Exploiting Puzzle Diversity in Puzzle Selection for ESP-like GWAP Systems

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GWAP = Games with a Purpose

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ESP Game - the 1st GWAP system

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PLAYER 1

PLAYER 2

ESP Game - the 1st GWAP system

PLAYER 1

PLAYER 2

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PLAYER 1

GUESSING: CAR

GUESSING: HAT

GUESSING: KID

PLAYER 2

ESP Game - the 1st GWAP system

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PLAYER 2

GUESSING: BOY

GUESSING: CAR

ESP Game - the 1st GWAP system

PLAYER 1

GUESSING: CAR

GUESSING: HAT

GUESSING: KID

PLAYER 2

GUESSING: BOY

GUESSING: CAR

Agreement reached: ***CAR***

Why is it important?

- Some statistics (July 2008)
  - 200,000+ players have contributed 50+ million labels.
  - Each player plays for a total of 91 minutes.
  - The throughput is about 233 labels/player/hour (i.e., one label every 15 seconds)

- Google bought a license to create its own version of the game in 2006 (called *Google Image Labeler*).

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  - Motivate people to play voluntarily
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- ***Question: how to evaluate the performance of GWAP systems?***

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- In [14], we formulated the problem as a variant of classic scheduling problems, and proposed an *Optimal Puzzle Selection Algorithm* (OPSA).

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- It does not consider the *puzzle diversity* (some puzzles are more productive, and some are hard to solve), which may result in the *equality of outcomes* problem.

Contribution

- Using realistic game traces, we identify the *puzzle diversity* issue in ESP-like GWAP systems.
- We propose the *Adaptive Puzzle Selection Algorithm* (APSA) to cope with puzzle diversity by promoting *equality of opportunity*.
- We propose the *Weight Sum Tree* (WST) to reduce the computational complexity and facilitate the implementation of APSA in real-world systems.
- We show that APSA is more effective than OPSA in terms of the number of agreements reached and the system gain.

Adaptive Puzzle Selection Algorithm

- APSA is inspired by the *Additive Increase Multiplicative Decrease* (AIMD) model of *Transmission Control Protocol* (TCP).

- APSA selects a puzzle to play based on a weighted value w_k, and the probability that the k-th puzzle will be selected is $p_k = \frac{w_k}{\sum_{i=1}^{K} w_i}$

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$$w_k = \begin{cases} 1 & \text{the initial value,} \\ w_k + 1 & \text{if agreements are reached,} \\ \frac{w_k}{2} & \text{if no agreements are reached.} \end{cases}$$

The more productive a puzzle is, the higher probability it will be selected in the next game round.

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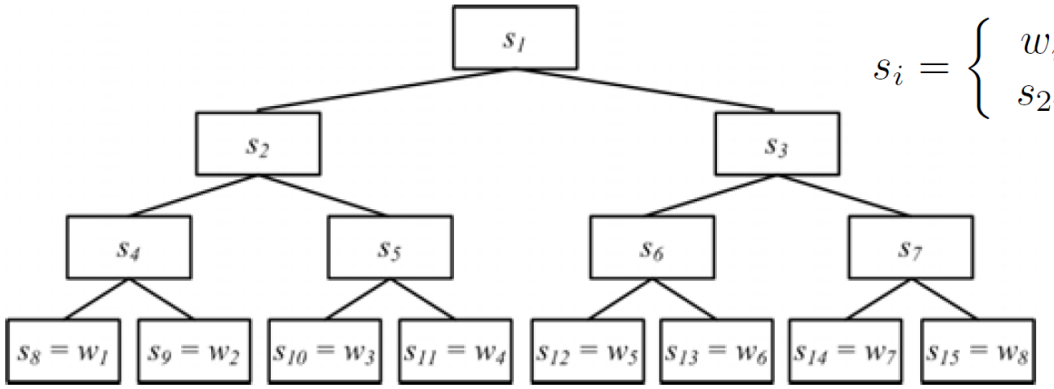
K = 8

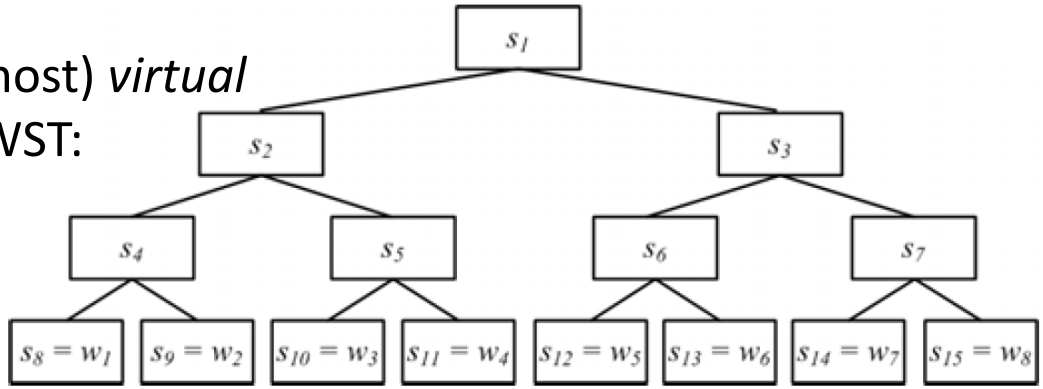


$$s_i = \begin{cases} w_{i-2^{h-1}+1} & \text{, when } 2^{h-1} \le i < 2^h; \\ s_{2i} + s_{2i+1} & \text{, when } 0 < i < 2^{h-1}. \end{cases}$$

s_i: the *i-th* node in the tree
h: the height of the tree

Implementation Method (2/3)

- Three cases to maintain the WST
  - After the *k-th* puzzle is played in a game round
    - Update the w_k and its ancestors: *O(logK)*
  - After a puzzle has been removed (say, the k-th puzzle)
    - Set the w_k to 0 (to become a *virtual puzzle*): *O(logK)*
  - After adding a new puzzle (say, the k-th puzzle)
    - Set the w_k to 1
    - Replace the first (leftmost) *virtual puzzle* or rebuild the WST: *O(logK) or O(K)*



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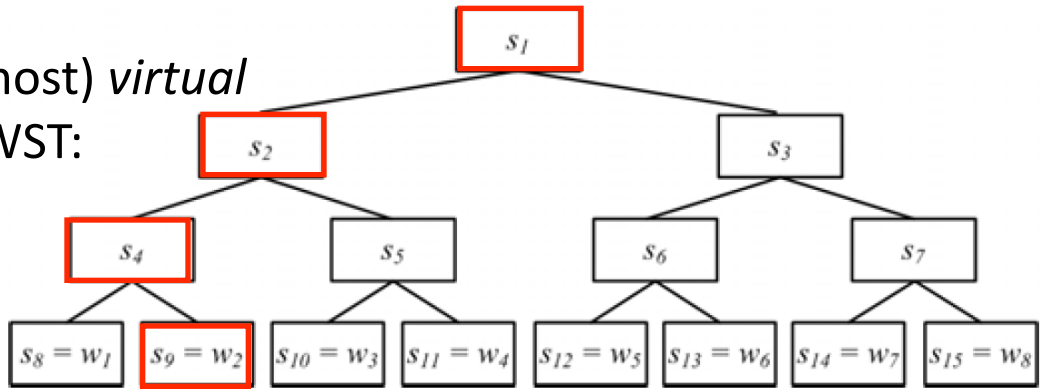
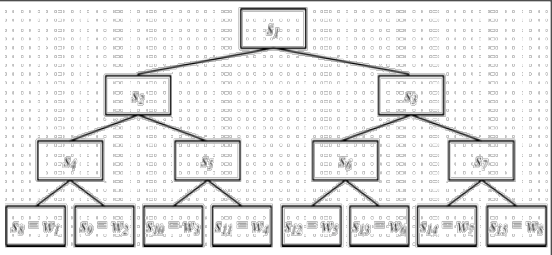


Implementation Method (3/3)



- Determine a random number *r* (0 ≤ r ≤ 1), and call the function *Puzzle_Selection(0,r)*

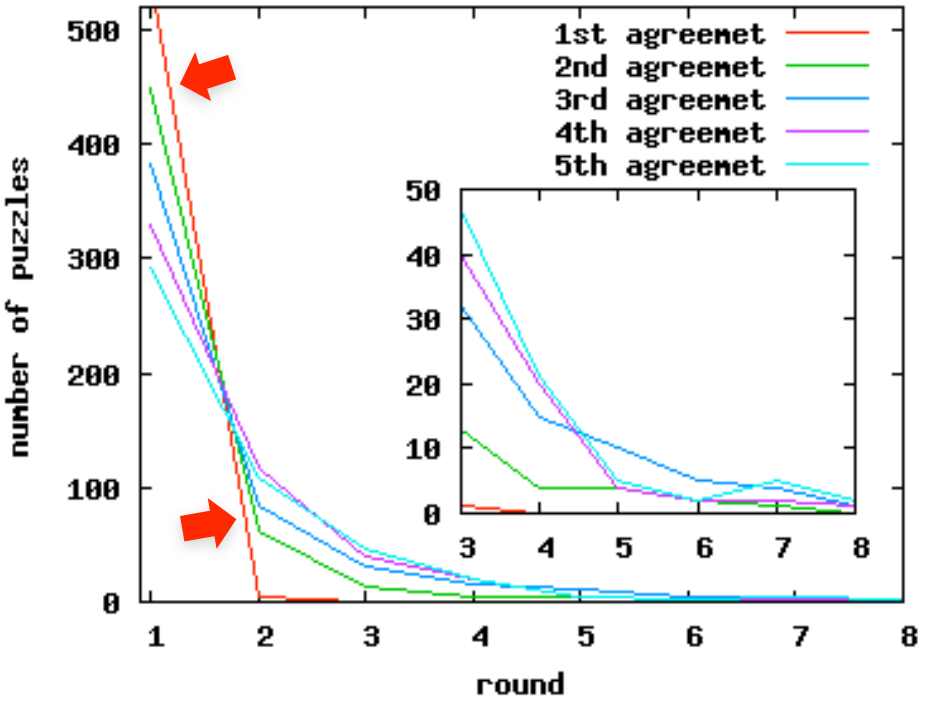
Algorithm 1 The proposed puzzle selection implementation based on the APSA scheme and the weight sum tree data structure.

1: **Function** $Puzzle\_Selection(k, r)$
2: **if** $k \geq 2^{h-1}$ **then**
3: Return the $(k - 2^{h-1} + 1)$th puzzle;
4: **end if**
5: **if** $r \leq \frac{s_{2k}}{s_1}$ **then**
6: $Puzzle\_Selection(2k, r)$;
7: **else**
8: $Puzzle\_Selection(2k + 1, r - \frac{s_{2k}}{s_1})$;
9: **end if**

Evaluation

- We evaluated the APSA scheme using trace-based simulations.
- The game trace was collected by the *ESP Lite* system.
  - The trace was one-month long (from 2009/3/9 to 2009/4/9).
  - The OPSA scheme was used in 1,444 games comprised of 6,326 game rounds. In total, 575 distinct puzzles were played and 3,418 agreements were reached.
  - The dataset is available at: http://hcomp.iis.sinica.edu.tw/dataset/

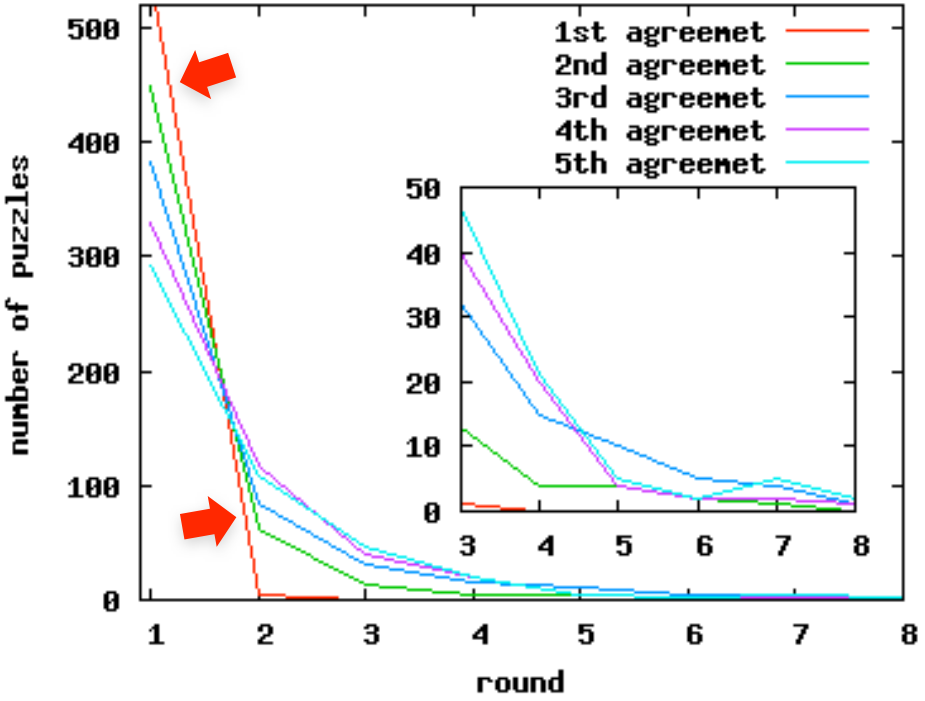
Evaluation – Puzzle Diversity



It is more difficult to reach the *(i+1)-th* agreement than the *i-th* agreement.

Evaluation – Puzzle Diversity

- The differences exist among the puzzles.



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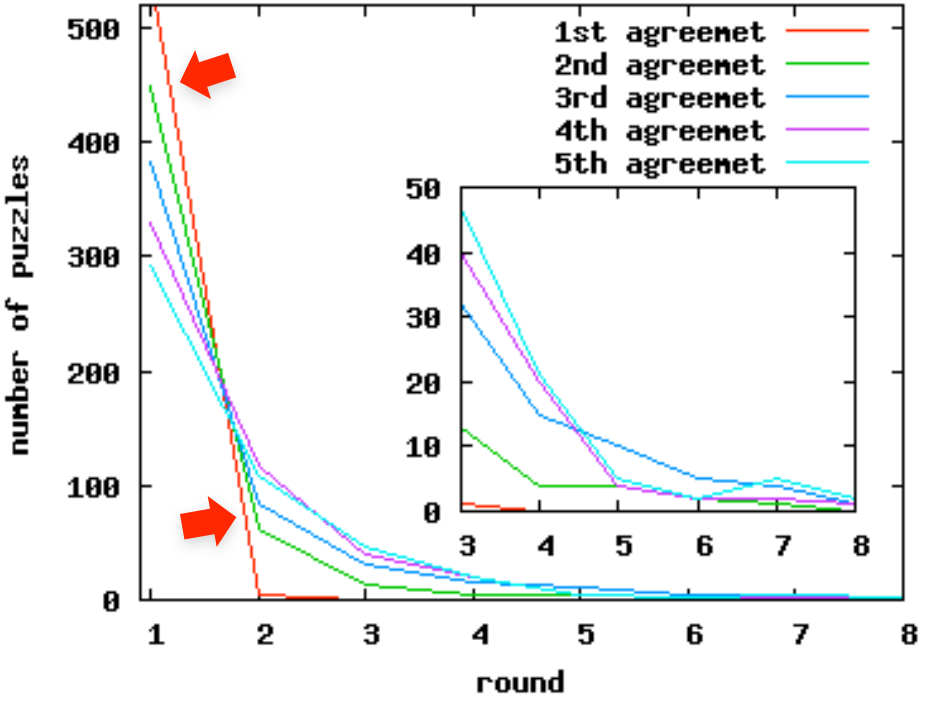

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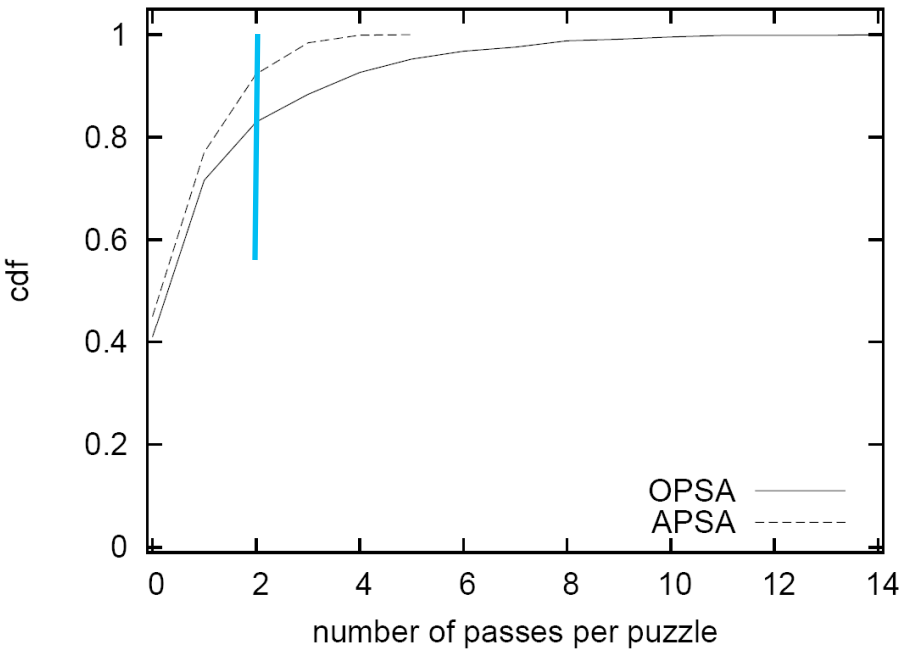
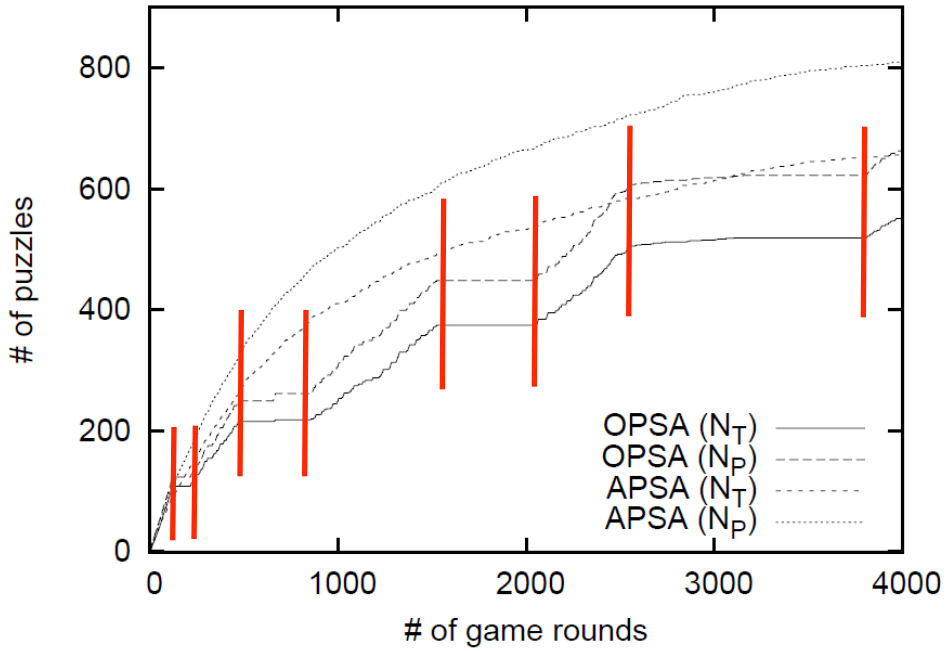
- **It is important to consider puzzle diversity!**

Simulation Results (1)



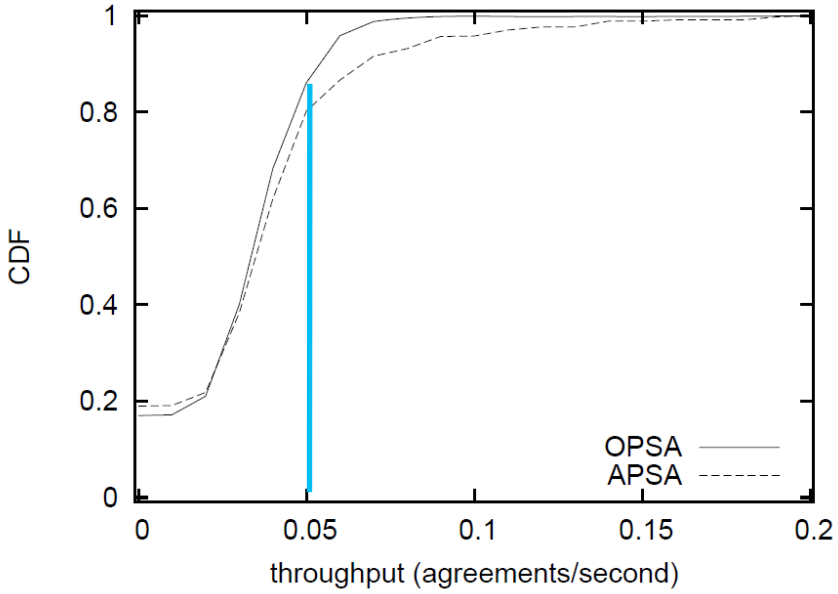


APSA scheme is superior in terms of reducing the number of the passed rounds.

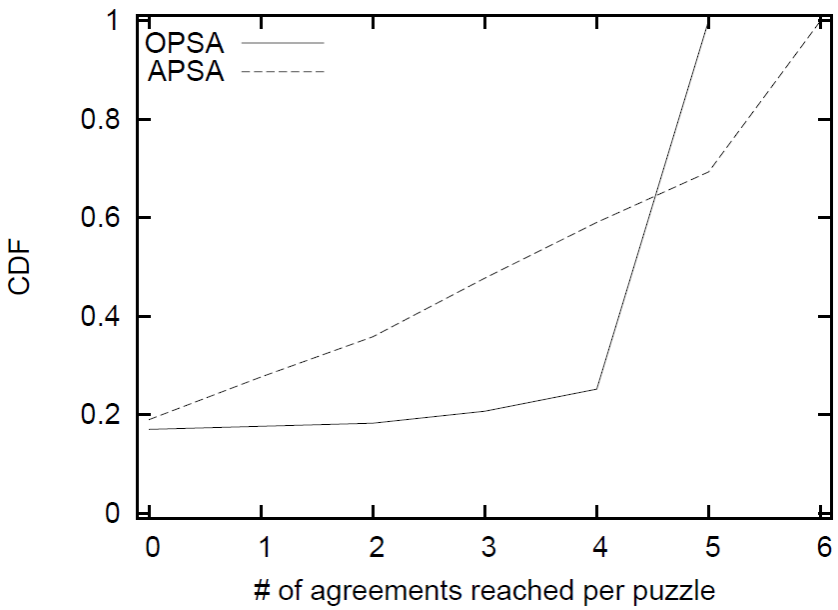
N_T: # of distinct puzzles with at least one agreement reached

N_P: # of distinct puzzles played

Simulation Results (2)

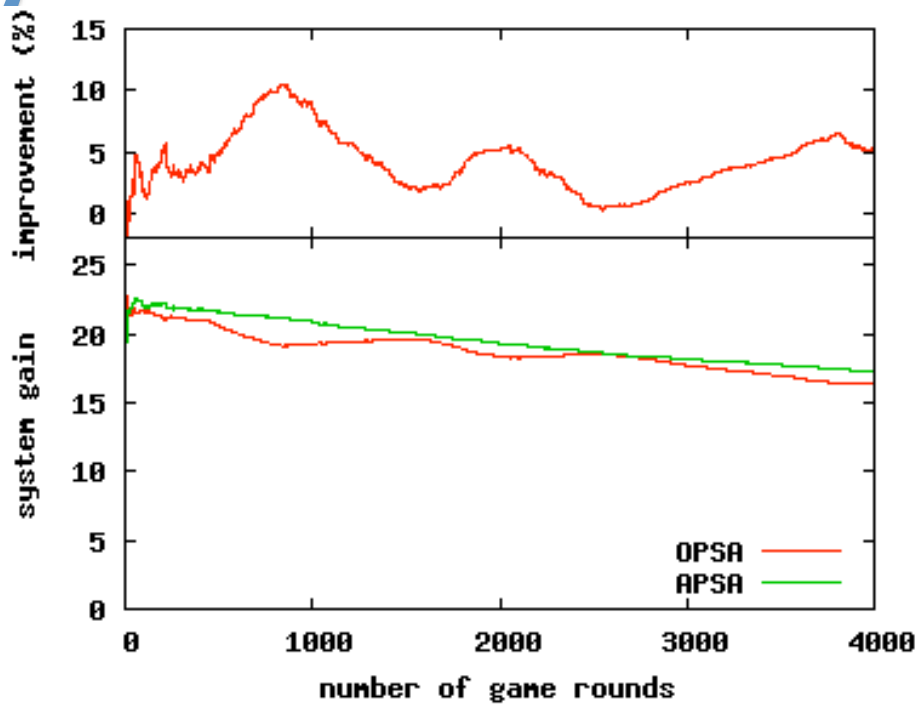


APSA scheme yields more agreements with better per-puzzle throughput



APSA scheme can better accommodate puzzle diversity than the OPSA scheme

System Gain Evaluation



- APSA always achieves a better system gain than the OPSA scheme (about 5% improvement).
  - The system gain could be improved further by modifying the second part of the metric (e.g., by introducing competition into the system [17]).

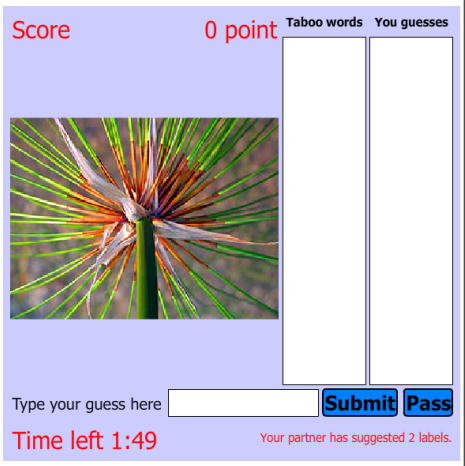
Summary

- We identify the *puzzle diversity* issue in ESP-like GWAP systems.
- We propose the Adaptive Puzzle Selection Algorithm (APSA) to consider *individual differences* by promoting *equality of opportunity.*
- We design a data structure, called Weight Sum Tree (WST) to reduce the computational complexity of APSA.
- We evaluate the APSA scheme and show that it is more

Advertisement ☺

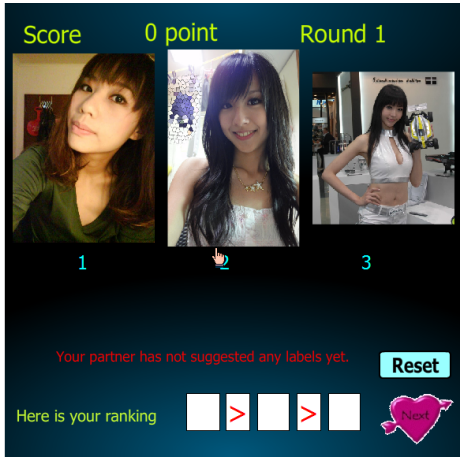
- GWAP API (http://hcomp.iis.sinica.edu.tw/GWAP_API/)
  - JAVA-based API source codes released
  - ESP Lite: an example of GWAP API
  - ESP Lite dataset (v2010.01.01)

ESP Lite



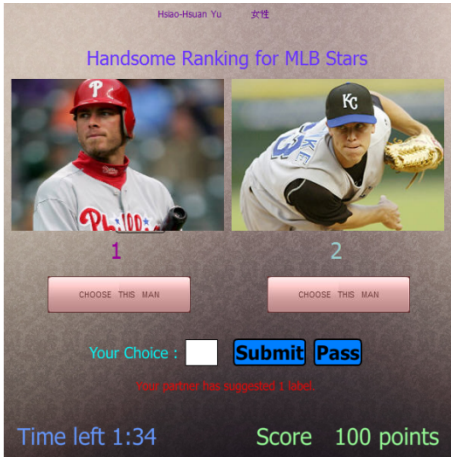
http://hcomp.iis.sinica.edu.tw/GWAP/ESPLite

Beauty Ranking



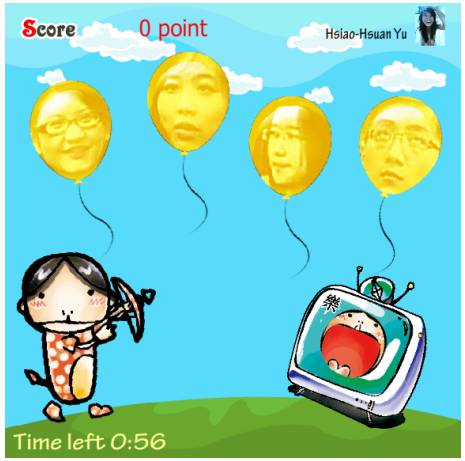
http://apps.facebook.com/wnranking/

Handsome Ranking



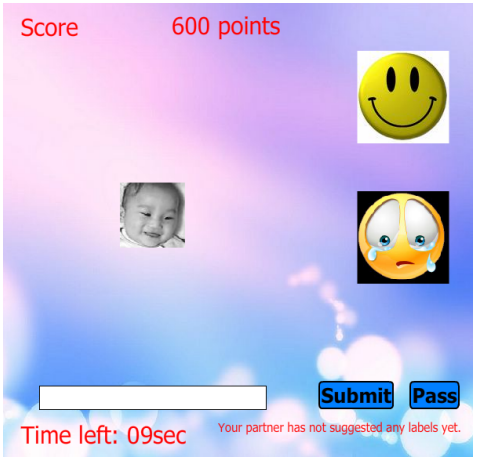
http://apps.facebook.com/menranking/

Gesture Recognition



http://apps.facebook.com/shootit/

Babies' Gesture Recognition



http://apps.facebook.com/testforclass/

Thank You!

Network Research Lab: http://nrl.iis.sinica.edu.tw/
GWAP API: http://hcomp.iis.sinica.edu.tw/GWAP_API/

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