Visual explanation of simple neural networks using interactive rainbow boxes

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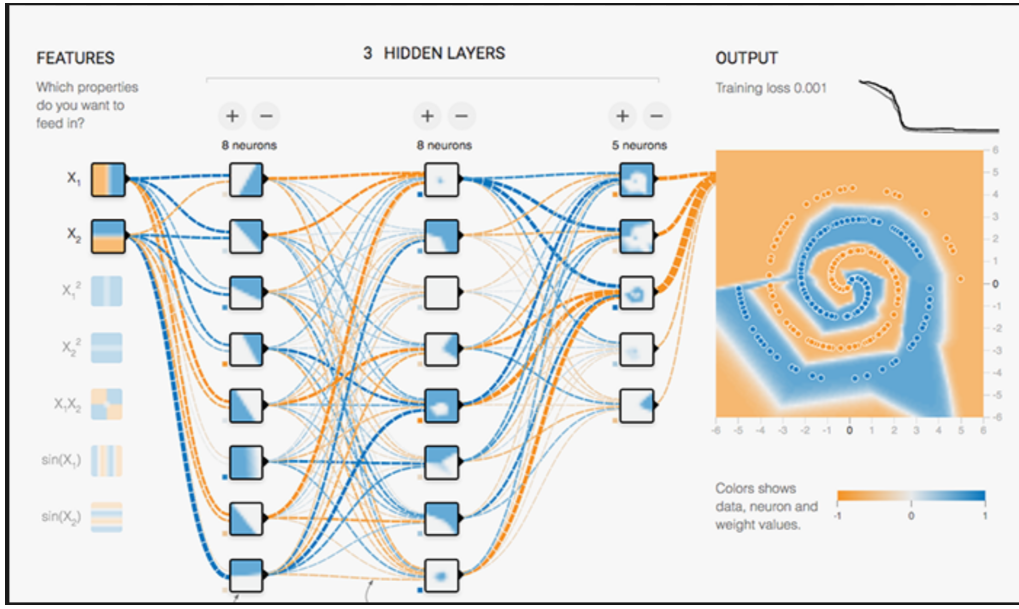
Introduction

- **Artificial neural networks are well-established in machine-learning**
  - Very good predictions
  - But “black-box” : predictions cannot be explained to a Human

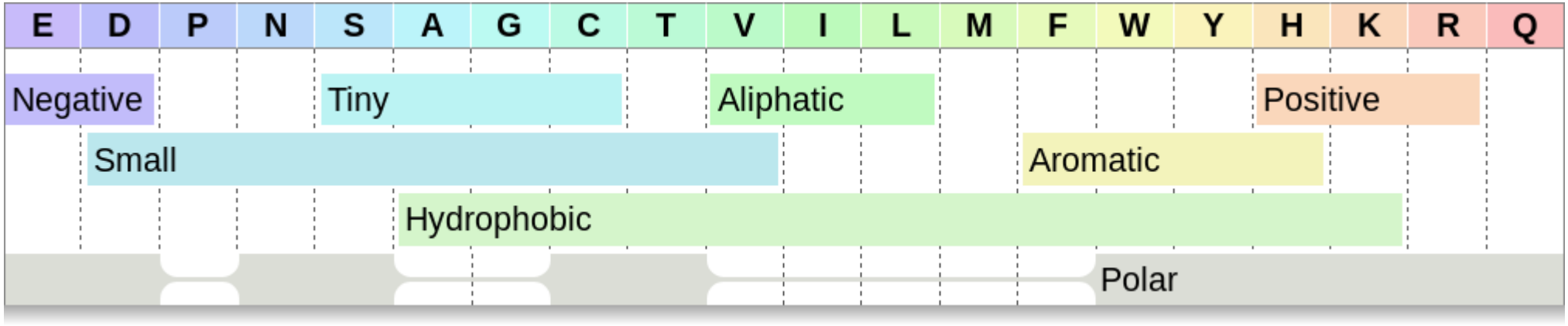


- **Many works on the visualization of neural networks recently**
  - Most focus on large network
  - Most target data scientists but not final user

- **Here, we propose a different approach**
  - Simple network
  - Visual explanation for final users (*e.g.* physicians for medical applications)

- **Previous work (iV2017) on a single neuron**
  - Using set visualization with rainbow boxes

Rainbow boxes

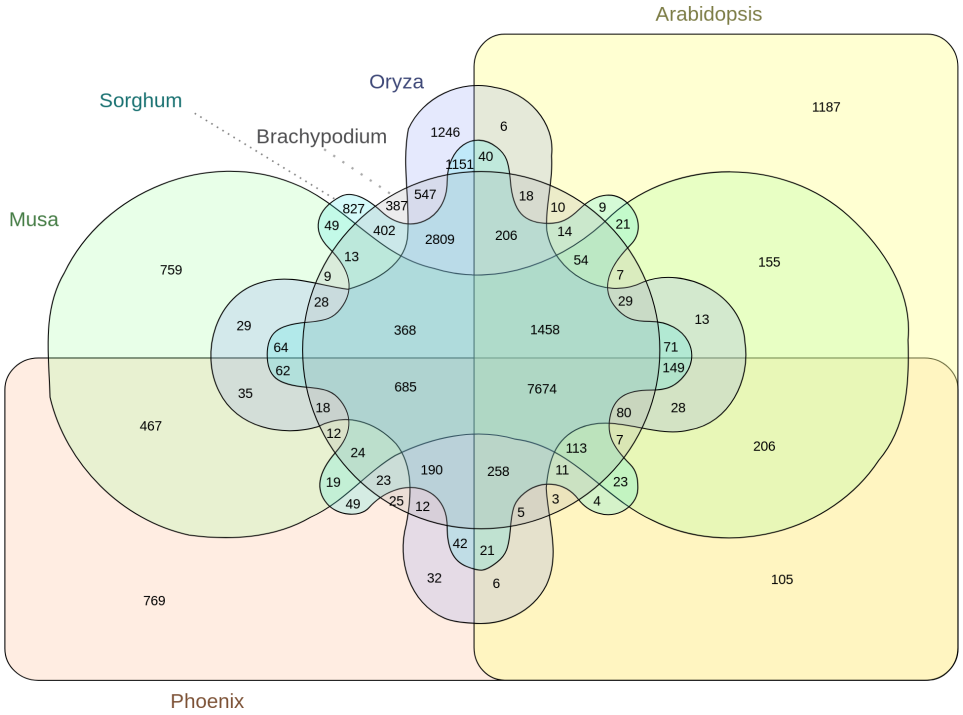


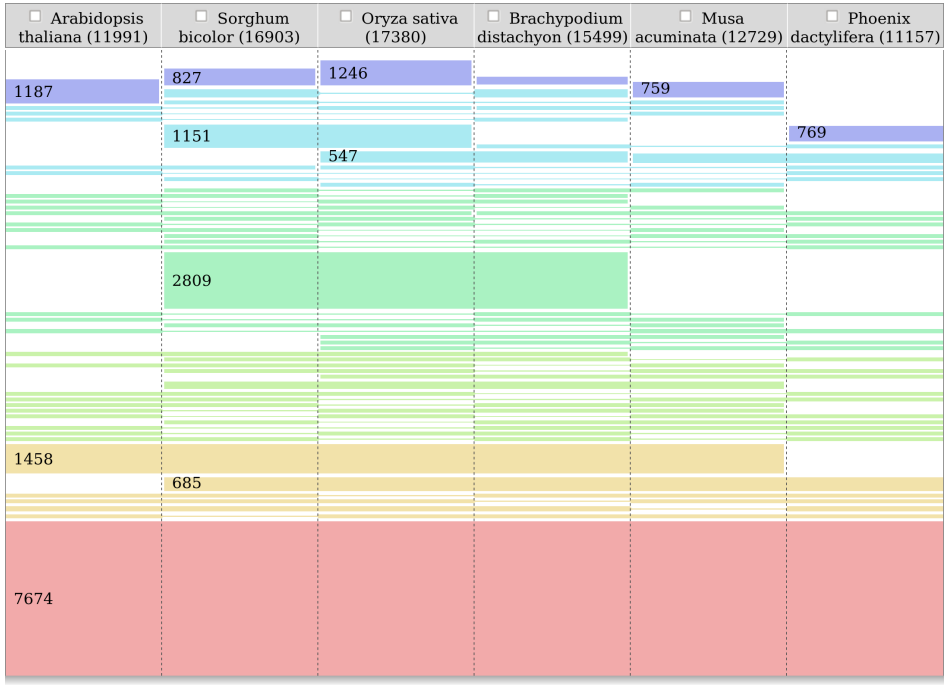
- **Rainbow boxes : a recent technique for set visualization**
  - elements => columns
  - sets => rectangular boxes
  - color => one color per element
  - box color is the mean of its elements color
  - non continguous element in a set => box hole
  - elements are ordered so as to minimize the number of holes
  - box are stacked vertically by size

[Lamy JB et al. Rainbow boxes: a new technique for overlapping set visualization and two applications in the biomedical domain. **Journal of Visual Language and Computing** 2017]

Rainbow boxes

- **Proportional variant : RainBio**
  - Box height encodes cardinality
  - Example in bioinformatics



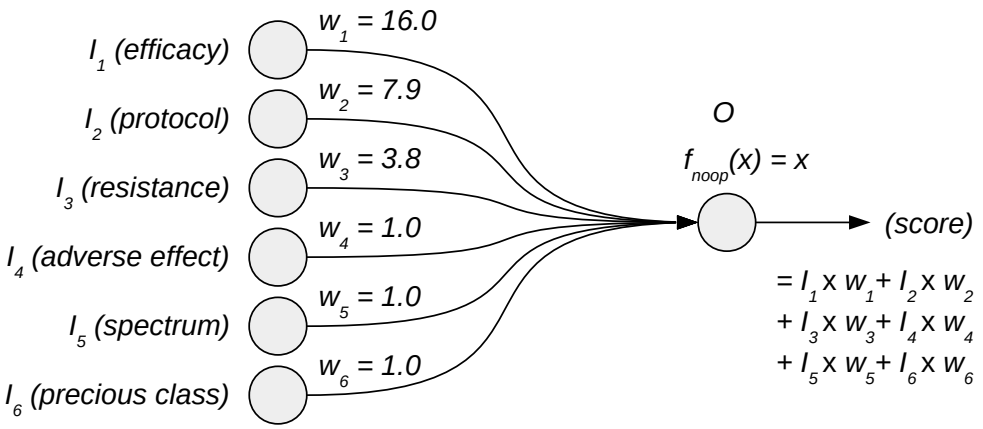


[Lamy JB et al. RainBio: Proportional visualization of large sets in biology. **IEEE Transactions on Visualisation and Computer Graphics** 2019]

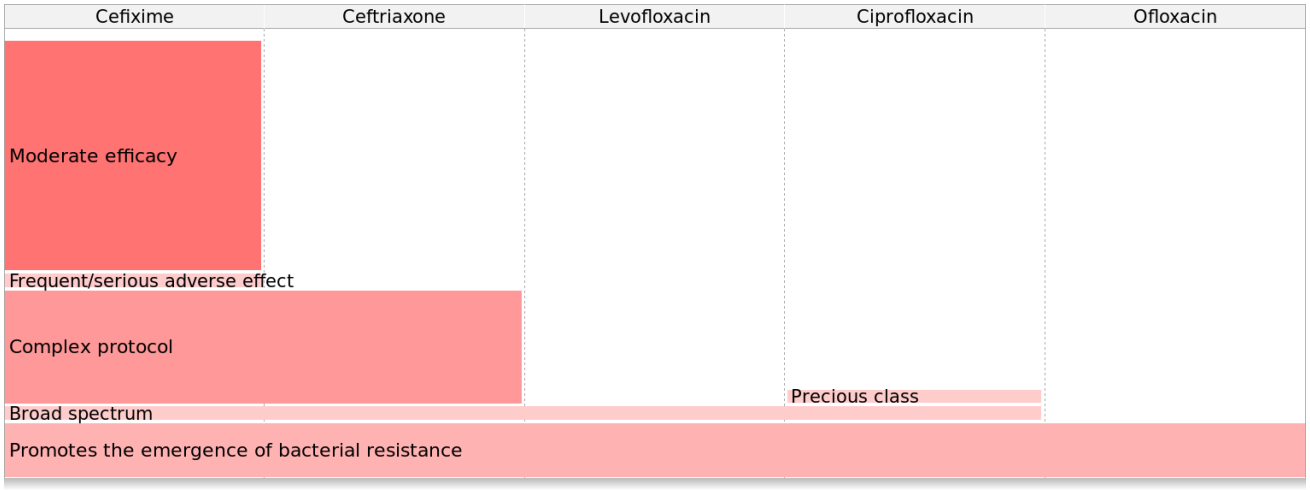
Previous works (iV 2017)

- **Visualizing an artificial neuron as sets :**
  - 1 input vector => 1 element => 1 column
  - 1 input => 1 set => 1 box

	Weight	Cefixime	Ceftriaxone	Levofloxacin	Ciprofloxacin	Ofloxacin
I_1	16.0	1	0	0	0	0
I_2	7.9	1	1	0	0	0
I_3	3.8	1	1	1	1	1
I_4	1.0	1	0	0	0	0
I_5	1.0	1	1	1	1	0
I_6	1.0	0	0	0	1	0
O		29.7	12.7	4.8	5.8	3.8



=> the vertical total height correspond to the neuron's output



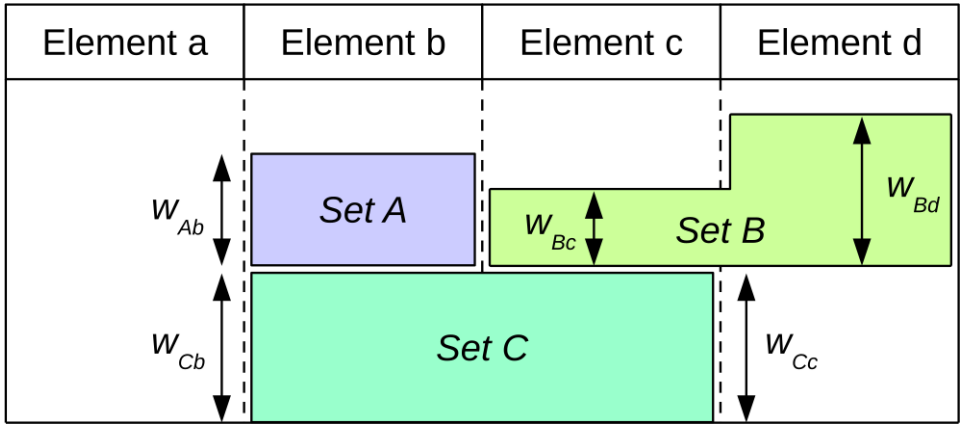
[Lamy JB et al. Translating visually the reasoning of a perceptron: the weighted rainbow boxes technique and an application in antibiotherapy. **iV** 2017]

Objectives

- **Extend this approach to simple neural networks with several outputs**
  - But no hidden level
  - With extensions to rainbow boxes :
    - Non-rectangular boxes
    - Deformable “soft” boxes
    - Interactive boxes

Non-rectangular boxes

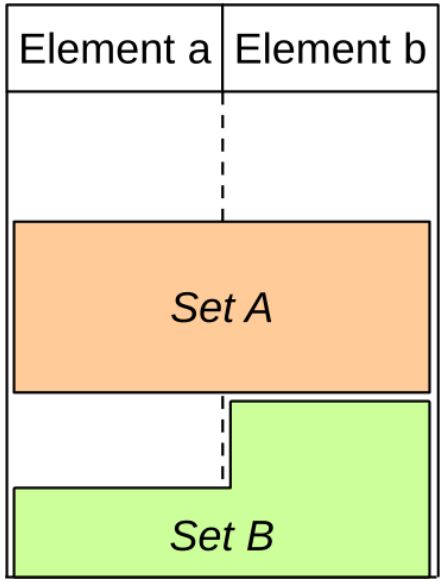
- **Non-rectangular boxes have per-column height**
  - Weights w are defined on a per-set per-element basis



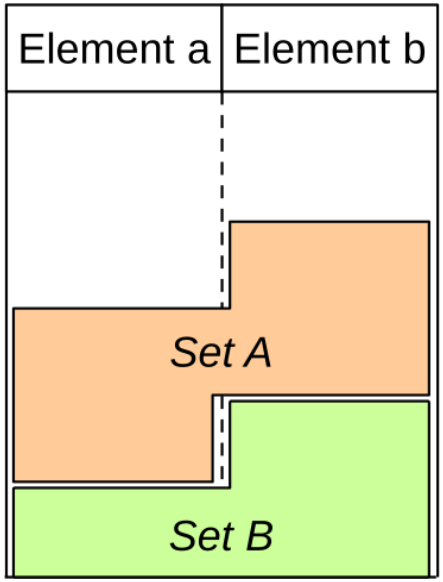
Deformable “soft” boxes

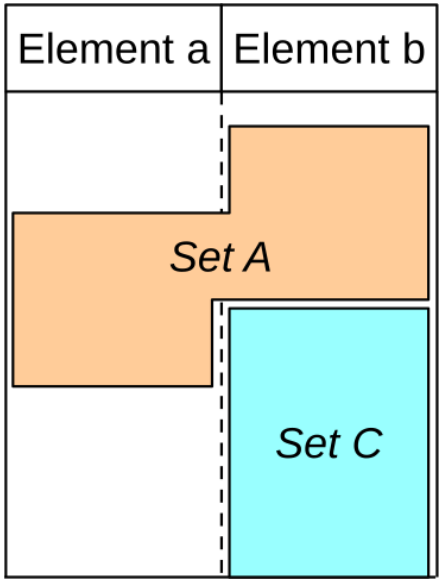
- **Deformable boxes are deformed to limit empty spaces between boxes**
  - Deformation is limited so as the box remains in a single piece
  - Facilitate the visual sum of heights when using non-rectangular boxes

Rigid boxes



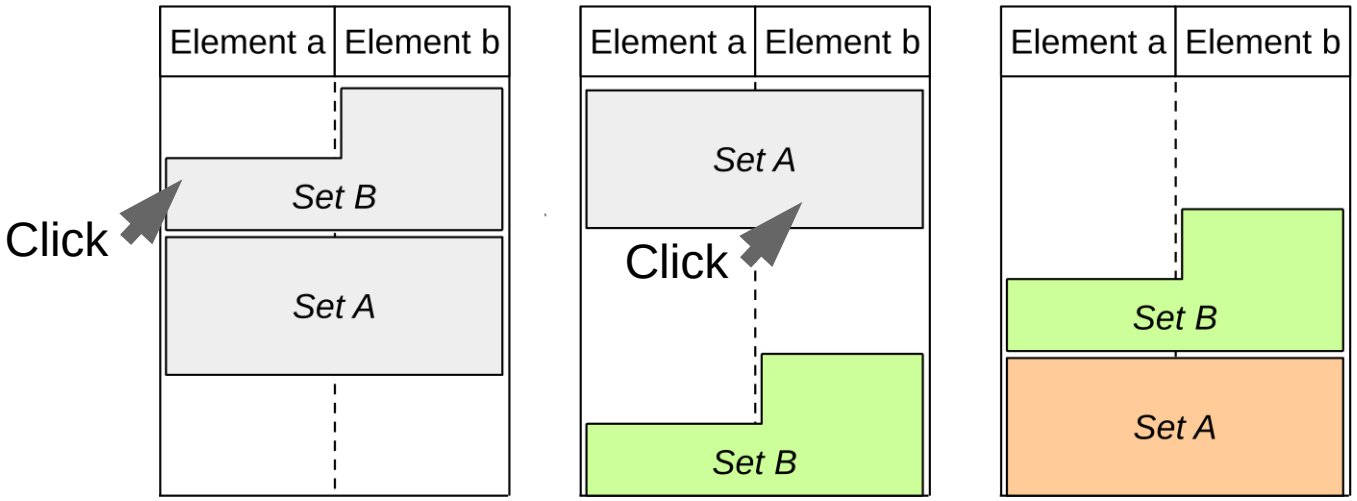
Deformable “soft” boxes





Interactive boxes

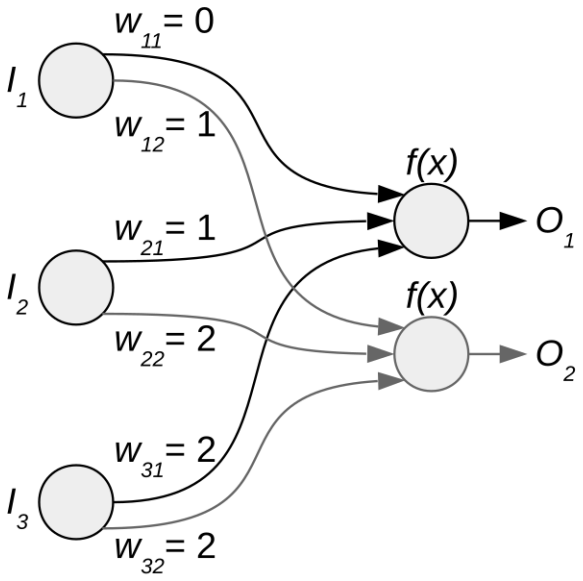
- **User interaction with boxes**
  - Boxes are unselected
    - They are grayed and they float at the top
  - The user can click an unselected box to select it
    - Selected boxes are colored and tightly stacked at the bottom
  - A second click on the select box unselect it

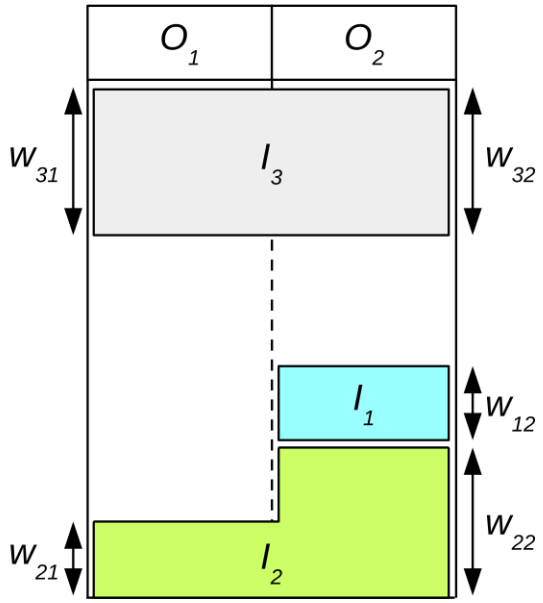


Application to simple neural networks

- **Let us consider a neural network with**
  - Boolean input
  - Positive real output
  - Positive weights
  - No bias
  - No hidden layer
  - A no-op activation function f(x) = x
- **Translation as a set visualization problem:**
  - 1 output O => 1 element => 1 column
  - 1 input I => 1 set I = { O : $w_{I,O} \neq 0$ } => 1 box

Application to simple neural networks





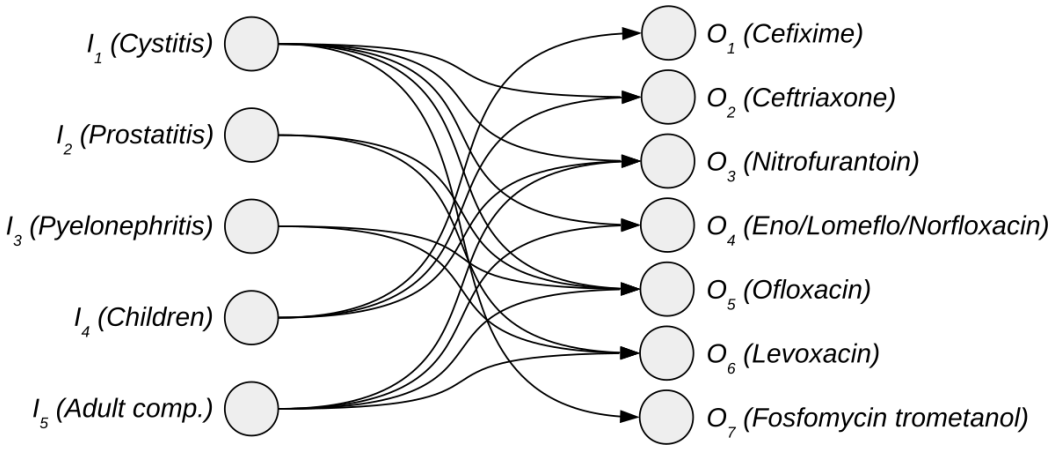
"When I_1 and I_2 are active, O_1 is 1 and O_2 is 3"

- **Translation as a set visualization problem:**
  - 1 output O => 1 element => 1 column
  - 1 input I => 1 set I = { O : $w_{I,O} \neq 0$ } => 1 box
- **Boxes are interactive:**
  - 1 activated input => 1 selected box

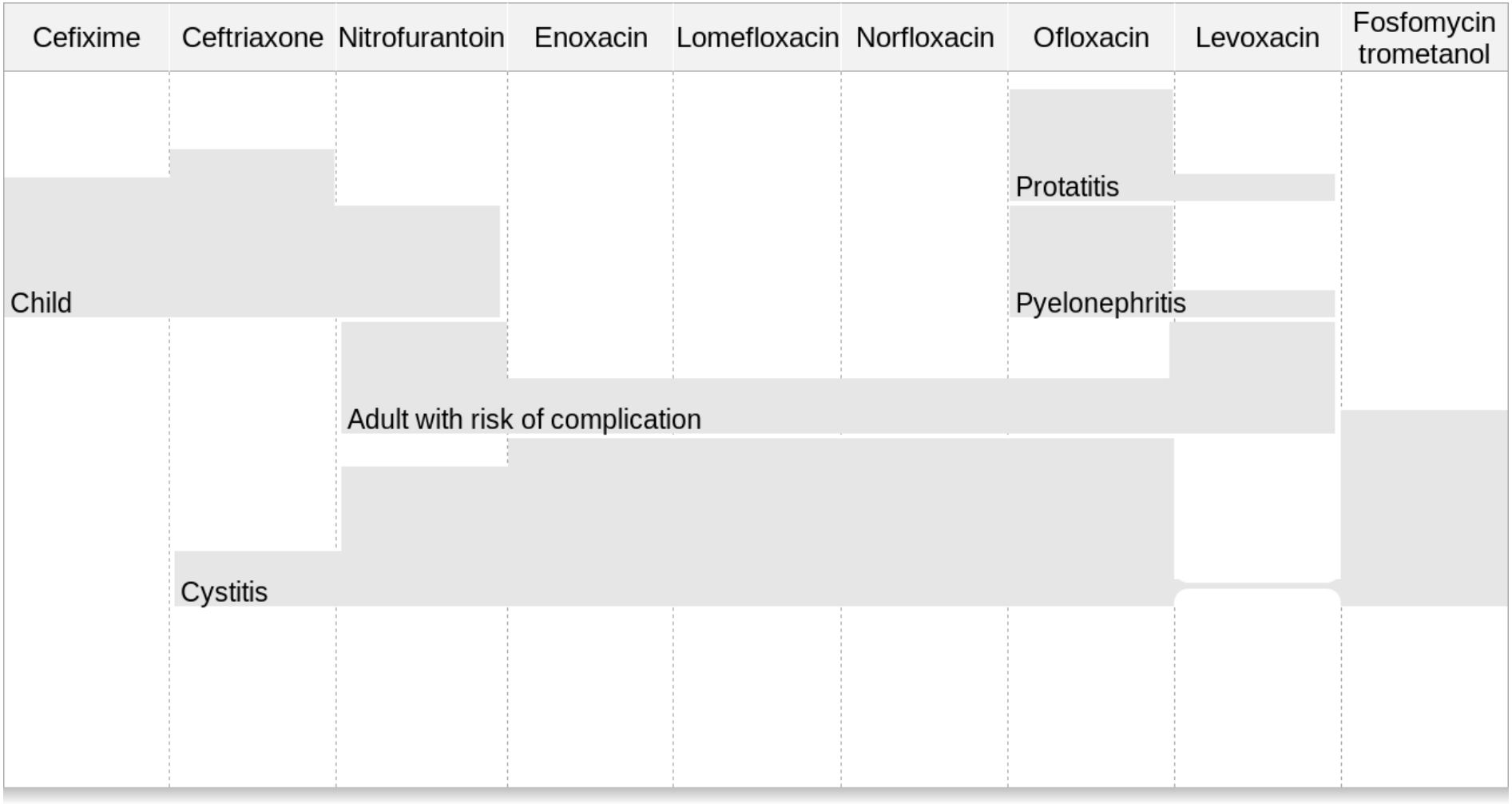
Application in antibiotherapy

- **Urinary infections in primary care**
- **Neural network produced from clinical practice guidelines**
  - Learned with the AFB metaheuristics
  - Predict the best antibiotics from the infectious disorder
    - Cystitis
    - Prostatitis
    - Pyelonephritis
  - and the patient profile
    - Children
    - Adult with complication
    - Normal adult

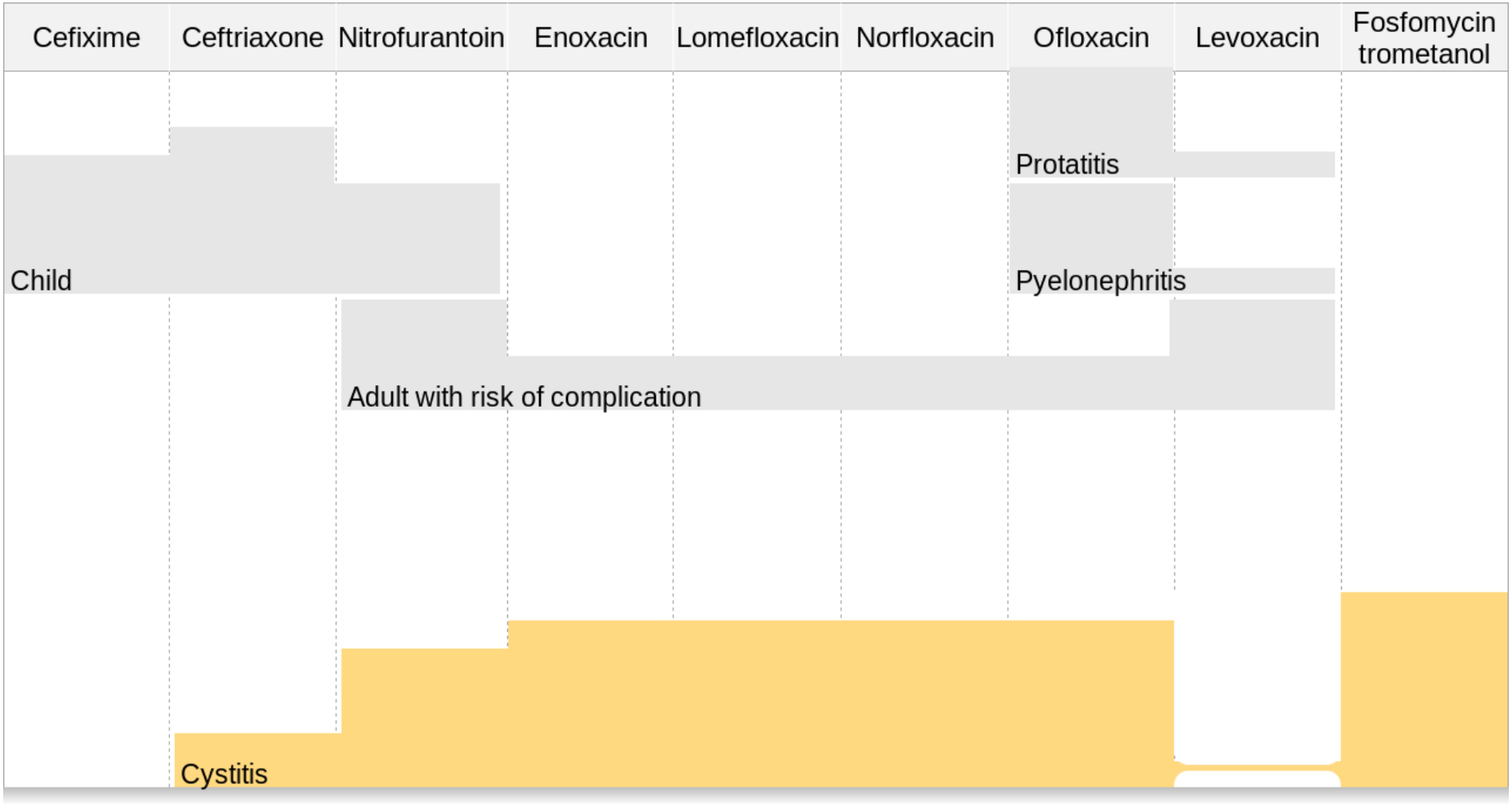
		Cefixime	Ceftriaxone	Nitrofurantoin	Eno/Lomeflo/Norfloxacin	Ofloxacin	Levoxacin	Fosfomycin trometanol
		O_1	O_2	O_3	O_4	O_5	O_6	O_7
I_1	Cystitis	0	1	5	6	6	0	7
I_2	Prostatitis	0	0	0	0	4	1	0
I_3	Pyelonephritis	0	0	0	0	4	1	0
I_4	Children	5	6	4	0	0	0	0
I_5	Adult comp.	0	0	4	2	2	4	0



Application in antibiotherapy

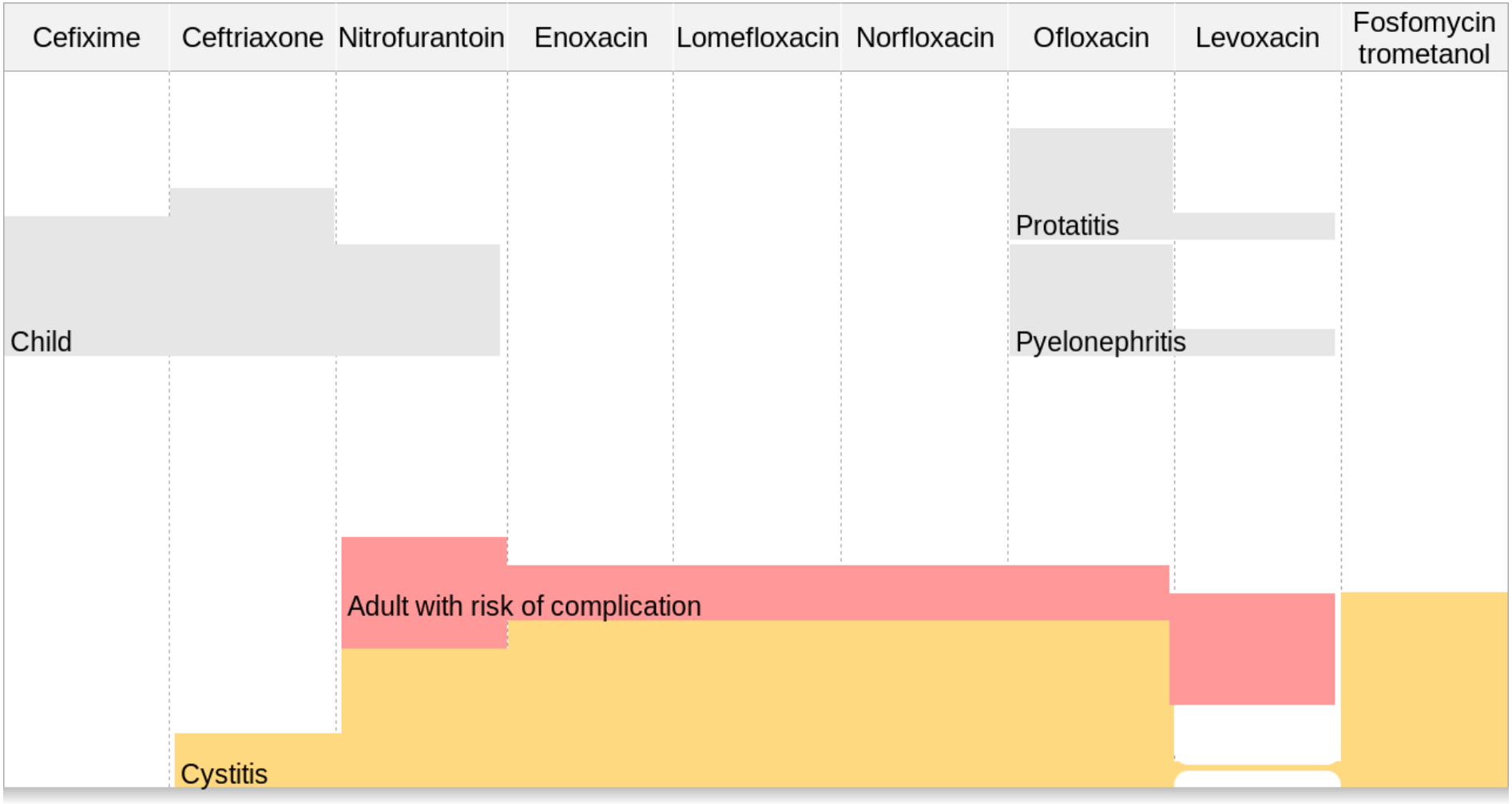


Application in antibiotherapy



Higher total box height
=> recommended drug

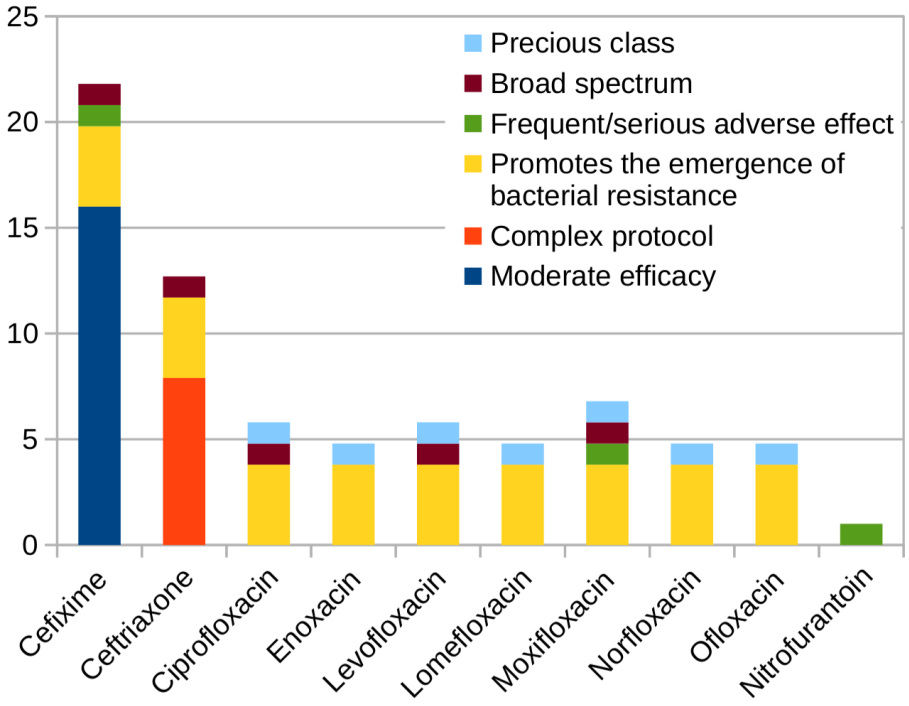
Application in antibiotherapy



Higher total box height
=> recommended drug

Discussion

- **An original approach for explainable decision support**
  - Before interacting with the system and selecting a box, the user can see the shape of the box and already know on which outputs it will act
- **Cumulative bar charts**
  - Rainbow boxes group similar columns together => simpler visualization
  - Labels are directly in the boxes => no need for key, remove one level of indirection



- **Perspectives**
  - Evaluate the proposed approach
  - Extend it to bigger and more complex neural networks
    - One hidden level
  - Explore the possibility to let the user adjust the height of boxes

References

Hohman FM, Kahng M, Pienta R, Chau DH, Visual Analytics in Deep Learning: An Interrogative Survey for the Next Frontiers. IEEE transactions on visualization and computer graphics 2019

Lamy JB, Berthelot H, Capron C, Favre M. Rainbow boxes: a new technique for overlapping set visualization and two applications in the biomedical domain. Journal of Visual Language and Computing 2017;43:71-82

Lamy JB, Tsopra R. Translating visually the reasoning of a perceptron: the weighted rainbow boxes technique and an application in antibiotherapy. International Conference Information Visualisation (iV) 2017;:256-261

Lamy JB, Tsopra R. RainBio: Proportional visualization of large sets in biology. IEEE Transactions on Visualisation and Computer Graphics 2019