Teaching-learning algorithms in technologically and artistically enhanced interactive environments

Zoltán KÁTAI
SAPIENTIA University

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“Transylvanian algorithmic dance”

DEMO

Overview

- educational principles
- 1. study: on the role of senses
- 2. study: including the kinesthetic sense
- 3. study: dancing algorithms
- 4. study: humanities vs. science
- 5. study: selective hiding
- 6. study: intercultural informatics education

<<<artistically enhanced interactive e-learning environment>>>

Multi-Sensory informatics education

- 2006 – 2016
- 2013: Informatics Europe
  - Best Practices in Education Award

Guidelines

- Informatics Europe & ACM Europe Working Group on Informatics Education
  - Computational thinking is an important ability that all people should possess
  - Informatics-based concepts, abilities and skills are teachable, and must be included in the primary and particularly in the secondary school curriculum

More senses more efficient learning

- More senses – more information
- Different students – different dominant senses
- Different students – different “intelligences”
- Multiple-senses – more pathways of locating the stored information
- Multiple-senses – distributed loading
- Combined senses – more efficient learning process

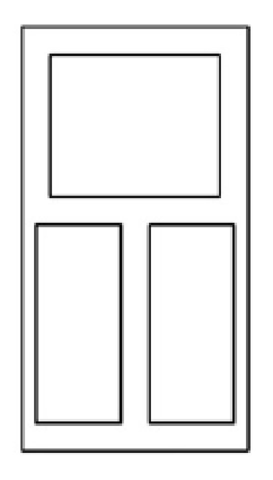
Increasing student motivation

- Purposeful focus on arousing and sustaining students' motivation
  - Principle of genuine active involvement
  - Principle of moderate progressive challenge
  - Principle of gradual shift from concrete to abstract.

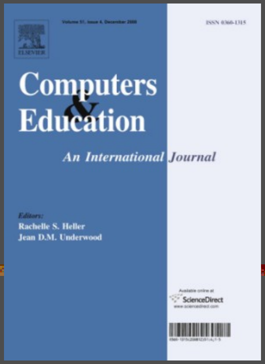
1. Learning elementary algorithms

- Seeing, hearing and feeling the pulsation of the algorithms
  - loudspeaker for the loop skeletons
  - drumming the loop skeleton in

```
loop
    loop
    end loop
    if <condition> then
        loop
        end loop
    else
        loop
        end loop
    end if
end loop
```

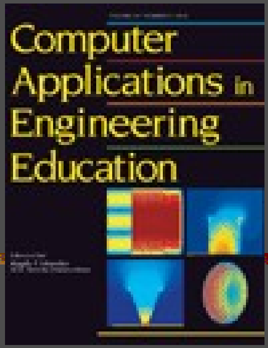


do fa_fa_fa__fa_fa_fa_fa_fa do fa_fa_fa__fa*_fa*_fa*_fa*



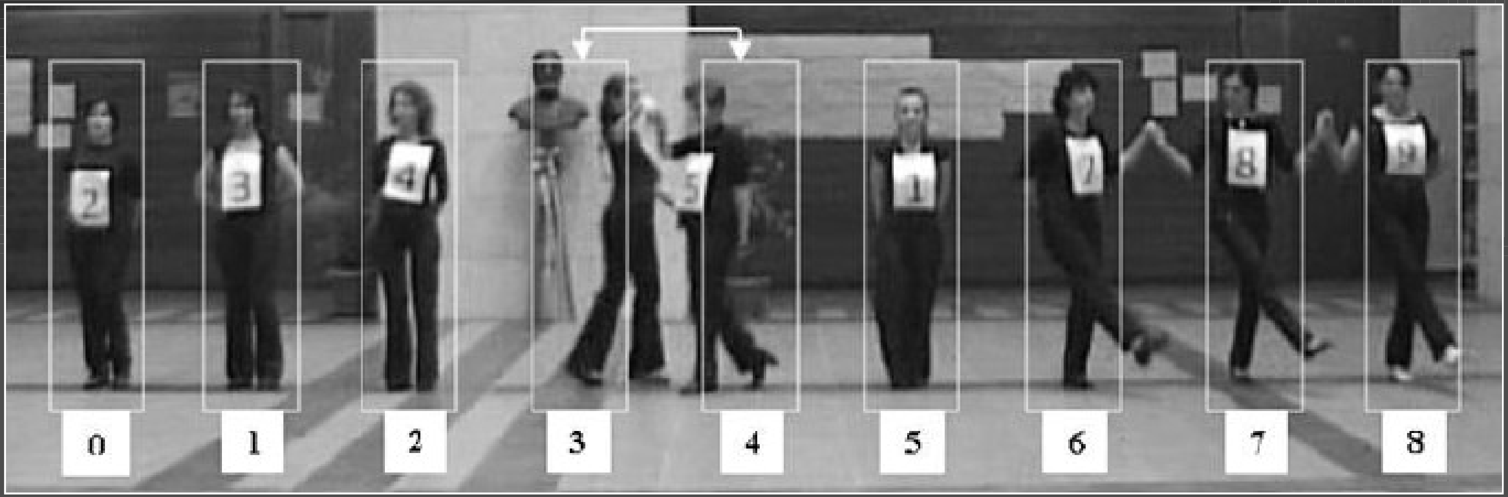
2. Teaching-learning recursion

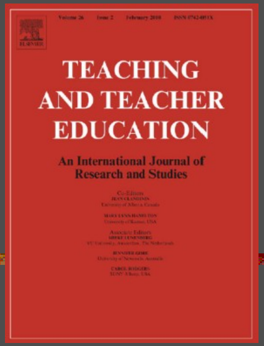
- Students are invited to play "recursive scenarios"
  - exploring visual, auditory and kinaesthetic senses
  - the application generates "the melody line" of the recursive procedures/functions



3. Learning sorting algorithms

- Additional multi-sensory elements through arts
  - dance, music, rhythm, theatrical role-playing





Intercultural informatics education

Quick-sort with “kükülőmenti legényes”

I PROGRAMMER

DEMO

We wait patiently for the Quicksort but still don't think it is danceable....

Yes I know I claimed that it would be impossible, or if possible the result would be a modern dance the like of which we have not seen, but.... they have done it.

… here is the ingenious culmination - the Quicksort, the most difficult of algorithms, complete with hats as pointers.

youtube.com/user/AlgoRythmics (2011-16)

- Feedback (218 countries)
  - views: 3,706,792
  - likes: 26,023
  - SHAREs: 13,821

- Hundreds of times: ‘like’ ‘awesome’ ‘great’ ‘best’ ‘nice’ ‘brilliant’ ‘love’ ‘epic’ ‘cool’ ‘amazing’ ‘excellent’ ‘fantastic’

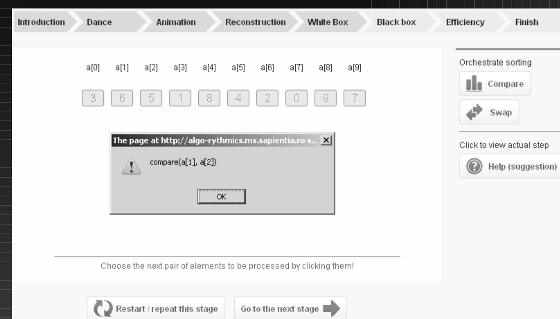
Recent comments

- This has got to be the greatest math’s lesson I’ve ever had!
- I've never enjoyed studying for finals more… I wish my teacher had used this in class.
- This is awesome! Make me want to go implement Quick-sort in every language I know even a little bit.
- The only true international language!
- Who said programming is boring?
- Showed it to the kids and they loved it!

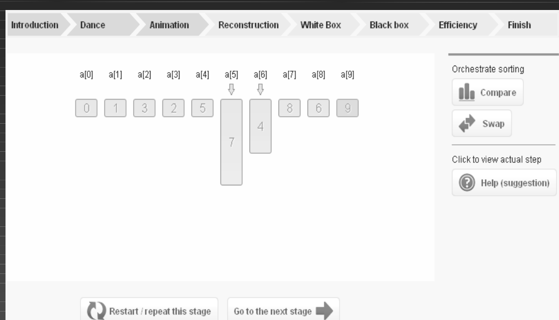
Online e-learning environment

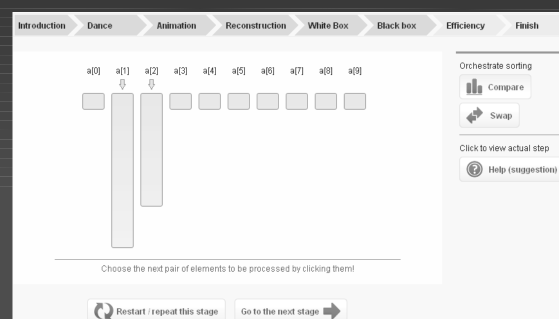
http://algo-rythmics.ms.sapientia.ro/

White-box task

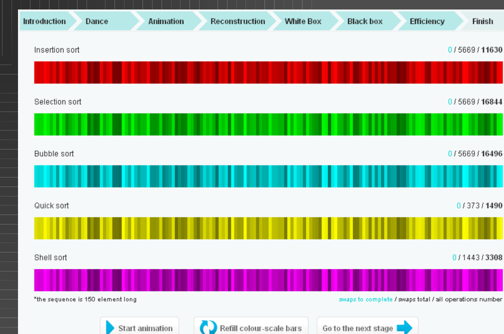


Animation





Black-box task



Simulation

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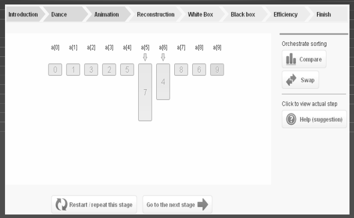
Implemented educational principles

- Generating and sustaining motivation
  - surprising science-art and modern-traditional combinations
  - moderate-progressive challenge
  - genuine active involvement
- Balanced involvement of both sides (academic/artistic) of the brain
- Sequenced multiple representations (gradual shift from concrete to abstract)
  - dancer / white-box / black-box sequences

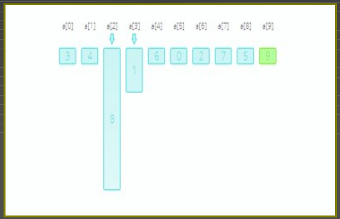
4. The challenge of promoting algorithmic thinking of both sciences and humanities oriented learners

- THE “TWO CULTURES”
  - Efficient learning environment for *both* learning communities
- EXPERIMENT
  - Participants:
  - 25 sciences oriented students
  - 23 humanities oriented students

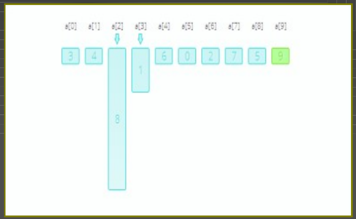
Illustration



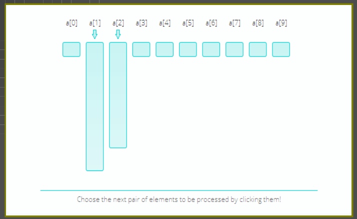
Animation



Reconstructing

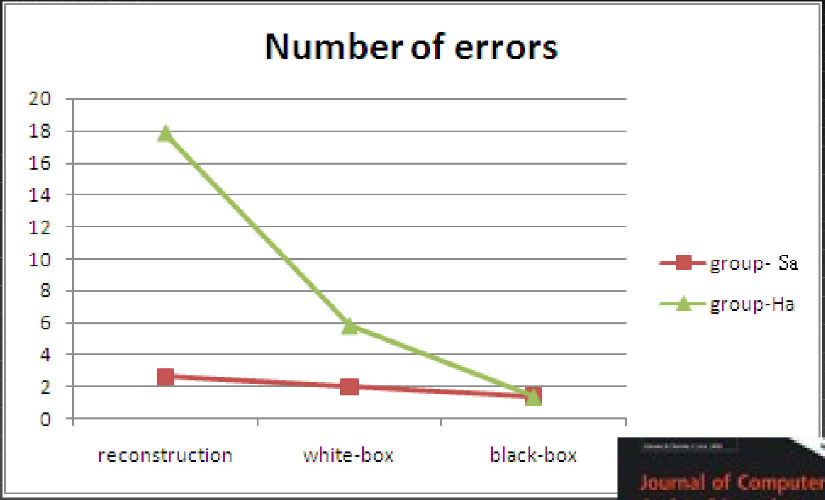


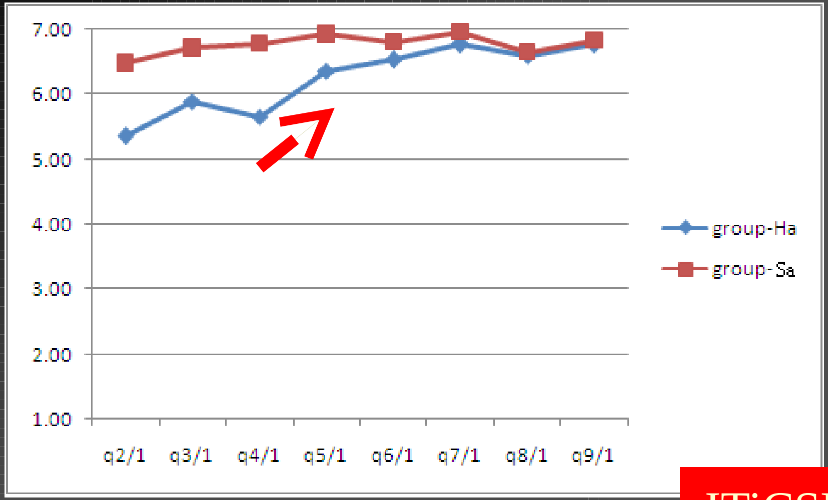
Orchestrating: white-box



Orchestrating: black-box

Results and Conclusions





ITiCSE

questionnaires to detect student motivation

5. Teaching "Not Blind Learners" to Program "Blind Computers"

- Compared to humans, computers are blind in many ways
  - Visualizing information that has extra meanings for learners
  - Difficult to follow a strict computer algorithm
- Potential side-effects of substituting "blind computers" with "not blind humans"

Selective Hiding for Improved Algorithmic Visualization

- Research questions:
  - Could it happen that information that might have extra meanings for human viewers obstructs them in following strict computer algorithms?
  - skip the explicit comparing operation if the current element-pair had to be swapped
  - omit to deal with the next element-pair if these are in the right order
  - Can wisely applied hiding result in more effective algorithm visualization?

Procedure

- “Listen to It” (A+B)
  - briefly: what a sorting algorithm means?
- “Watch It (A+B)
  - folk-dance illustration + computer animation
- “Try It”
  - (A) to orchestrate the algorithm on a random sequence stored in a white-array
  - (B) to orchestrate the algorithm on a random sequence stored in a black-array

RESULTS AND DISCUSSION (1)

	Time /step	Help	Errors	WPN	WAS		WPS	
					C	S	C	S
A	5.05	1.58	9.6	1.48	1.42	0.62	5.32	0.76
B	4.15	1.19	5.56	1	0.52	0.47	2.53	1.02
p	**0.002**	0.34	**0.009**	0.1	**0.0002**	0.24	**0.006**	0.28

RESULTS AND DISCUSSION (2)

	WPN	WAS		WPS	
		C	S	C	S
A	1.48	1.42	0.62	5.32	0.76
B	1	0.52	0.47	2.53	1.02
p	0.1	**0.0002**	0.24	**0.006**	0.28

1. Correct next element-pair / Incorrect operation
   a) S in place of C
   b) C in place of S
2. Wrong element-pair was selected when the next operation had to be
   a) C
   b) S

RESULTS AND DISCUSSION (3)

	Time/ step	Hel p	Errors
A	5.05	1.5 8	9.6
B	4.15	1.1 9	5.56
p	**0.002**	0.34	**0.009**

- Time/step:
  - less distracting factors
  - focusing on the sorting strategy

CONCLUSIONS

- Students working on white-arrays had significantly more problems with comparing operations than those who had to sort invisible sequences
  - They skipped more frequently comparing operations
- A plausible explanation
  - Students who saw the numbers performed the comparing operation in their mind, implicitly
  - Students who did not see the numbers were forced to explicitly perform the comparing operations

Same phenomenon in other circumstances

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“Too much visualized information can be harmful”

- From the perspective of epistemic fidelity theory:
  1. Invisibility could contribute to higher epistemic fidelity
  2. Wisely applied hiding results in higher epistemic fidelity especially when learners are substituting computers in their algorithm processer role
  3. High epistemic fidelity AV systems supports not blind learners in identifying with blind-computer

6. Intercultural Computer Science Education

- Key players in the twenty-first century
  - Inter- and Multi-cultural Education (IcE, McE)
  - Computer Science (CS) and Computer Science Education (CSE)

Intercultural Computer Science Education

- Pioneering initiative
  - Current literature lacks studies that address CSE from the perspective of IcE.

- In this study we propose to investigate whether students' ethnic background might influence (or perturb) their approach to the scientific content in terms of the cultural frame (context) in which it is presented.

Intercultural Computer Science Education

- Transylvania (Romania)
  - Romanian, Hungarian, German, Gipsy, etc
  - “Opposite cultures”: Romanian and Hungarian
  - Mono-, bi- and multicultural educational institutions
- The core research question
  - How might the existing cultural concepts held by students (from mono- and bi-cultural institutions) affect their appreciation of sorting algorithms presented in a cultural context different to their own?

Participants

- Ninety-six 9th grade novice computer science students
  - School_1: **31** Romanian students, group **monoRO**
  - School_2: **21** Hungarian students, **group monoHU**
  - School_3:
  - **18** Romanian students, **group biRO**
  - **26** Hungarian students, **group biHU**

  - After: introduced to programming
  - Before: studying sorting algorithms

Procedure

"I liked this algorithm-dance show" (1: Strongly disagree … 7: Strongly agree)

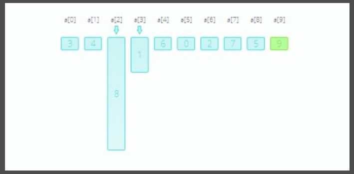
DEMO

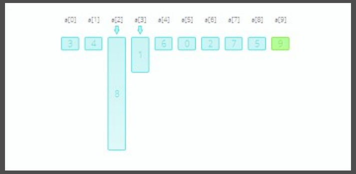
DEMO

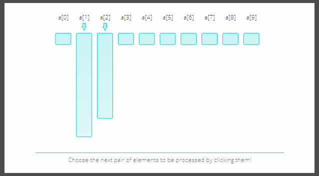
"Which algorithm performed the sorting-task **most efficiently**? GIPSY / ROMANIAN / HUNGARIAN"

"Which algorithm performed the sorting-task **most efficiently**? BUBBLE-sort / SELECTION-sort / INSERTION-sort"

The easiest one: "Selection-sort with GIPSY folk-dance / Insertion-sort with ROMANIAN folk-dance / Bubble-sort with HUNGARIAN folk-dance"







RESULTS AND DISCUSSION

Response scores with respect to the algorithm-dance shows

	Gipsy	Romanian	Hungarian
RO	5,24	5,65	5,16
HU	5,45	5,40	5,96
monoRO	5,23	5,55	5,58
monoHU	5,10	5,43	5,43
biRO	5,28	5,83	4,44
biHU	5,73	5,38	6,38

Most efficient algorithm – Culture

- Coding
  - 1: “Own” – most efficient
  - -1: “Opposite” – most efficient
  - 0: “Neutral” – most efficient
- Means
  - monoRO: [0] 11(own), 11(opposite), 9(neutral)
  - monoHU: [-0.04] 9(own), 10(opposite), 2(neutral)
  - biRO: [0.72] 14(own), 1(opposite), 3(neutral)
  - biHU: [0.42] 16(own), 5(opposite), 5(neutral)

Most easiest algorithm – Culture

- Coding
  - 1: “Own” – most easiest
  - -1: “Opposite” – most easiest
  - 0: “Neutral” – most easiest
- Means
  - monoRO: [-0.09] 11(own), 14(opposite), 6(neutral)
  - monoHU: [-0.04] 7(own), 8(opposite), 6(neutral)
  - biRO: [0.61] 12(own), 1(opposite), 5(neutral)
  - biHU: [0.19] 12(own), 7(opposite), 7(neutral)

Performance results

- Comparing students' **performance results** with respect to their white/black-box tasks we did not find any significant differences.
  - mono-bi
  - monoRO-biRO
  - monoHU-biHU
  - boys-girls

CONCLUSIONS

- Research results
  - students’ culture related concepts and feelings may even influence the way they relate to the scientific content
  - The bi-cultural character of an educational institution does not promote ethno-relativism implicitly
  - It can polarize differences
  - The mono-cultural character of an educational institution does not promote ethno-centrism implicitly
- Carefully designed IcCSE could have potential to move students from ethnocentrism to ethnorelativism

FUTURE PLANS

- Other topics
  - searching algorithms (linear/binary)
  - parallel algorithms (merge/quick-sort)
  - to illustrate programming strategies
  - greedy, backtracking, dynamic programming, etc.
  - bicultural merge-sort

BBC Documentary

Thank you for your attention