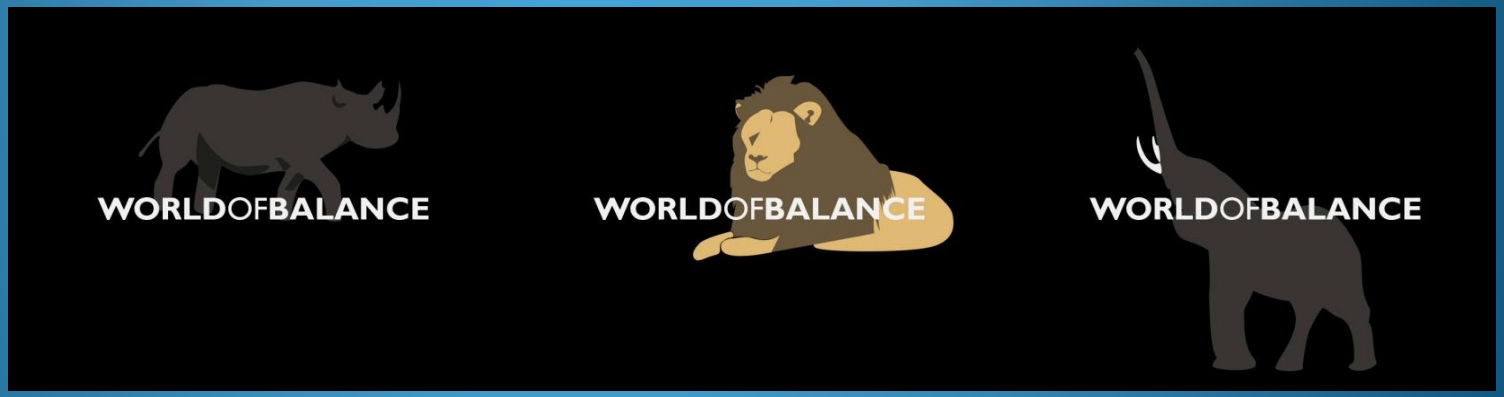
Steps towards Crowd Computing for Exploration of Complex Ecosystems



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Outline

- Related Work
  - Human Computing, Crowd Computing, Gamification
  - Ecology Research (Biodiversity and Sustainability)
- ‘World of Balance’ Multiplayer Online Game/Social Game
- Discussion

ESP Game (Image Labeling Game)

Luis von Ahn, 2005

- Can computer program (AI + Vision) label images as human do?
- Can a person make objective label? Maybe yes, but how effectively?

- Rather than using computer vision techniques, which don't work well enough, crowd computing encourages people to do the work by taking advantage of their desire to be entertained.

- Partners strive to agree on as many images as they can in 2.5 minutes. Every time two partners agree on an image, they get a certain number of points.

ESP Game (Image Labeling Game)

- During initial 4 month test run, 1.3 million labels were collected with only 13,630 players, some of whom spent over 50 hours playing the game!
- Internet can connects people to do these work together!!!
- Acquired by Google

Player 1 guesses: purse
Player 1 guesses: bag
Player 1 guesses: brown

Success! Agreement on "purse"

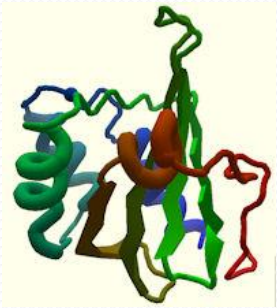
Player 2 guesses: handbag

Player 2 guesses: purse
Success! Agreement on "purse"

Foldit - Predicting protein structures with a multiplayer online game

- Prove that more complex scientific problems can be solved with human-directed computing.
- Protein structure prediction - locating the biologically relevant native conformation of a protein is a formidable computational challenge given the very large size of the search space.
- Engages non-scientists in solving hard prediction problems.
- Check Foldit – Youtube “Biology for Games by Nature”

Foldit



- The integration of human visual problem-solving and strategy development capabilities with traditional computational algorithms through interactive multiplayer games is a powerful new approach to solving computationally-limited scientific problems.
- A protein causing AIDS in rhesus monkeys that hadn't been solved for 15 years was resolved by Foldit players and confirmed by x-ray crystallography. That paper was named "Article of the month" by Nature Structural & Molecular Biology in October 2011.
- The Foldit paper analyzing the amazing recipes Foldit players have come up with was published in the Proceedings of the National Academy of Sciences of the USA in November 2011:
  - (thanks to 240,000 Foldit players)

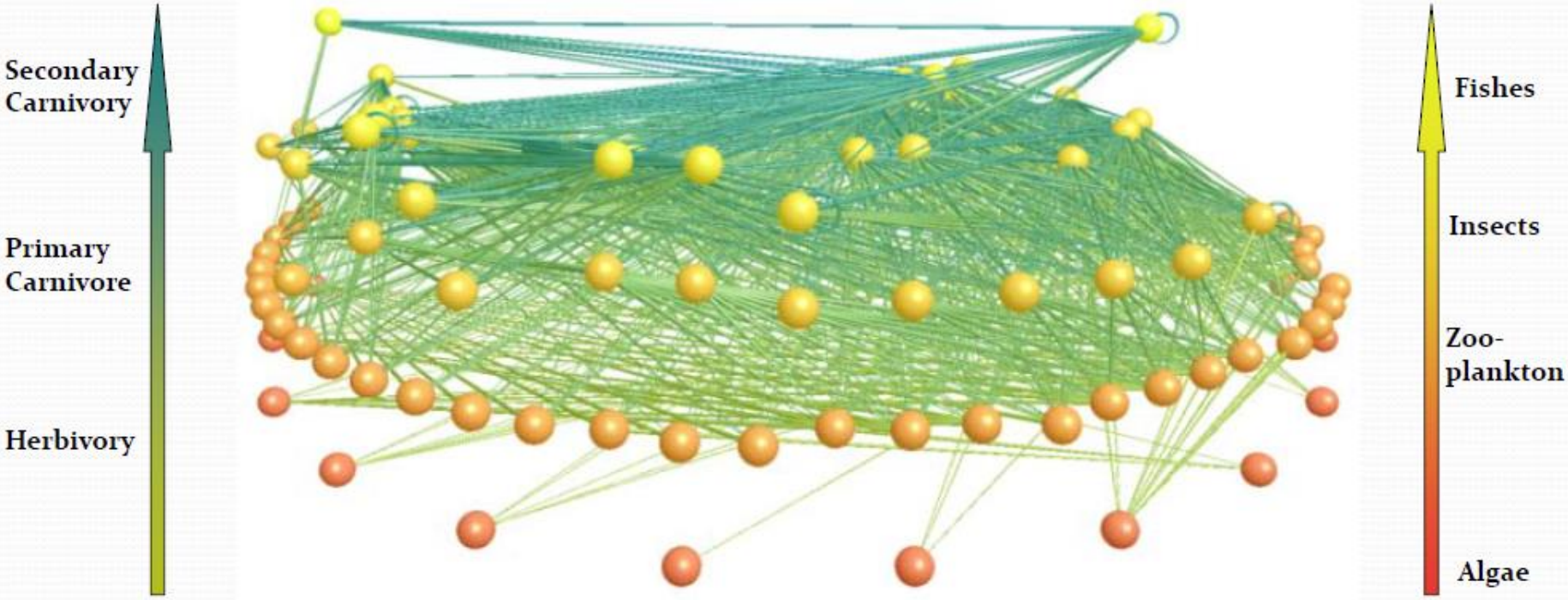
Checkpoint

- Benefits of Gamification, (or called Crowd Computing, Human Computing….)
  - Combine what computer program can not be good at +
  - Human guidance with game flavor and social interactions
- Can I apply this to Complex Ecosystem Exploration?
  - What is the significance of Ecosystem Research?
    - http://www.youtube.com/watch?v=us6UQqrGXMg
  - What are challenges within Ecosystem Research computational approach?
  - How can human contribute to the challenges while having fun?

Ecosystems: Complex Ecological Networks

Little Rock Lake Food Web: 92 Species (S) & 997 Links (L)

Connectance (C) = L / S^2



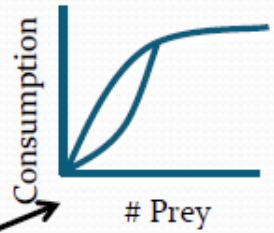
Link Color indicates Type of Feeding Link

Node Color indicates Trophic Level of Taxa

Martinez 1991 *Ecological Monographs*

Bioenergetic Dynamics

Handling
Attack
Interference



$$B_i'(t) = G_i(B) - x_i B_i(t) + \sum_{j=1}^{n}\left(\left(x_i y_{ij} \alpha_{ij} F_{ij}(B) B_i(t) - x_j y_{ji} \alpha_{ji} F_{ji}(B) B_j(t)\right) / e_{ji}\right)$$

Rate of change in biomass = Production rate of basal spp. − Loss of biomass to metabolism + (Gain of biomass from resource spp. − Loss of biomass to consumer spp.)

Time evolution of species' biomasses in a food web result from:

- Basal species grow via a carrying capacity, resource competition, or Tilman/Huisman models
- Other species grow according to feeding rates and assimilation efficiencies (e_{ji})
- All species lose energy due to metabolism (x_i) and consumption
- Functional responses determine how consumption rates vary
- Rates of production and metabolism (x_i) scale with body size
- Metabolism specific maximum consumption rate (y_{ij}) scales with body type

Yodzis & Innes (1992) Body size and consumer-resource dynamics. *Amer. Nat.*
Williams & Martinez (2004) Stabilization of chaotic and non-permanent food web dynamics. *Eur. Phys. J. B*

Application: Species loss

2009 *PNAS* 106:187-191

Simple prediction of interaction strengths in complex food webs

Eric L. Berlow[a,b,c,1,2], Jennifer A. Dunne[c,d], Neo D. Martinez[c], Philip B. Stark[e], Richard J. Williams[c,f], and Ulrich Brose[b,c,2]

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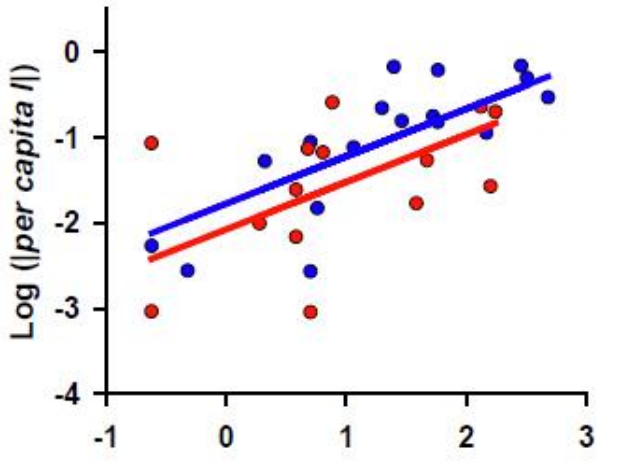
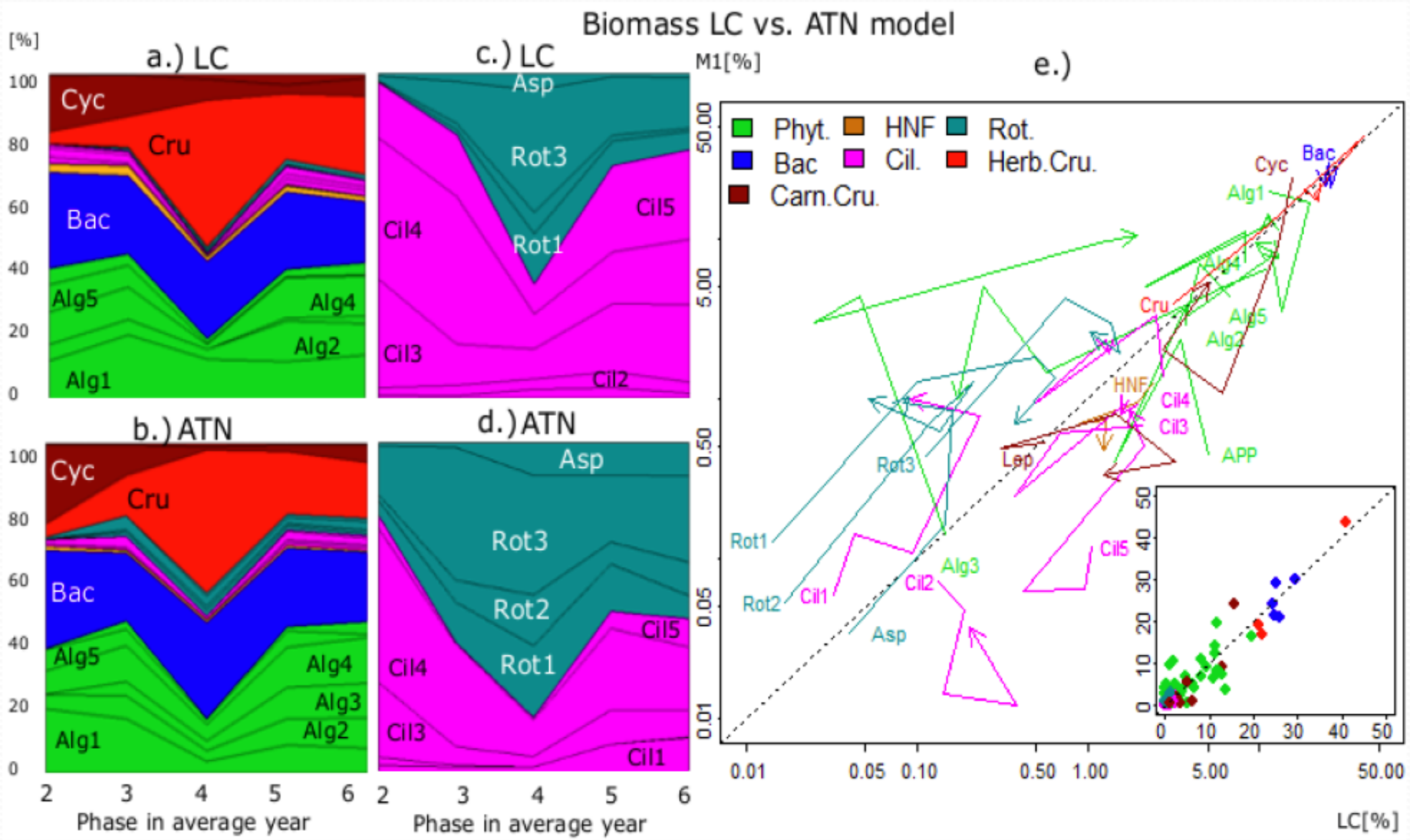
Edited by Simon A. Levin, Princeton University, Princeton, NJ, and approved November 10, 2008 (received for review July 15, 2008)

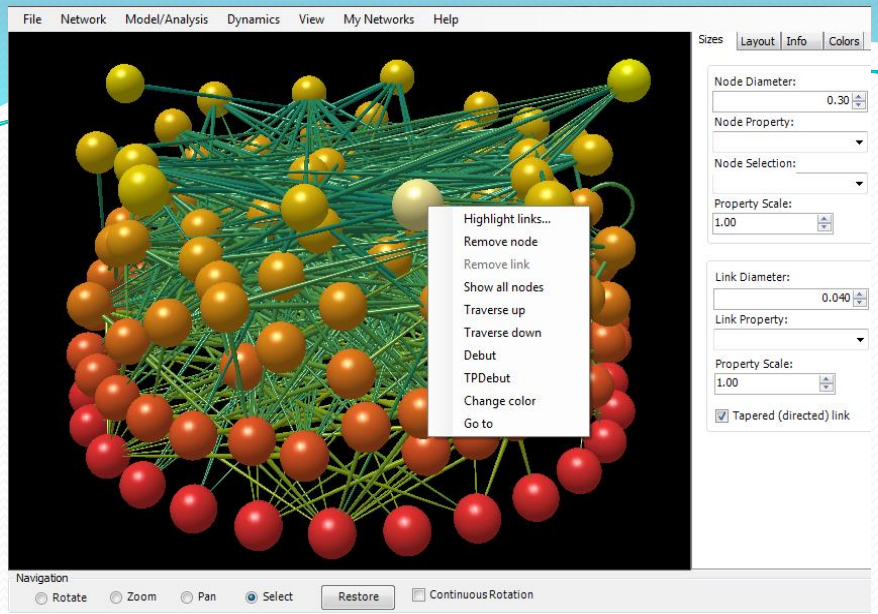


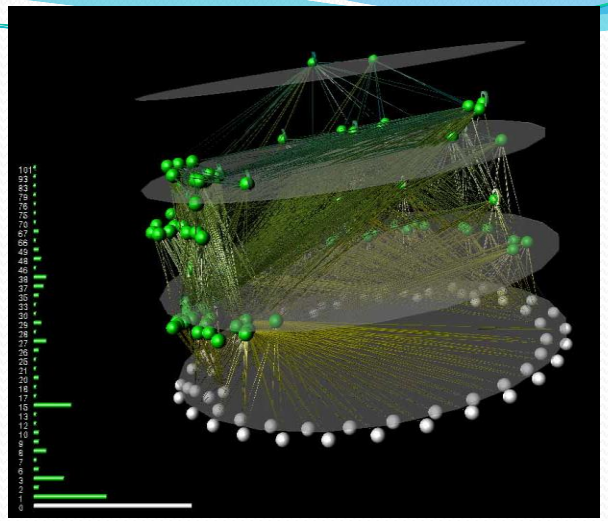
predicted
- High *R* Biomass
- Low *R* Biomass

observed
- High *R* Biomass
- Low *R* Biomass

Lake Constance Biomass: Model-Data Similarity = 0.82







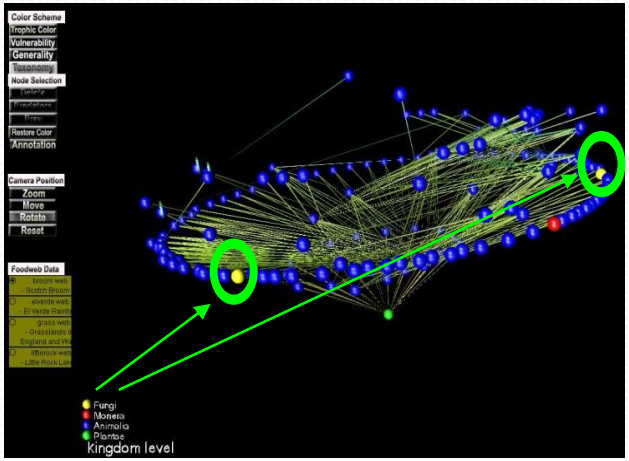


Fig.4.a. Taxonomical color on Broom food web. Fungi kingdom (yellow), Monera (red), Animala (blue), and Plantae kingdom (green) are shown.

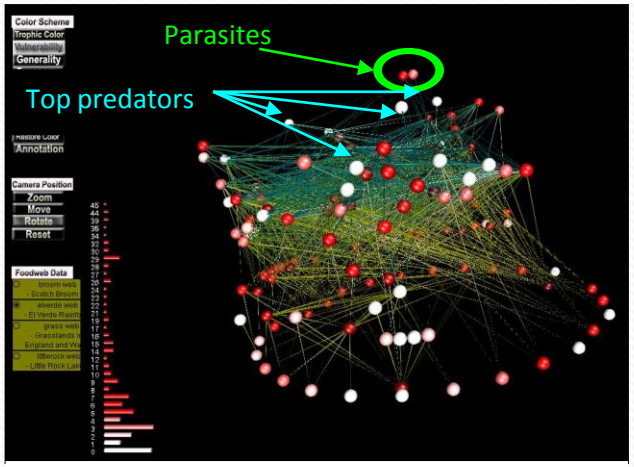
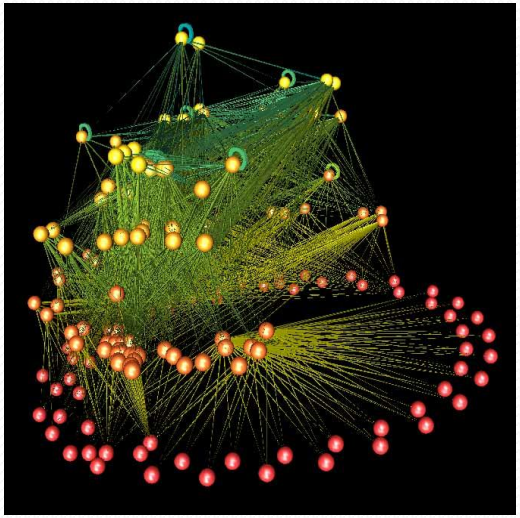
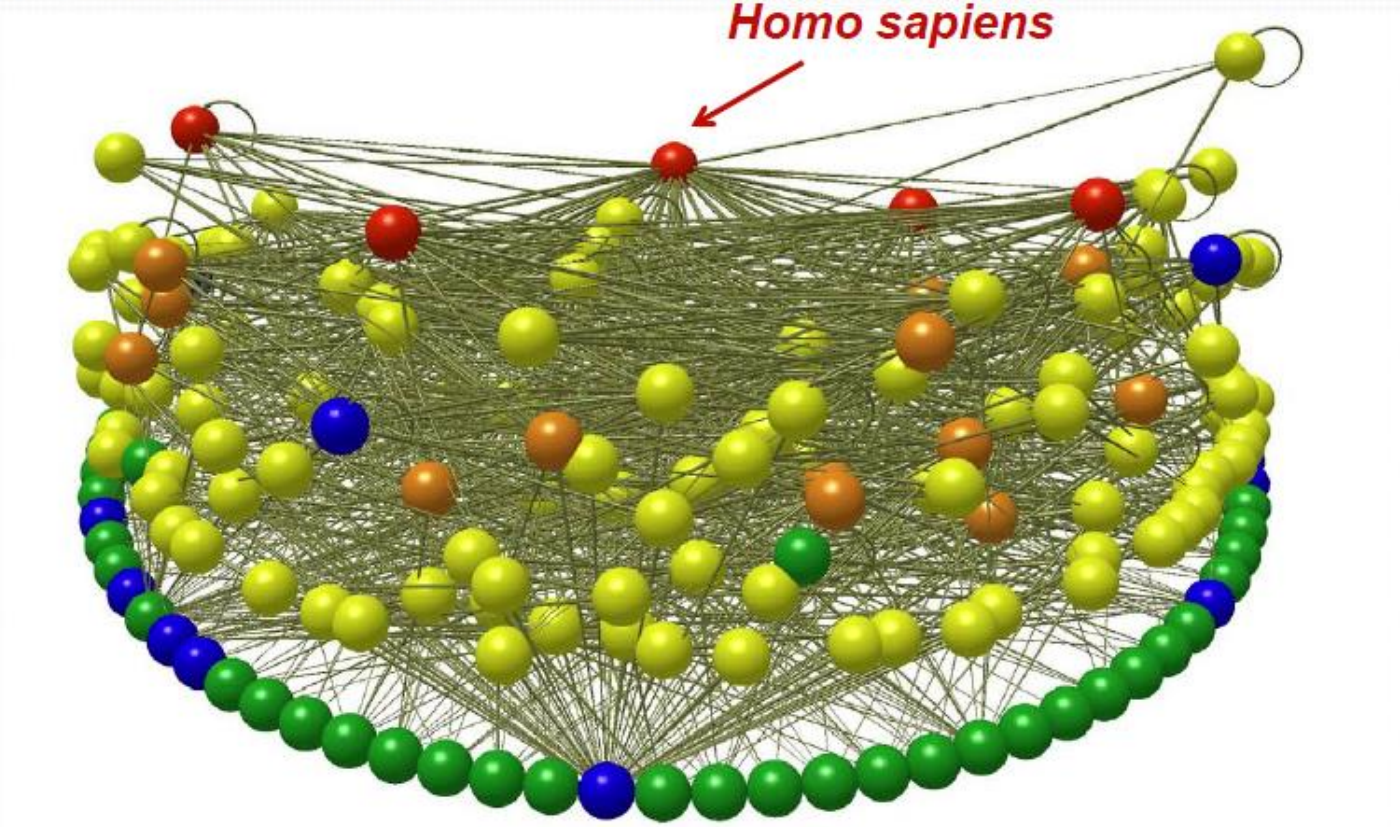


Fig.4.b. Vulnerability color on Elverde food web. Histogram shows slots indexed from 0 to 45 (not continuous). The index represents the number of species that are eating the species under the specific index. the0 or up to 44 different species.



Forecasting Example: Humans

- Coupled Human-Natural Networks
- Aleuts on the Sanak Archipeligo



Martinez, Tonin, Bauer, Rael, Singh, Yoon, Yoon & Dunne *AAAI2012*

Ecology Research

- **Only recently has this understanding progressed to the point that realistically complex ecosystems can be computationally modeled.**

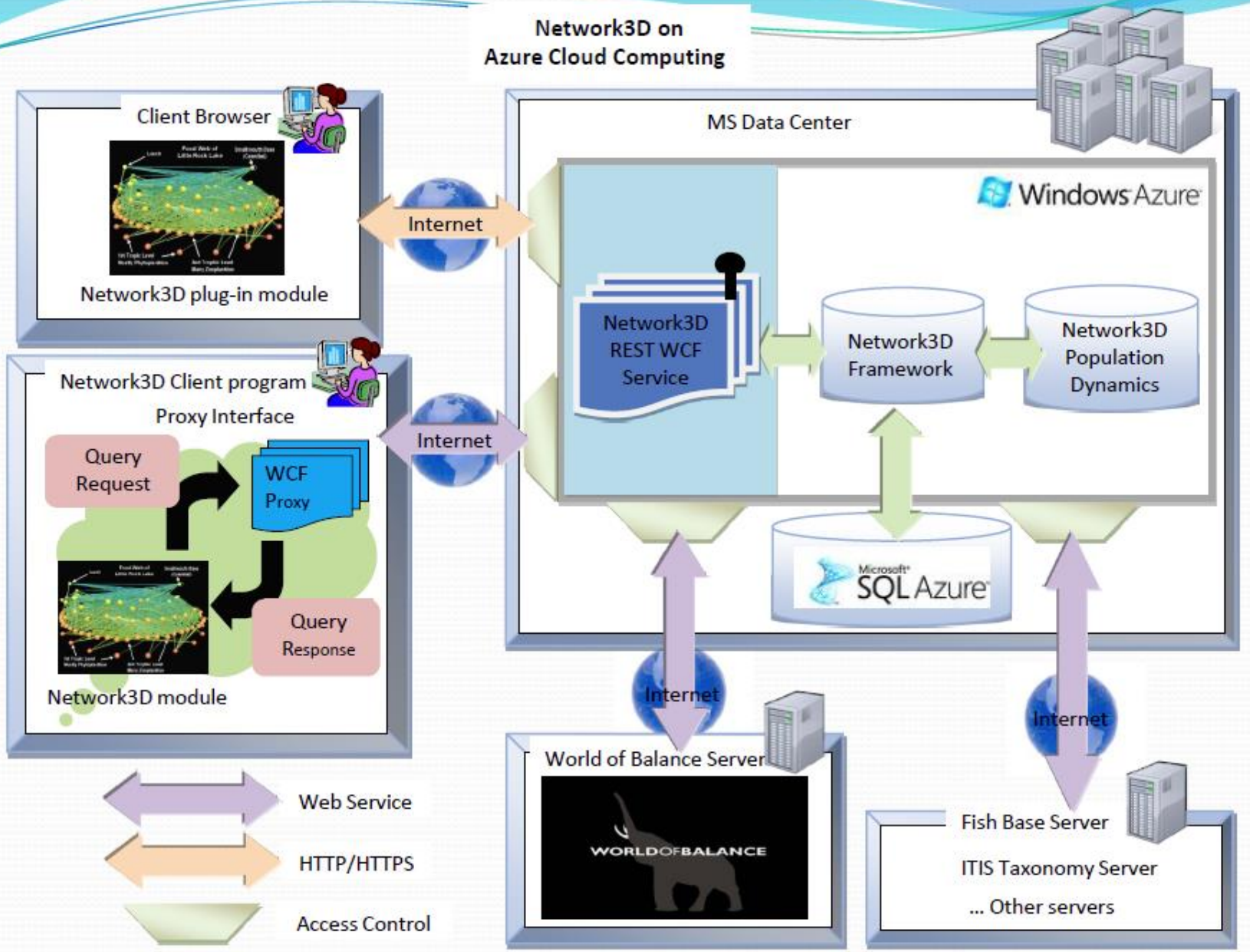
- **Simpler model produces much less accurate data than more realistic ones**

- New insights enabled such systems modeled as nonlinear, high dimensional, coupled ordinary differential equations to characterize the bioenergetic feeding and biomass dynamics of complex networks

How can crowd computing help complex ecology research?

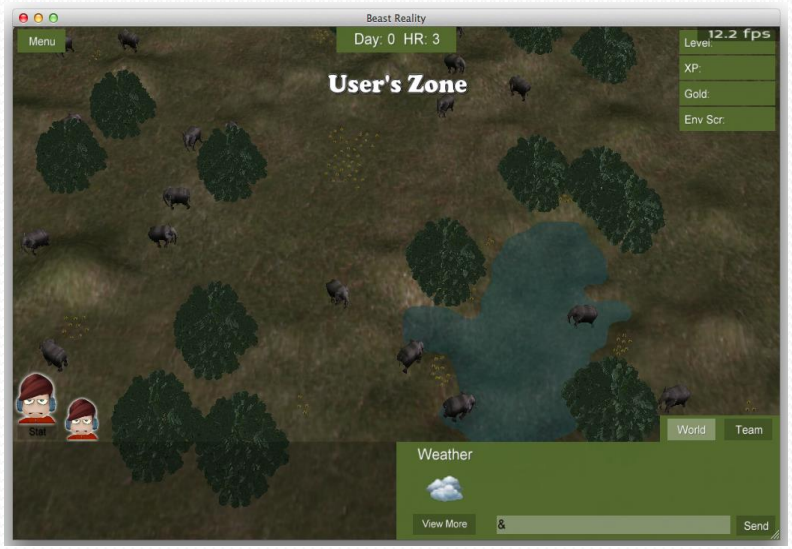
- 8 system parameters, 8 node parameters and 15 link parameters. In case of Serengeti web, there are 95 nodes and 547 links, then there are 8 system parameters, 760 node parameters and 8205 parameters that are all interdependent.
- 8*100*760*100*8205*100 = 48,000,000,000,000 cases if each parameter has about 100 interpolation gap.
- Scientists run simulations by tweaking parameters to match to realistic food web parameter sets.
- Can we use a game like FarmVille for players to nurture a ecosystem that is close to a realistic food web?

Network3D on Azure Cloud Computing



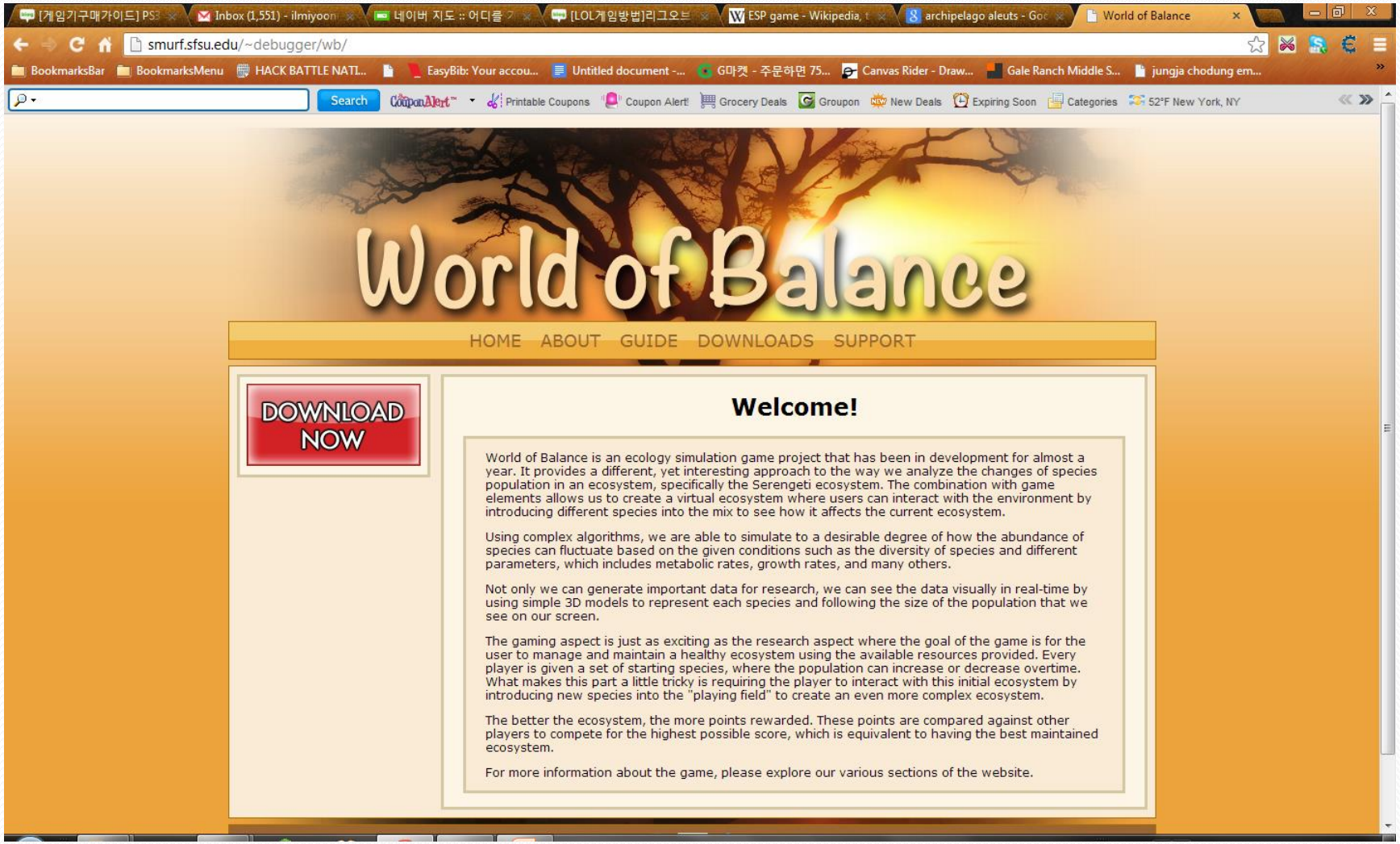
World of Balance Game

- PvE (like Farmville) players are collaboratively nurture habitat
- PvP (like Starcraft) players are playing against other players and destroy the other's eco system
- Special credit to CSc 631/831 students (Game Development Class Fall 2011)



World of Balance Game

http://smurf.sfsu.edu/~debugger/wb/



WoB: World of Balance

http://smurf.sfsu.edu/~debugger/wb/guide_user_interface.php

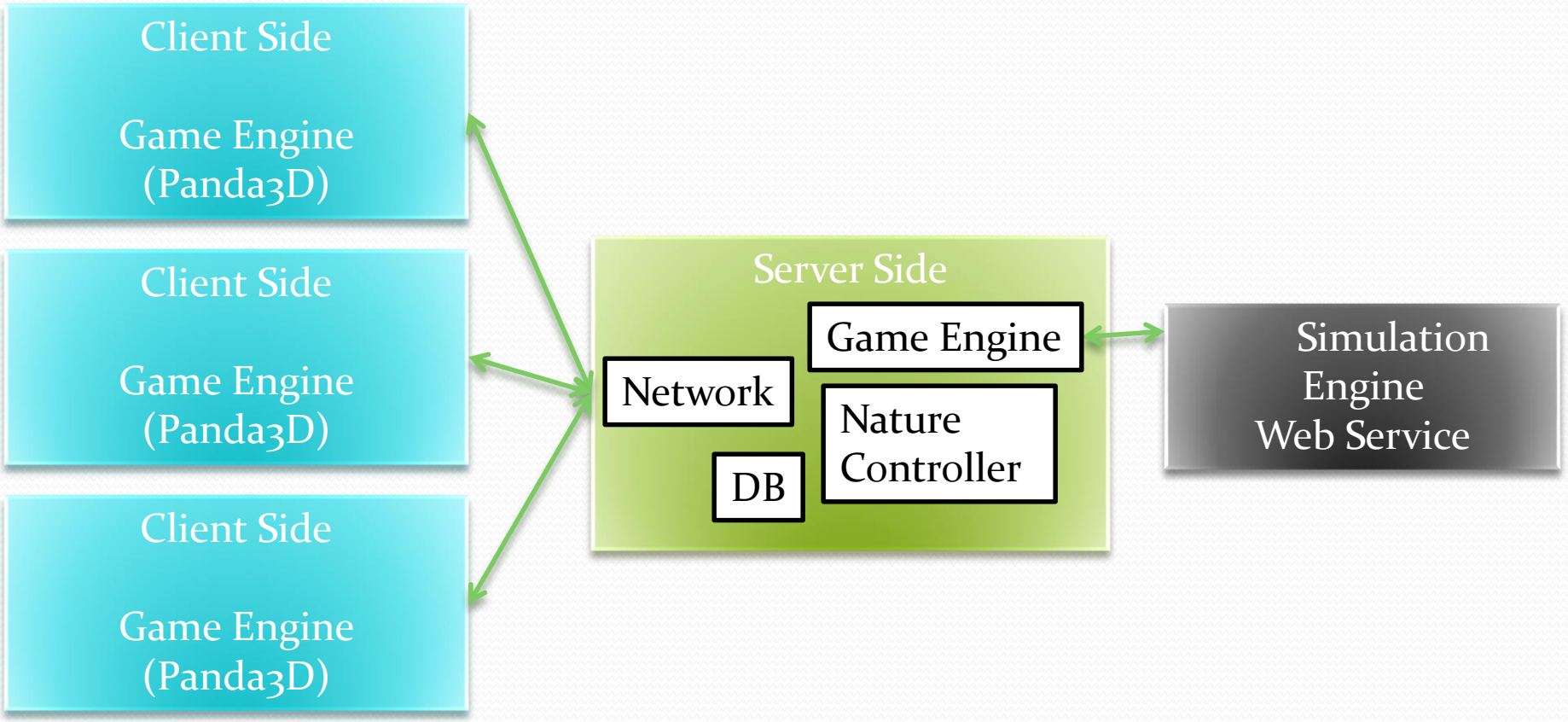
Objective of World of Balance

- The name, World of Balance, comes from the idea of creating a balanced ecosystem.
- The game requires you to manage an ecosystem by introducing the appropriate species, purchasable from the Shop, that will help you create a sustainable ecosystem to achieve the highest score as possible.
- Highest score is calculated to encourage players to create more diverse ecosystem.
- Environment score = $([\log_2 (\text{Total Biomass})] * 5)^2 + (\#\ \text{of Species})^2$

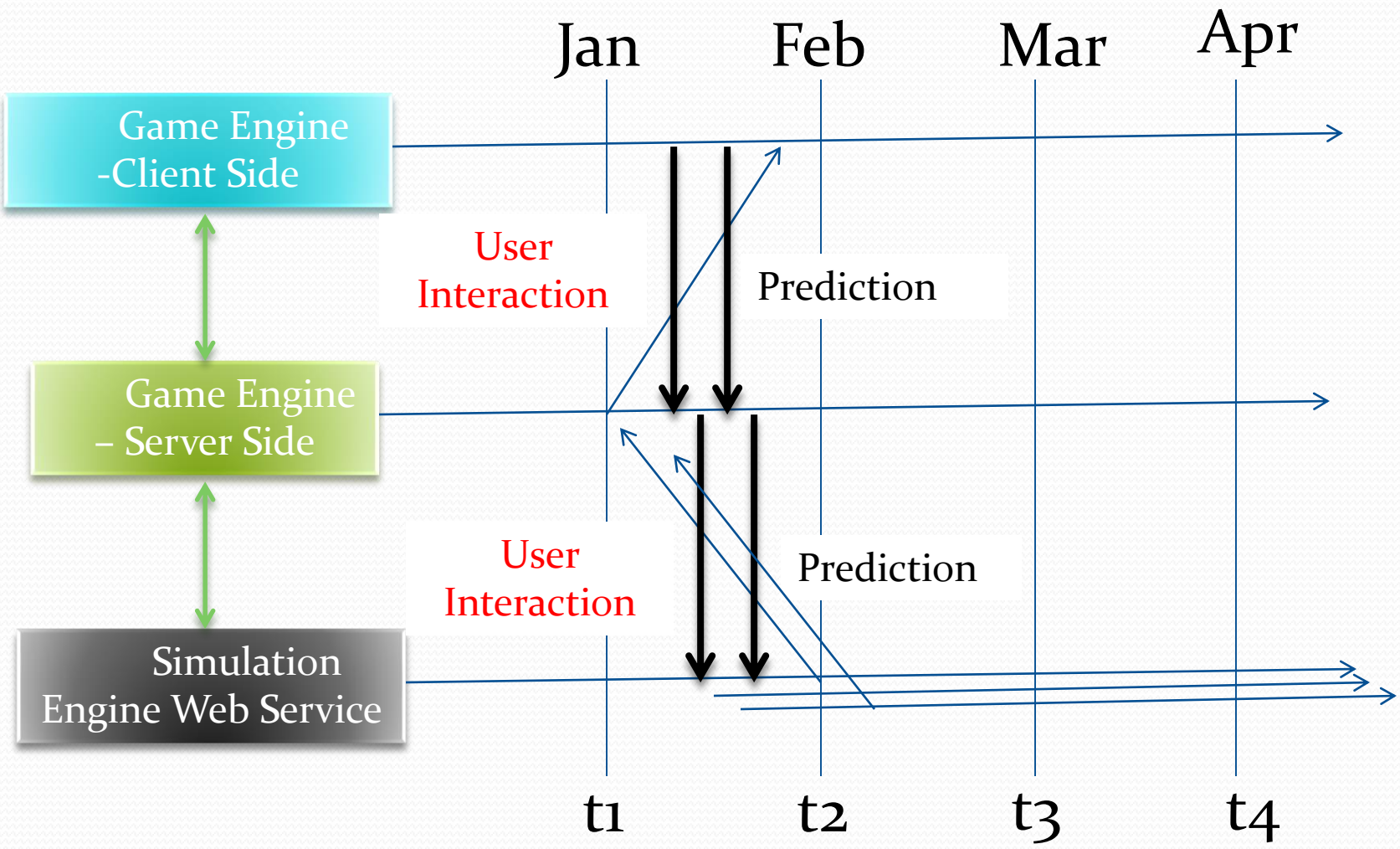
World of Balance Game Play

- How to gain experience?
  - Every 10 minutes of game time
  - Beginning of a new month
  - Increase in population
  - Purchases from the Shop
  - Increase in biomass, ex. 1k, 10k, 100k…
- Experience is used to increase level
- Levels are used to unlock new kinds of species
  - http://smurf.sfsu.edu/~debugger/wb/guide_game_tips.php
- Game Currency

World of Balance talking to Population Dynamics Simulation Engine



How does Population Dynamics Simulation communicate with game?



World of Balance – How it is made

- SFSU CS Multiplayer Online Game Design and Development Course [Fall 2011]
  - ~24 graduate/undergrad students
  - Made in to 8 teams
    - Game Concept Team
    - Server Team
    - Client Team
    - DB Team
    - QA Team
    - Art Support Team
    - Game Content Team
    - Launching Team/IT support Team

World of Balance – User Trial (Educational Impact)

- Phase 1—User Engagement Evaluations
  - Over the course of 2 months (beginning of April, 2012 to beginning of June, 2013), 10 psychology undergraduate and graduate students participated in user engagement evaluation
- Phase 2—Efficacy Testing of World of Balance
  - 11 psychology undergraduate students (M age = 21.36; SD = 1.12; 4 males and 7 females), attending San Francisco State University. All participants successfully completed a 5-days study with approximately 10-12 hours of their participation including 8 hours and more of game playing.

World of Balance – User Trial

- **Serengeti Ecosystem General Knowledge Pre- and Post-Test:** forced-choice questioned examined participants' general understanding of the Serengeti ecosystem. Through comparing participant's pre- and post-test scores, we examined whether participant's understanding of Serengeti ecosystem was significantly increased (and improved) as the result of playing World of Balance for 8 hours.

- **User Engagement Pre- and Post-Test:** mixture of Likert-scale as well as open-ended questions which examined (1) participant's own perception of their knowledge gains and intrinsic motivation to learn about Serengeti ecosystem (2) participant's positive affects, interactive and perceived engagement experience.

- **Constructive Feedbacks:** Through detailed open-ended questions, participants were asked to provide constructive feedbacks on the ways for our research team to further improve World of Balance.

World of Balance – User Trial

- Only after 8 hours of playing World of Balance, participant's general knowledge of Serengeti ecosystem increased significantly as the result, $t(10) = 3.81$, $p < 0.001$ (Pre-test: $M = 6.45$; $SD = 1.968$; Post-test: $M = 10.27$; $SD = 2.24$).
- Participants reported that they feel they knew a lot about the Serengeti ecosystem in general after playing World of Balance, $t(10) = 1.09$, $p < 0.05$ (Pre-Survey: M = 2.18; SD = 0.12; Post-Survey: M = 2.27; SD = 0.47).
- Especially, their felt that they learned a lot about the species living in the Serengeti ecosystem, $t(10) = 1.47$; $p < 0.001$, (Pre-Survey: M = 2.27; SD = 0.46; Post-Survey: M = 3.18; SD = 1.07).
- Not only their perception of knowledge about Seregenti ecosystem, participants also felt that they were more curious about the Serengeti ecosystem and would like to know more about it, $t(1) = 0.71$, $p < 0.01$, (Pre-Survey: $M = 3.64$; $SD = 0.81$; Post-Survey: $M = 4.36$; $SD = 0.50$).

Educational Impact

- Over 80% of the participants agreed or strongly agreed that they
  - though this type of learning is useful in order to improve their knowledge about the Serengeti ecosystem
  - they can easily improve their knowledge about the Serengeti ecosystem with this type of learning
  - this type of learning would help them regain their knowledge,
  - that they would highly recommend using this type of learning to learn about Serengeti ecosystem (5) that they felt while they were playing the game, they felt time went by unusually fast.

Future Direction

- Make the game entertaining
  - Tuning of Environment Score
  - Currency control
  - Leveling up speed
  - Unlocking species
- Develop PvP and other features
- Extract Scientific Data out from the play data
- Iterative Development Approach with Ecology Researchers to maximize the effectiveness of scientific data.
- Apply to other habitats.