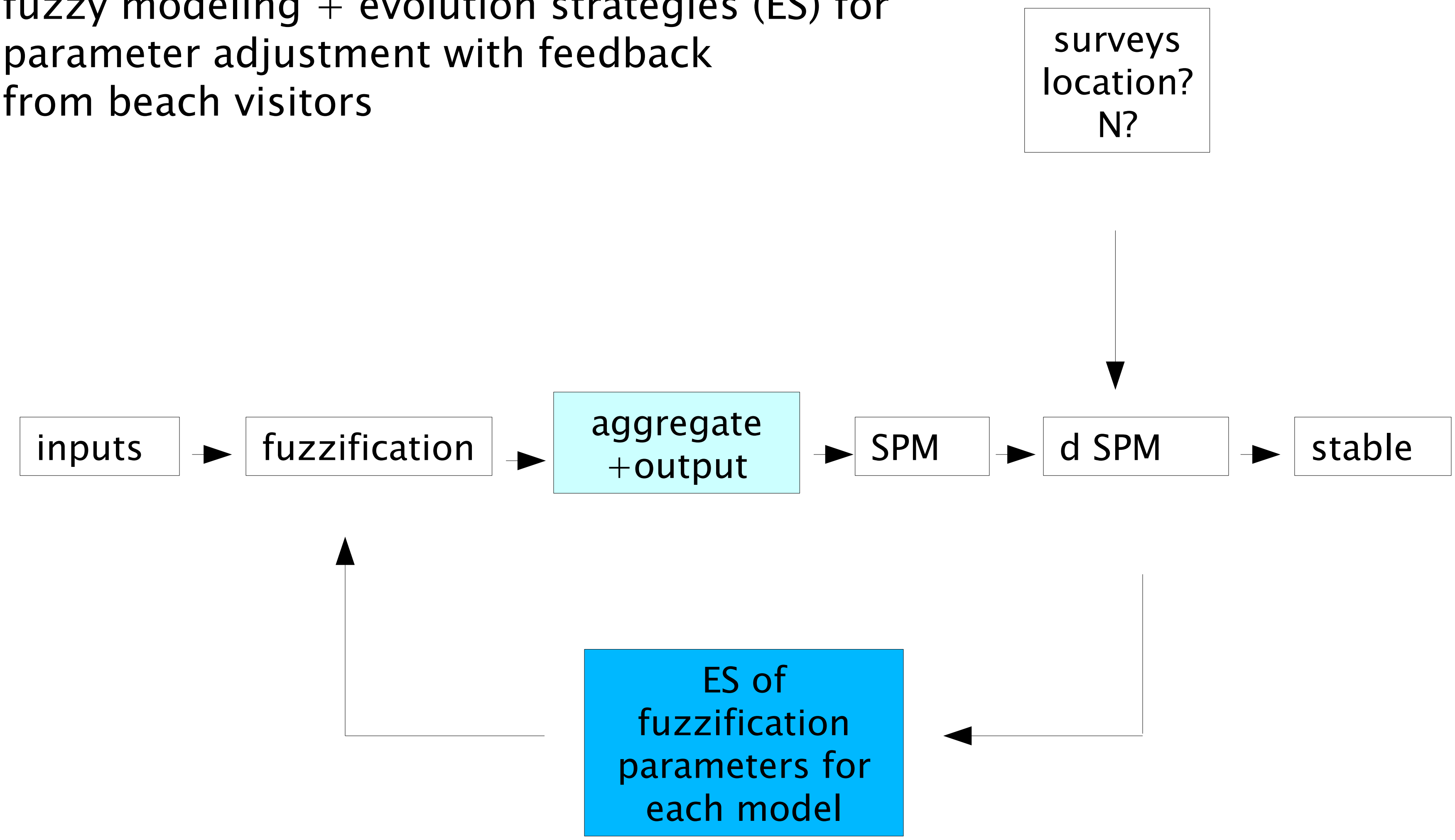
	lower limit	upper limit		
1	-20	**5**	0	very low
2	**5**	10	0.25	low
3	10	15	0.5	medium
4	15	20	0.75	high
5	20	25	1	veryhigh
6	25	28	0.75	high
7	28	34	0.5	medium
8	34	**45**	0.25	low
9	**45**	100	0	very low

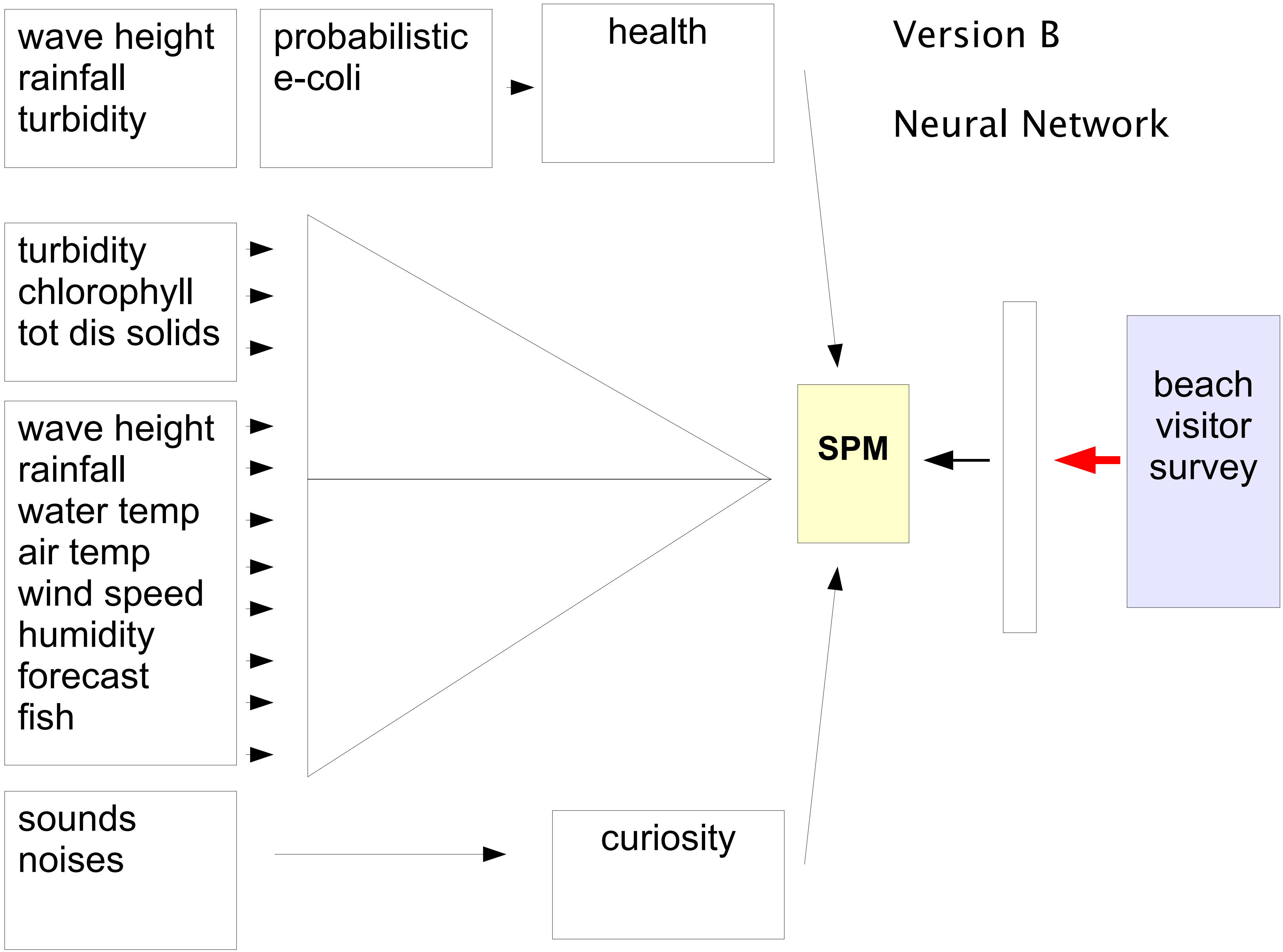


fuzzy logic modeling -
differentiable functions

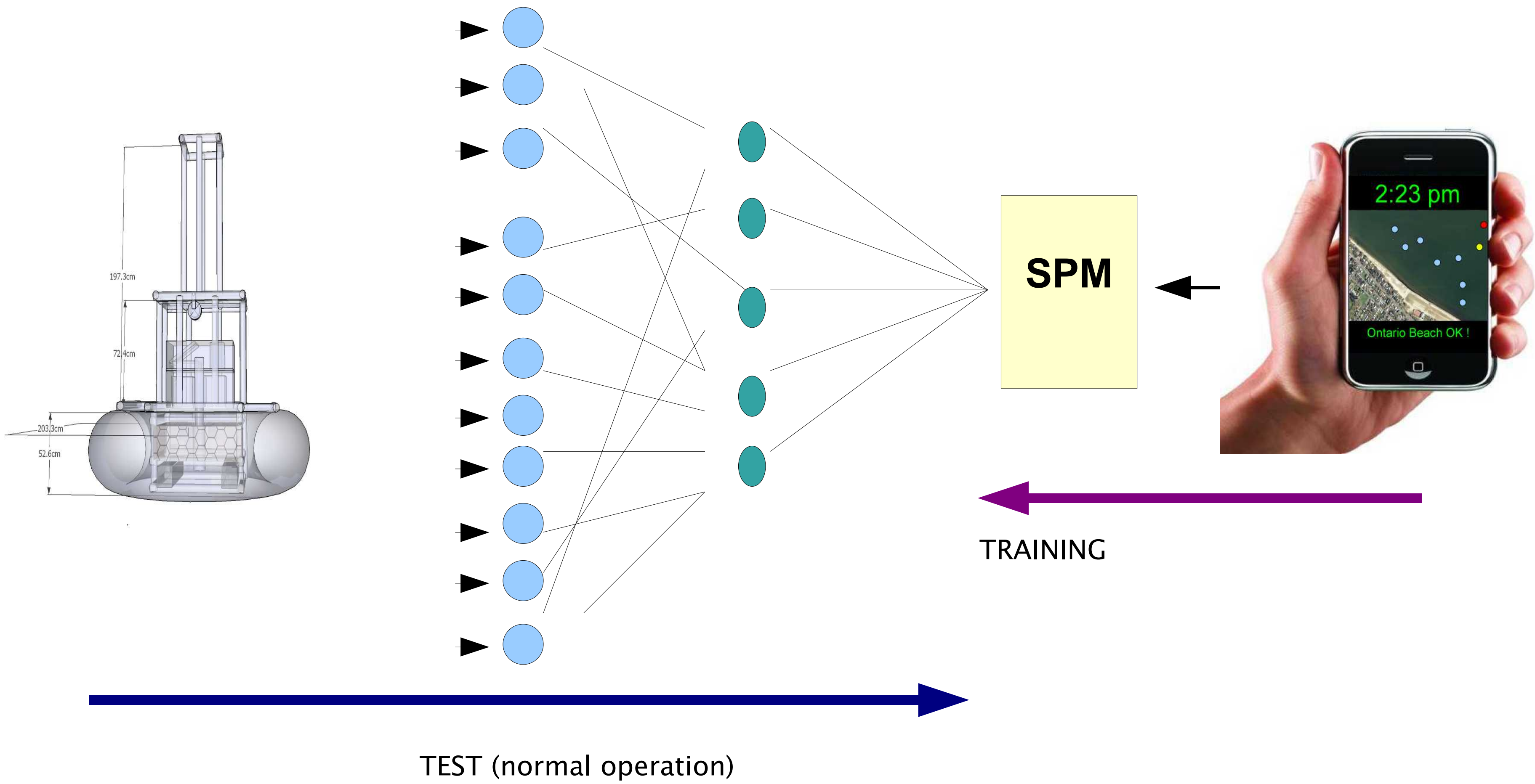


fuzzy modeling + evolution strategies (ES) for parameter adjustment with feedback from beach visitors



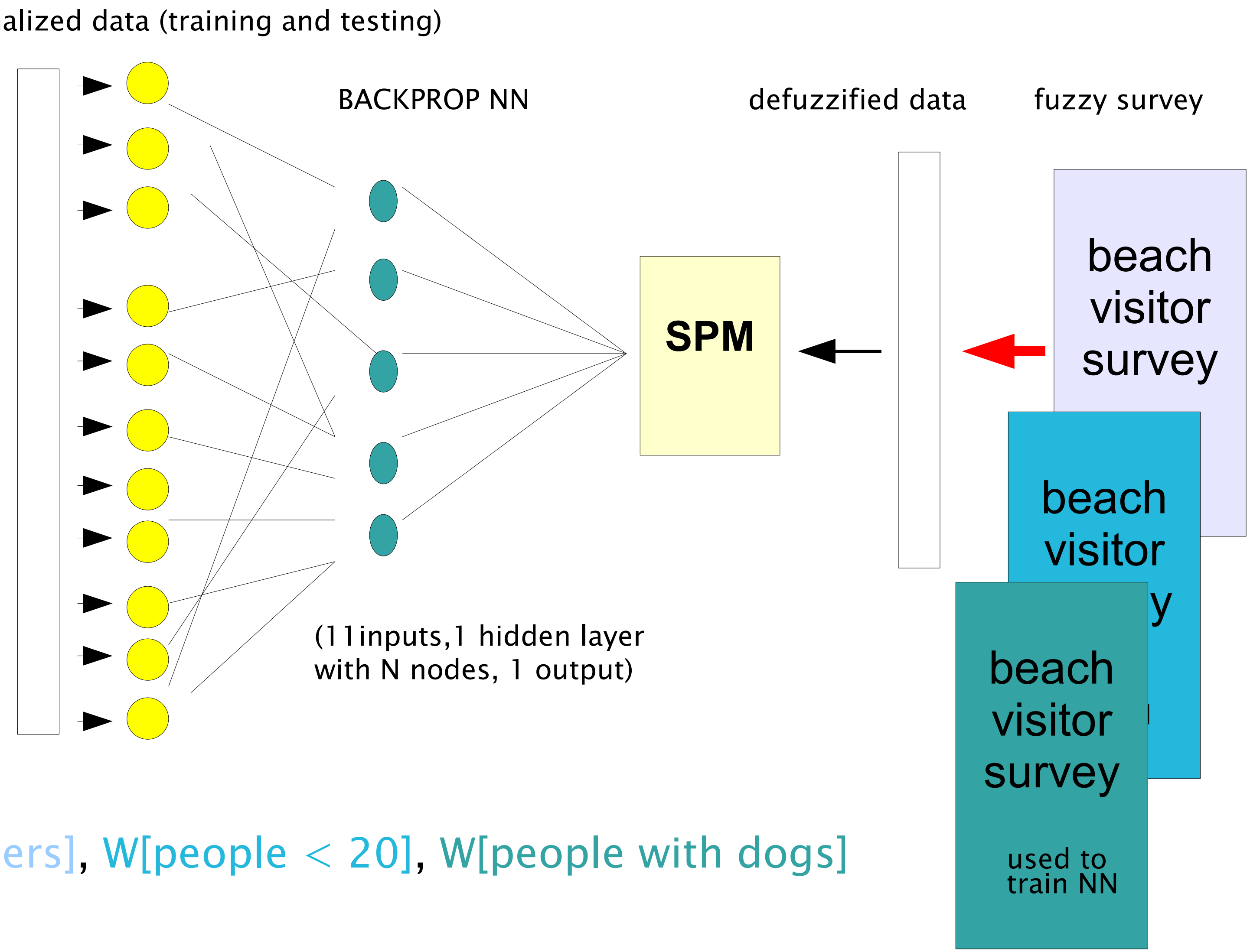


wave height
rainfall
turbidity
probabilistic
e-coli
health
Version B
Neural Network
turbidity
chlorophyll
tot dis solids
wave height
rainfall
water temp
air temp
wind speed
humidity
forecast
fish
SPM
beach
visitor
survey
sounds
noises
curiosity

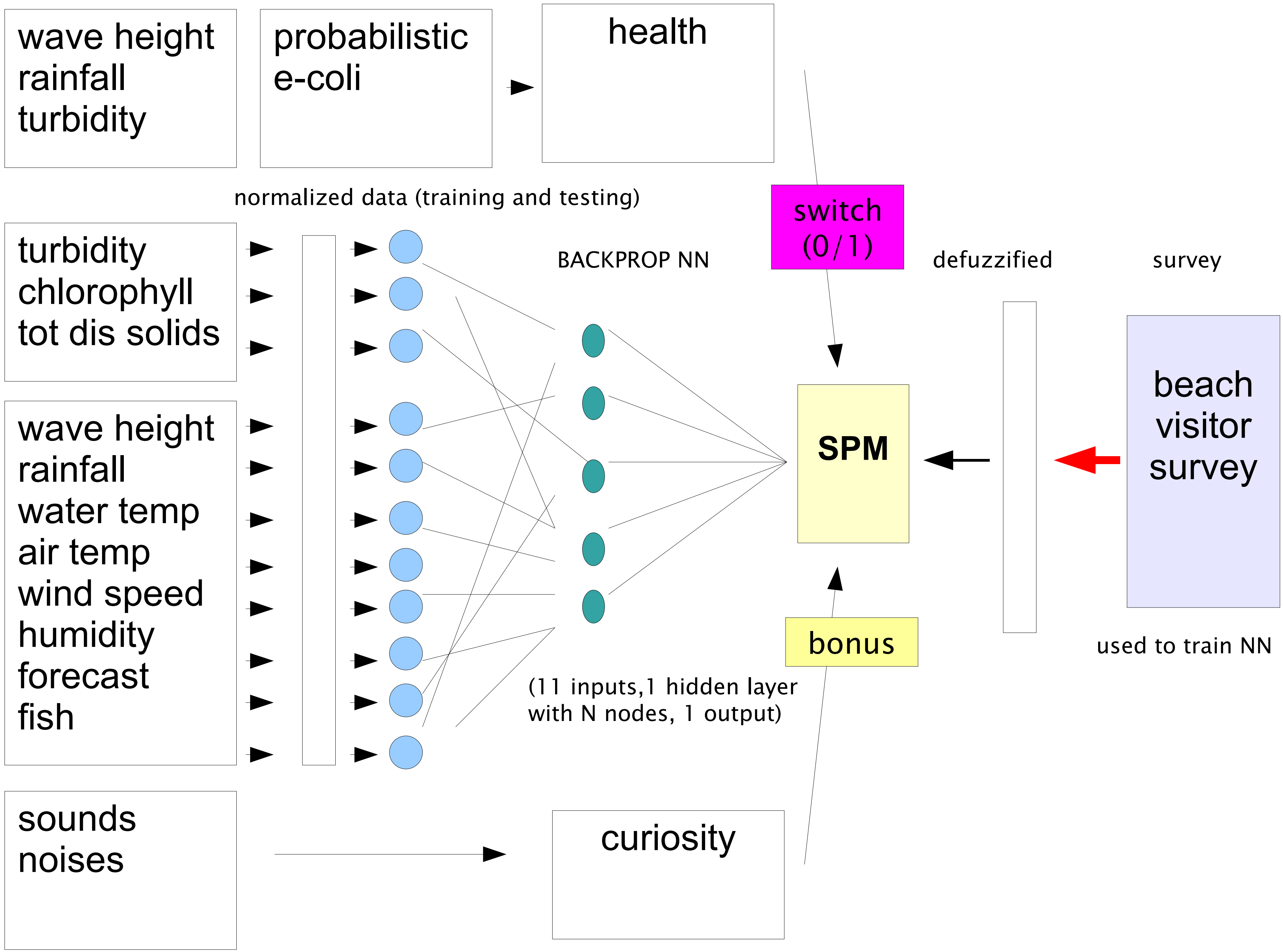

197.3cm
72.4cm
203.3cm
52.6cm
SPM
2:23 pm
Ontario Beach OK !
TRAINING
TEST (normal operation)

Possible alternative to backpropagation for supervised learning:

support vector machines



W[all users], W[people < 20], W[people with dogs]



wave height
rainfall
turbidity
probabilistic
e-coli
health
normalized data (training and testing)
switch
(0/1)
turbidity
chlorophyll
tot dis solids
BACKPROP NN
defuzzified
survey
wave height
rainfall
water temp
air temp
wind speed
humidity
forecast
fish
SPM
beach
visitor
survey
bonus
used to train NN
(11 inputs,1 hidden layer
with N nodes, 1 output)
sounds
noises
curiosity

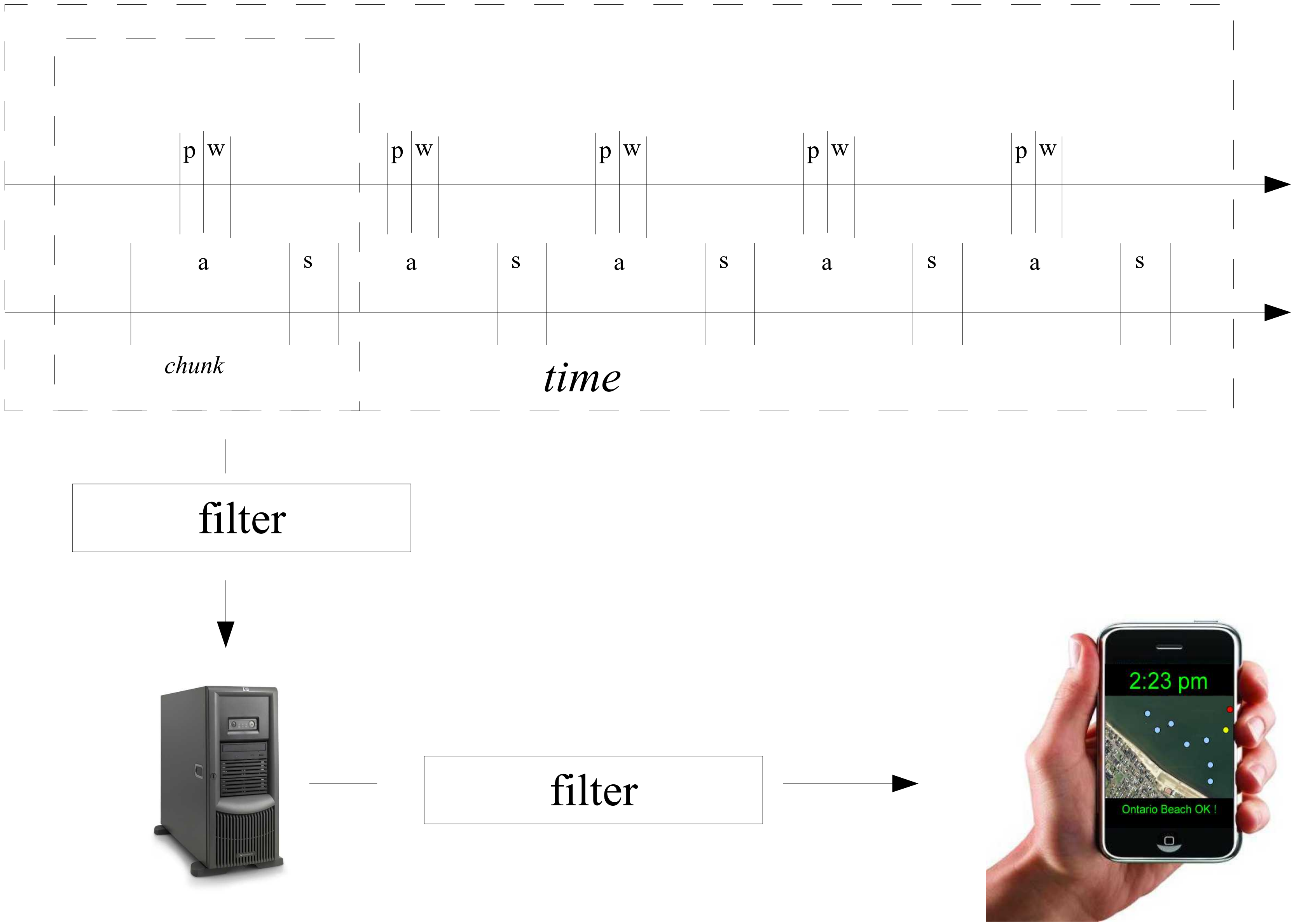
Backpropagation Neural Net (python version) – highlevel functions only

```
#training
inputlayer = 11          hiddenlayer = 6          outputlayer = 1
iterations = 3000
learningrate = 0.8       momentum = 0.1           errorlimit = 0.001

inputdata = readdata(filename)
trainingdata = normalizedata(inputdata)
currentNN = NN(inputlayer, hiddenlayer, outputlayer)
currentNN.train(trainingdata, iterations, learningrate, momentum, errorlimit, printint)


# GBF SPM after training
NNspm = currentNN.evaluateSPM(sampledata)

#human SPM via mobile phone for correction and retraining
currentNN.train(trainingdata, iterations, learningrate, momentum, errorlimit, printint)
```


p
w
p
w
p
w
p
w
p
w
a
s
a
s
a
s
a
s
a
s
chunk
time
filter
filter
2:23 pm
Ontario Beach OK !