Teaching the Art of Computer Programming at a Distance by Generating Dialogues using Deep Neural Networks

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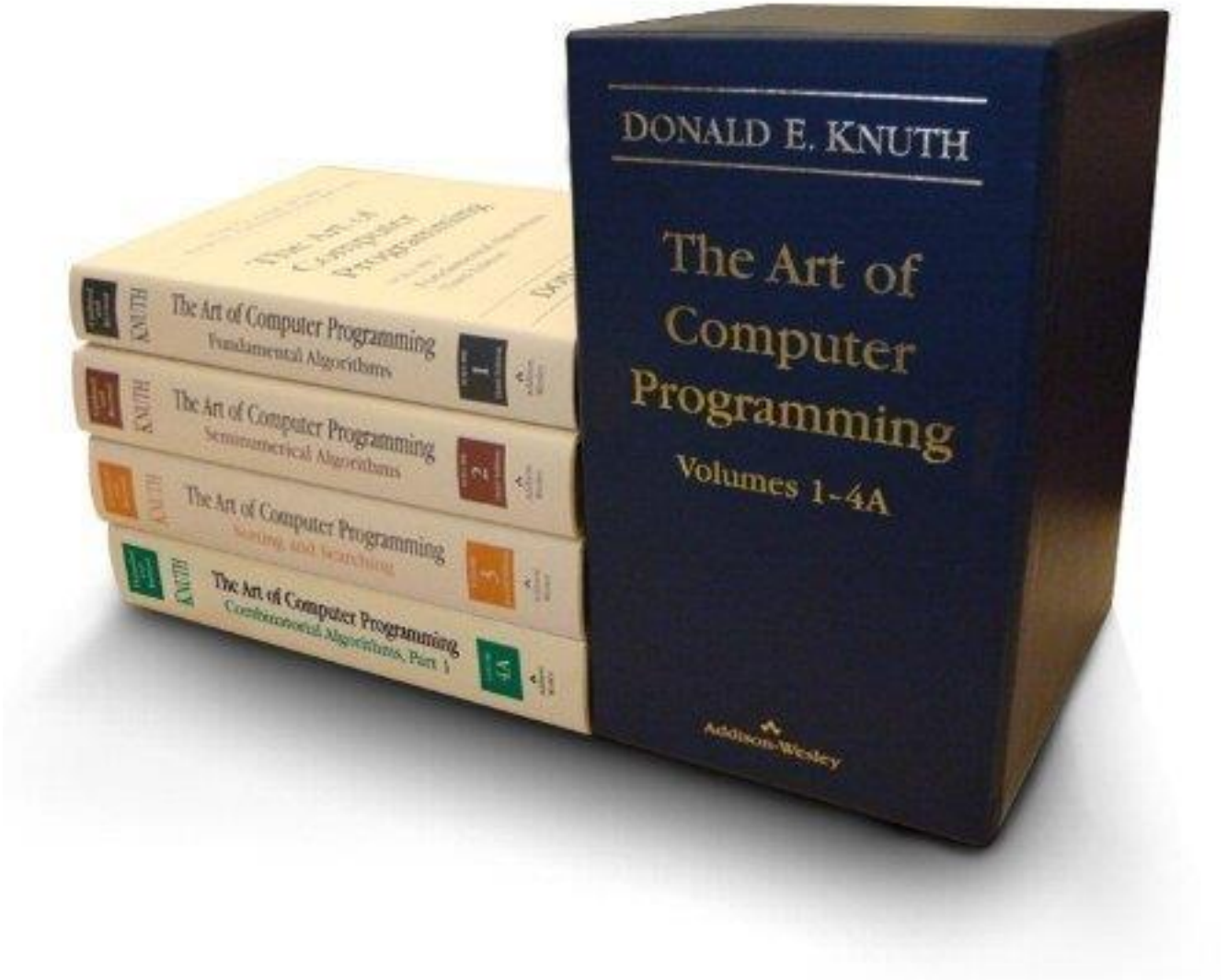
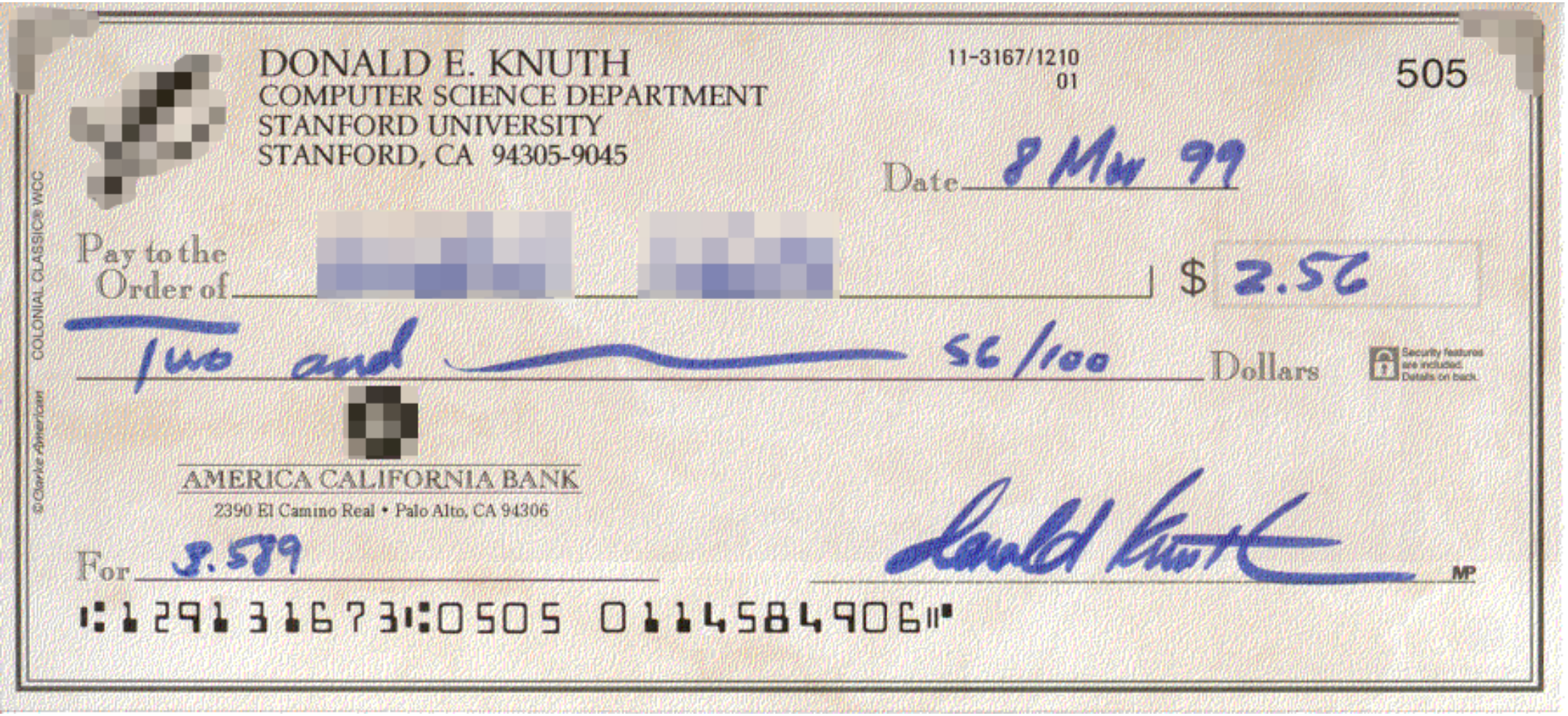
November 6, 2019 @ Convention Centre Dublin, Ireland
28th ICDE - World Conference on Online Learning

The Art of Computer Programming



Finding an error in a Knuth text.

Stupidity: Cashing that $2.56 check you got.



Algorithms

Program S (*Straight insertion sort*). The records to be sorted are in locations INPUT+1 through INPUT+N; they are sorted in place in the same area, on a full-word key. rI1 $\equiv j - N$; rI2 $\equiv i$; rA $\equiv R \equiv K$; assume that $N \geq 2$.

01	START	ENT1	2-N	1	S1. Loop on j. $j \leftarrow 2$.
02	2H	LDA	INPUT+N,1	$N-1$	S2. Set up i, K, R.
03		ENT2	N-1,1	$N-1$	$i \leftarrow j-1$.
04	3H	CMPA	INPUT,2	$B+N-1-A$	S3. Compare $K : K_i$.
05		JGE	5F	$B+N-1-A$	To S5 if $K \geq K_i$.
06	4H	LDX	INPUT,2	B	S4. Move R_i, decrease i.
07		STX	INPUT+1,2	B	$R_{i+1} \leftarrow R_i$.
08		DEC2	1	B	$i \leftarrow i-1$.
09		J2P	3B	B	To S3 if $i > 0$.
10	5H	STA	INPUT+1,2	$N-1$	S5. R into R_{i+1}.
11		INC1	1	$N-1$	
12		J1NP	2B	$N-1$	$2 \leq j \leq N$. ∎

Teaching Java at a distance

Pedagogy of The Open University module M250

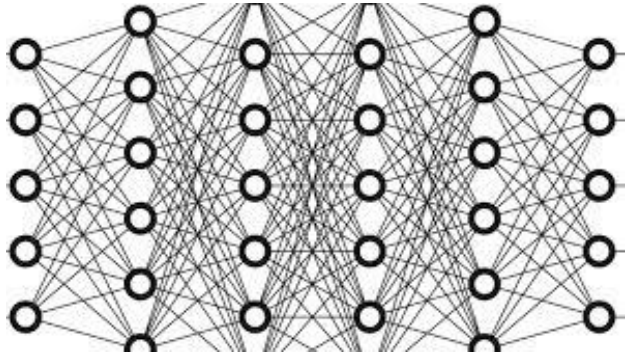
- 2nd year flagship undergraduate module at the School of Computing and Communications
- 1400 students per presentation
- Unique challenges and traditional distance teaching approaches
  - Recruit at least 1 associated lecturer per 20 students
  - Tutoring is mostly done through online materials, but also through face to face consultations
  - Tutor Marked Assignments (TMAs) and close book Exams
  - Interactive Computer Marked Assignments (iCMA)

An algorithm in Java

```
1  public static void insertionSort()
2
3      {
4      int i = 1;
5
6      while
7
8          (i < arr.length)
9      {
10         int j = i;
11         while
12
13         (j > 0)
14         {
15         if (arr[j].key < arr[j-1].key)
16         {
17             InsertionSortNode tmp = arr[j];
18             arr[j] = arr[j-1];
19             arr[j-1] = tmp;
20         }
21         j = j - 1;
22         }
23         i = i + 1;
24     }
25     }
26
27
```

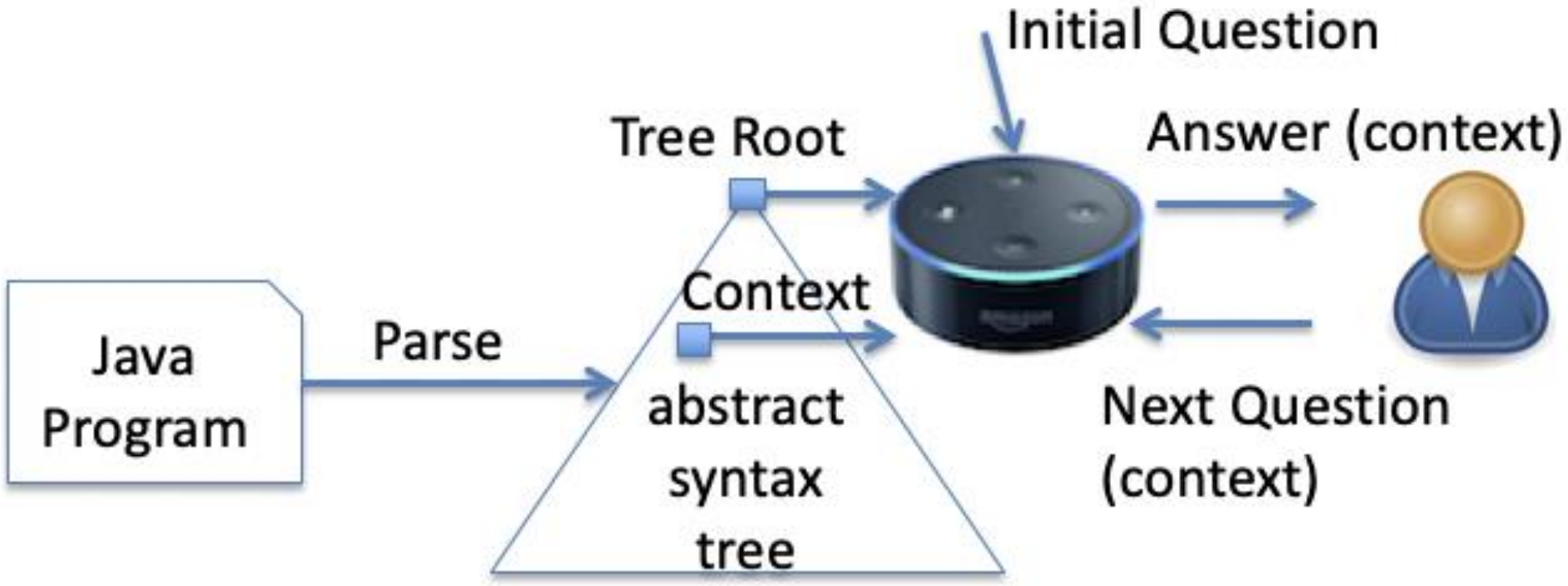
The needs for AI

- Neural Networks
  - Image classification (convolutional)
  - Recurrent NN
  - Reinforced Learning
  - …



- Unique challenges
  - Unlike natural languages, algorithms are structured
  - Algorithms are agnostic to programming languages
  - They are more germane to the machine, i.e., assembler
  - Students still need to learn in a natural way

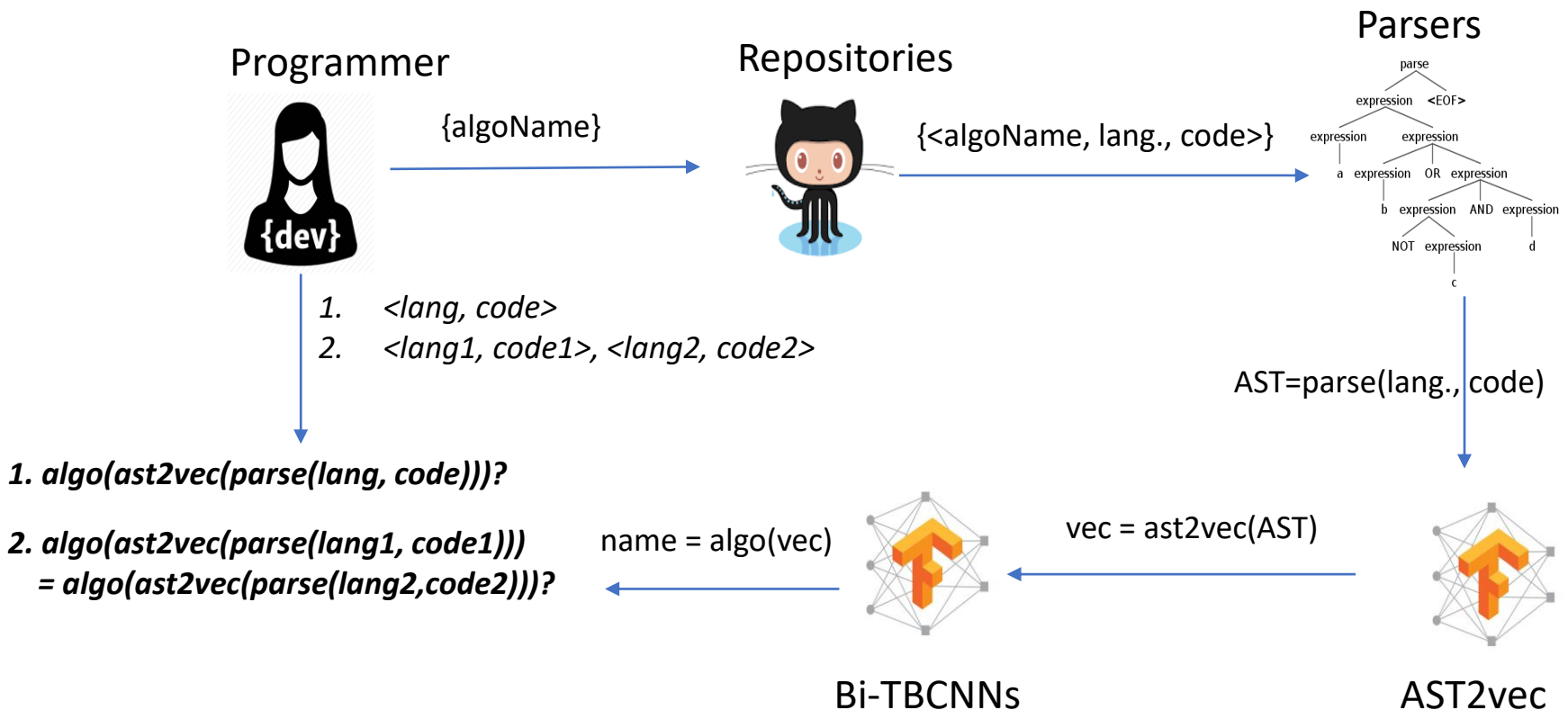
Overview: Dialogues with Echo



Knowledge Representation for Code

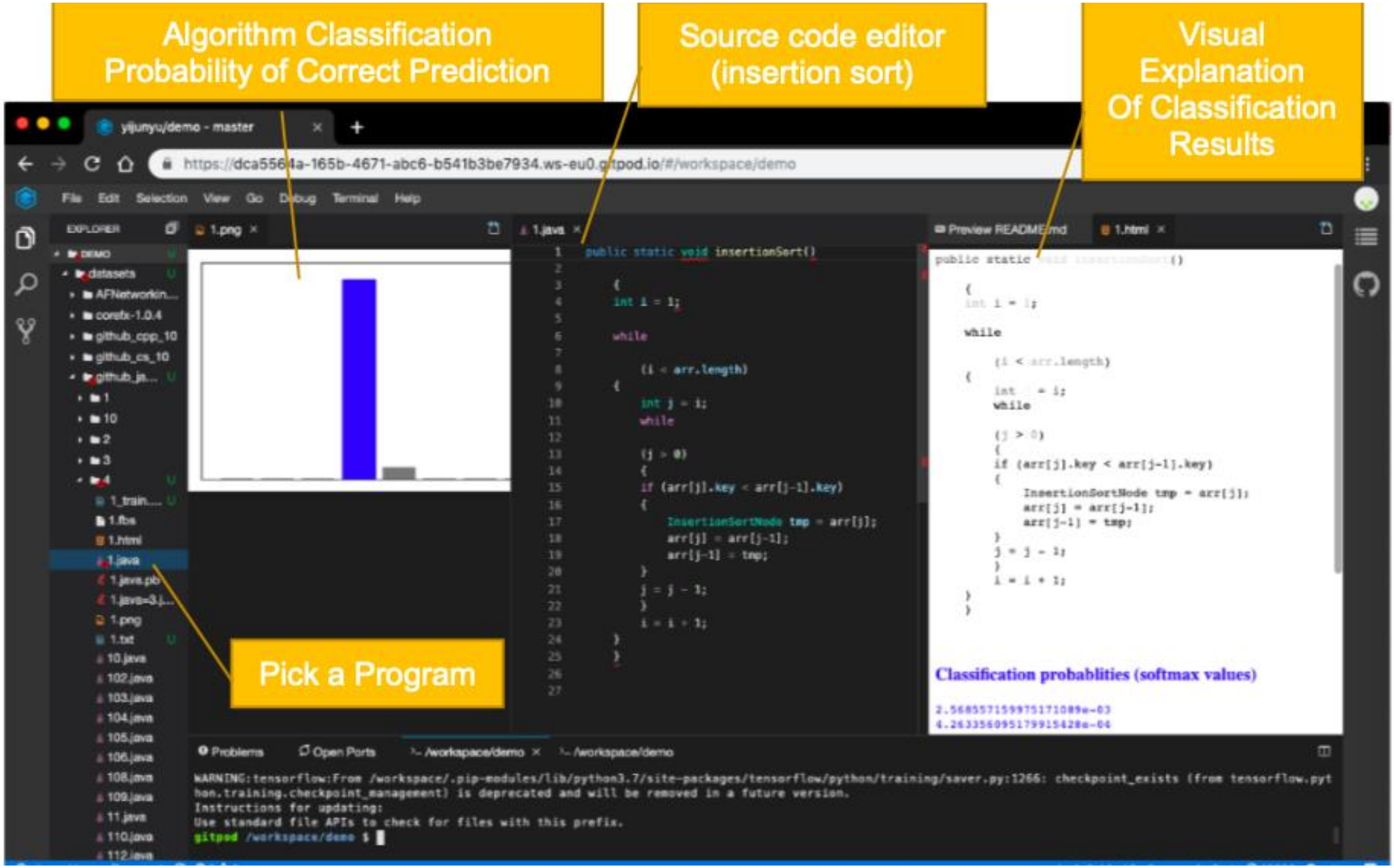
- What are the key features of an algorithm
  - Abstract Syntax Trees
  - Dependence Graphs
  - Def-Use chains
- What are not key features
  - Exact names of variables/methods
- Suitable representations
  - Tree-based Convolution Neural Networks [AAAI'16]
  - Gated Graph Neural Networks [SANER'19]
  - Tree Capsules Networks [FSE'19]

The Machine Learning Process



https://github.com/yijunyu/bi-tbcnn

https://github.com/yijunyu/demo



Conclusions and Future work

- Summary
  - With student's *unstructured* inputs and the underlying **structured** knowledge representations, NNs are effective in generating dialogues with *unstructured* outputs.
  - Dialogues can take different forms:
    - An Interactive Visual Programming Environment [ICSE'19]
    - Structured Arguments [JSS'15]
    - Chatbots [EPSRC Johnny project]
- Future work
  - iCMA replacement with smarter feedback (M250)
  - Evaluation with the examinable components, i.e. automated marking, using Generative Adversarial Networks [FSE'19]

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