Automated Sensing and Social Network Analysis in Virtual Worlds

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Outline

- Introduction & Motivation
- History & Initial Investigations
- Sensing & Analysis Methodology
- Experiment in Second Life
- Results
- Summary

Virtual Environments and MMOGs

Picture from: O'Harrow, Jr., R. (2008). Spies' battleground turns virtual: Intelligence officials see 3-D online worlds as havens for criminals. *Washington Post*, February 6, 2008.

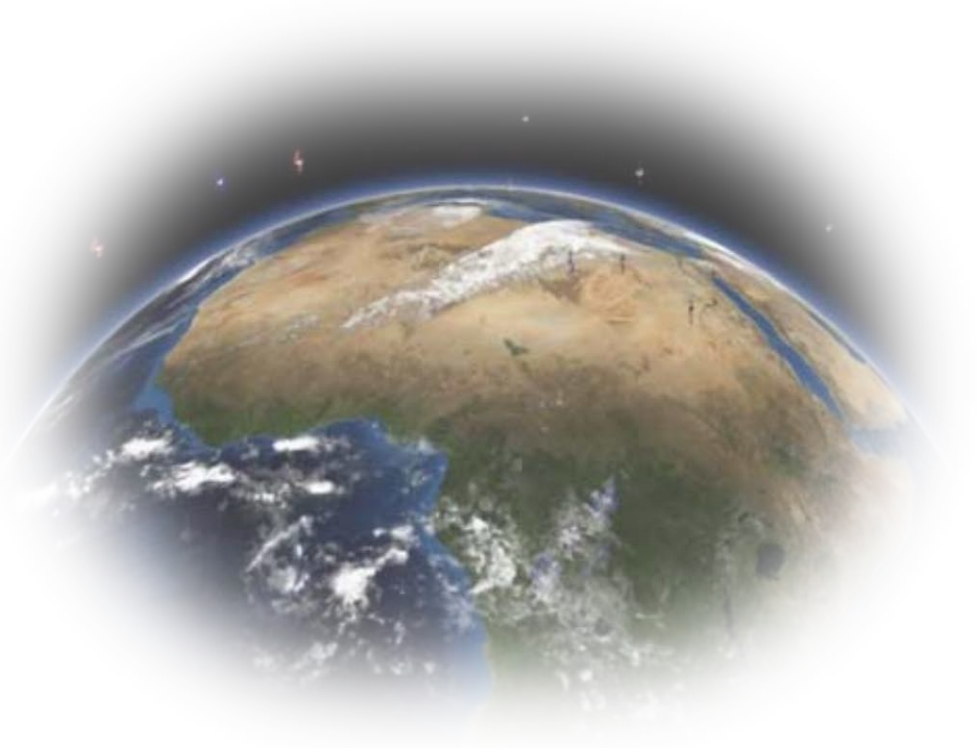
Picture from: http://moviechopshop.com/2009/07/22/sam-raimi-to-direct-world-of-warcraft-movie-i-wish-i-could-get-excited-about-that/

Picture from: www.hipihi.com/

Picture from: http://pal.muxlim.com/

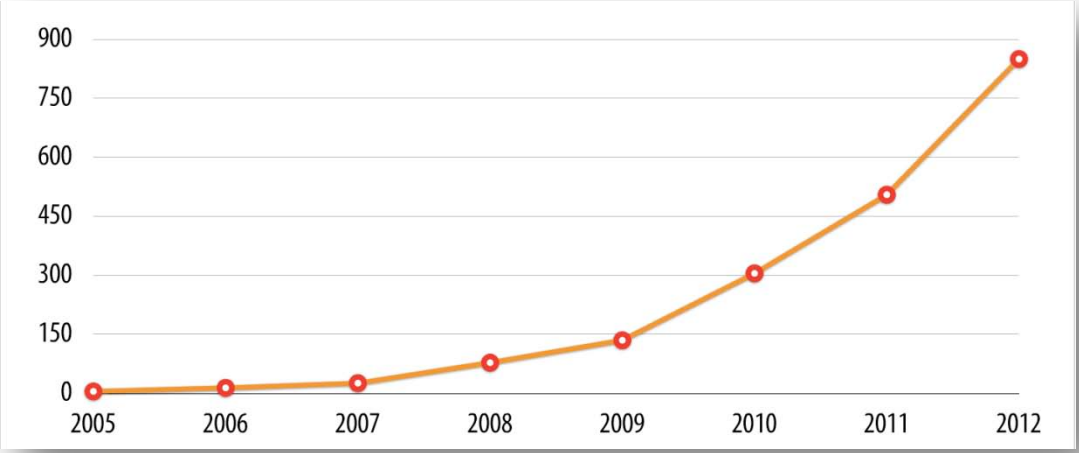
Virtual Worlds

- **Community-driven experiences**
- **Massively multiplayer online real-life games (MMORLGs)**
- **Typically persistent (state-maintaining)**
- **Users involved with the creation of the world itself**
- **Users have a variety of motivations**
  - Collaboration
  - Exploration
  - Business
  - Commerce
  - Education
  - Social networking
  - Model building
  - Gaming
  - Arts
- **Examples**
  - Second Life
  - There
  - Active Worlds
  - Entropia Universe

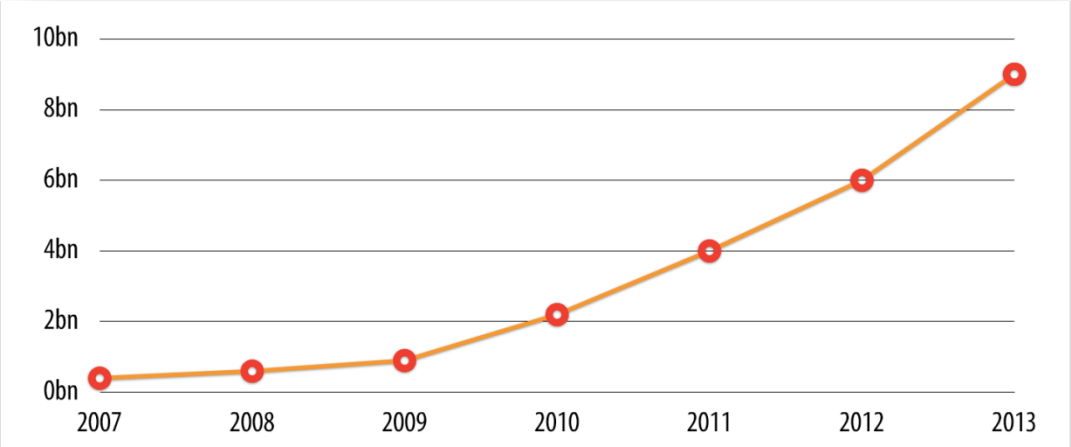


Virtual Worlds Projected Growth

Number of Virtual Worlds

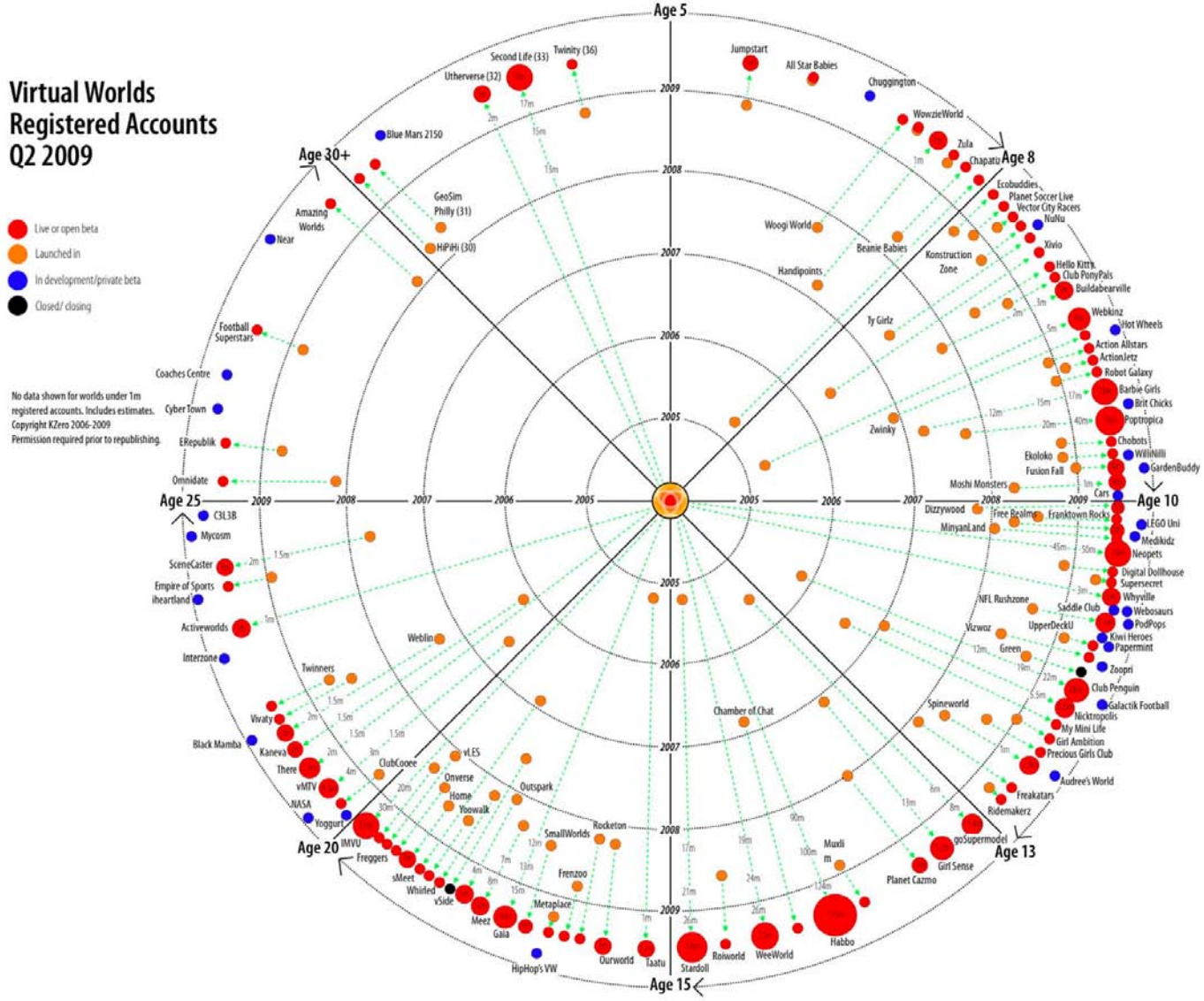


Virtual World Revenues (USD)



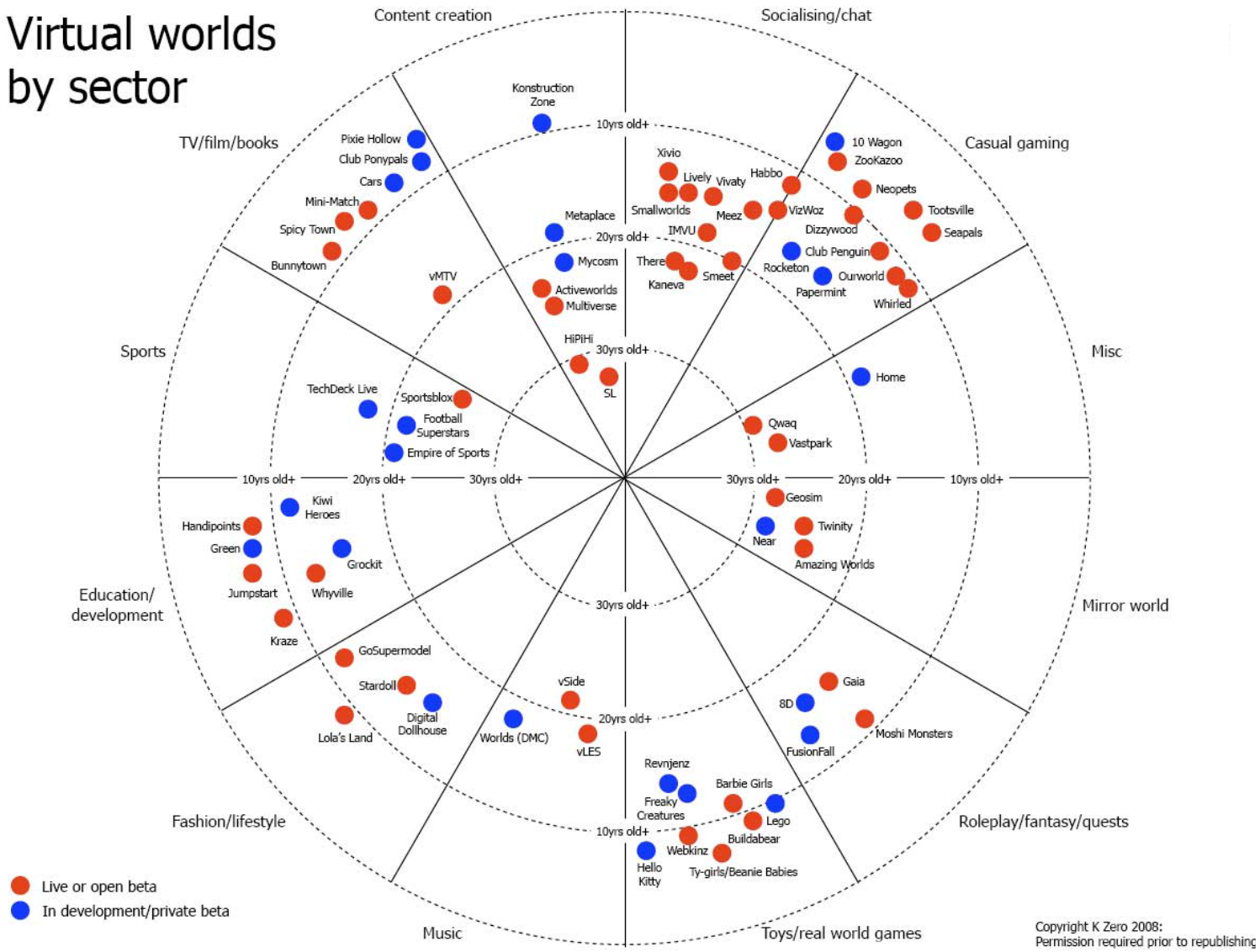
From: K-Zero , Virtual Worlds 2010+: Insight and Assessment of the Key Drivers and Trends Emerging in the Virtual Worlds Sector in the Next Three Years (Technical Report). Cambridge, UK: Kzero Worldwide, 2009.

Virtual World Variety



From: K-Zero , Virtual Worlds 2010+: Insight and Assessment of the Key Drivers and Trends Emerging in the Virtual Worlds Sector in the Next Three Years (Technical Report). Cambridge, UK: Kzero Worldwide, 2009.

Virtual World Types



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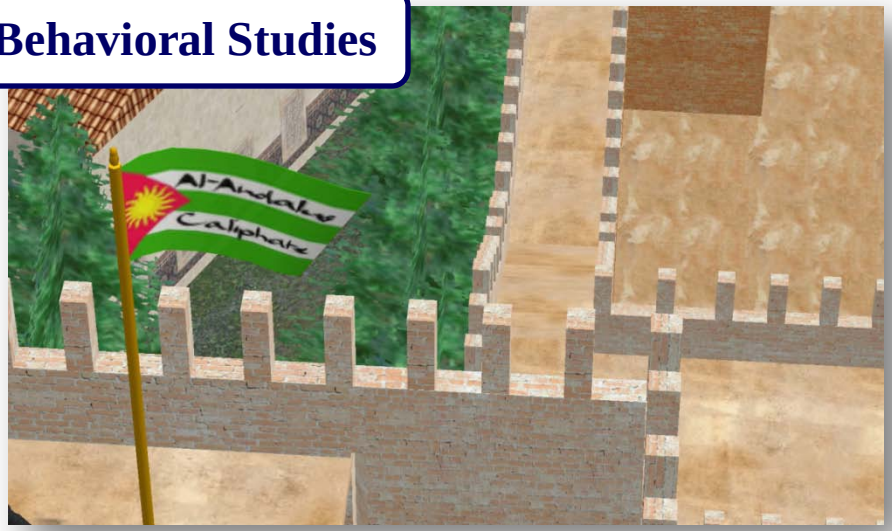
Motivation: Application Areas

Collaboration

Behavioral Studies

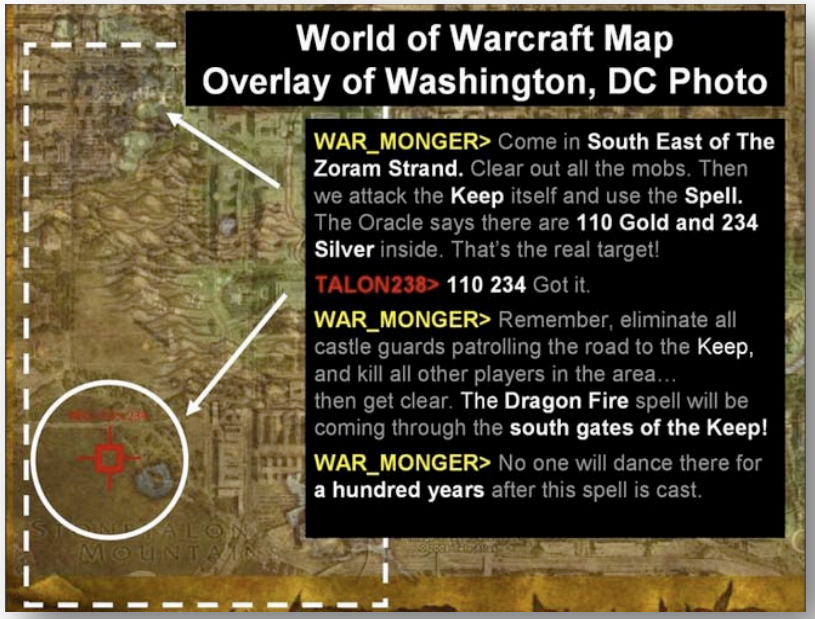


Digital Diplomacy

Intelligence & Security

Motivation: Intelligence and Security

- **Virtual world qualities of interest to criminals and terrorists**
  - Anonymity
  - Global access
  - Financial transfers outside normal channels
  - Diverse communication mediums
- **Ways criminals and terrorists can exploit virtual worlds**
  - Propaganda and recruitment
    - Photographs and images
    - Streaming video
    - Personal conversations
    - Messages and links
  - Passing covert messages
    - Visual signals
    - Steganography
    - Bots
    - Predetermined signals in state-maintaining environments
  - Passing covert messages
  - Training and planning
  - Clandestine money transfers to finance real world criminal activities
  - Gambling



Current Work

- Exploring techniques to automatically collect behavioral information from virtual worlds (focus: Second Life)
- Examine the use of social network analysis on behavioral data from virtual worlds
- Focus on identifying potential covert/terrorist activities

History & Initial Investigations

Front National virtual terrorism, griefing, and response in late 2006

History & Initial Investigations

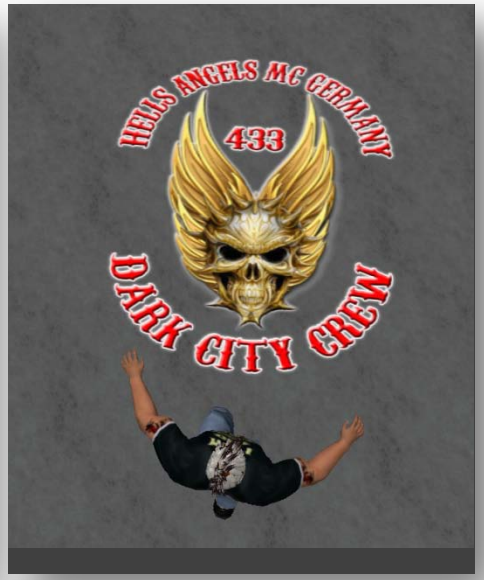
Protests at the Palestinian Holocaust Museum in late 2008 after attacks on the Gaza Strip

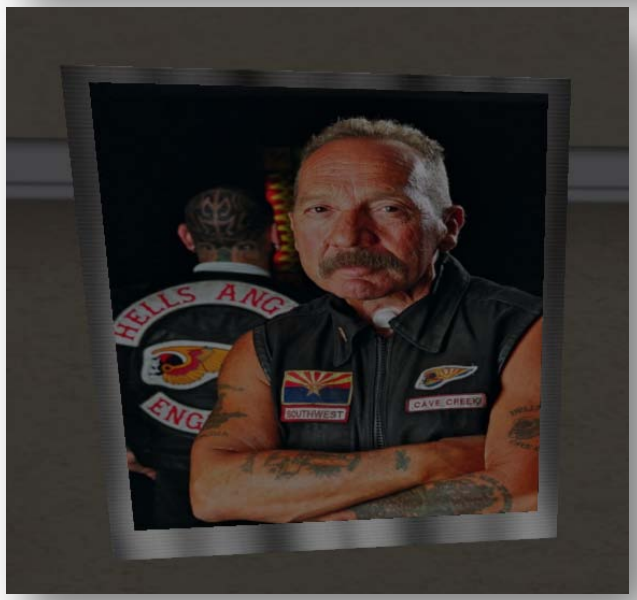
History & Initial Investigations

Protests in Iran during the Elections in June 2009

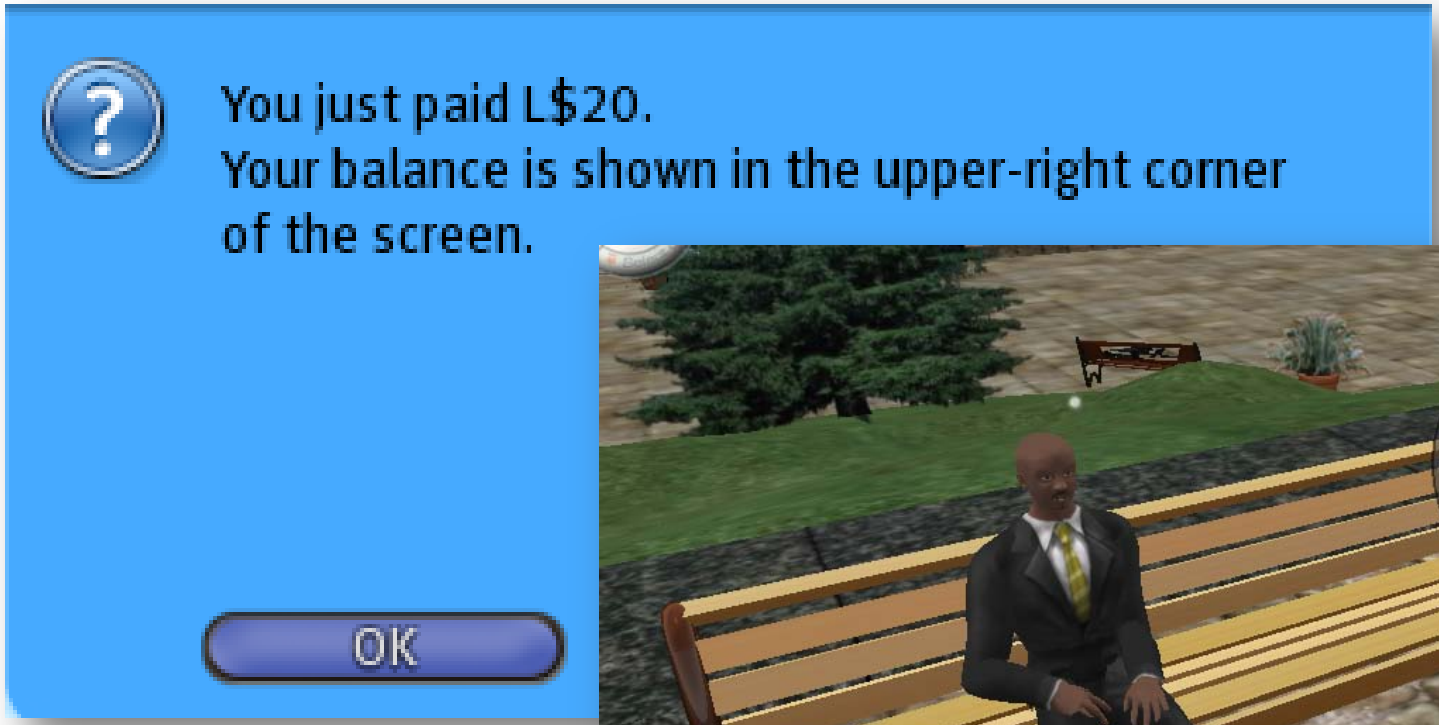
[8:20] Avatar1: Okay I wanted you all to know that I've started watching Twitter, and word is the Iran Protests are firing up again today!!!
[8:21] Avatar2: rally starts at four bridges at 11 am
[8:21] Avatar1: If you have Twitter, a simple thing you can do is set your location to Tehran, Iran, to confuse Iranian military forces who are monitoring Twitter
[8:23] Avatar3: to all iranians, fight for your right. we are on your side here in austria!!!
[8:24] Avatar1: Fresh VIDEO from today: http://www.youtube.com/watch?v=W-46HmGAfeM
[8:25] Avatar1: Following this link, and regularly refreshing, can help you keep up with events relatively live:
[8:25] Avatar1: http://search.twitter.com/search?q=%23iranelection
[8:29] Avatar1: AFP "Iran police fire tear-gas as 1000s mark 1999 unrest" http://hub.tm/?BCzjc #IranElection (This link also has some great Iranian artwork)
[8:33] Avatar2: we hoped to get the Iranian Country Specialist from Amnesty but because of the unrest, she has been called away. we will have her on Monday

History & Initial Investigations



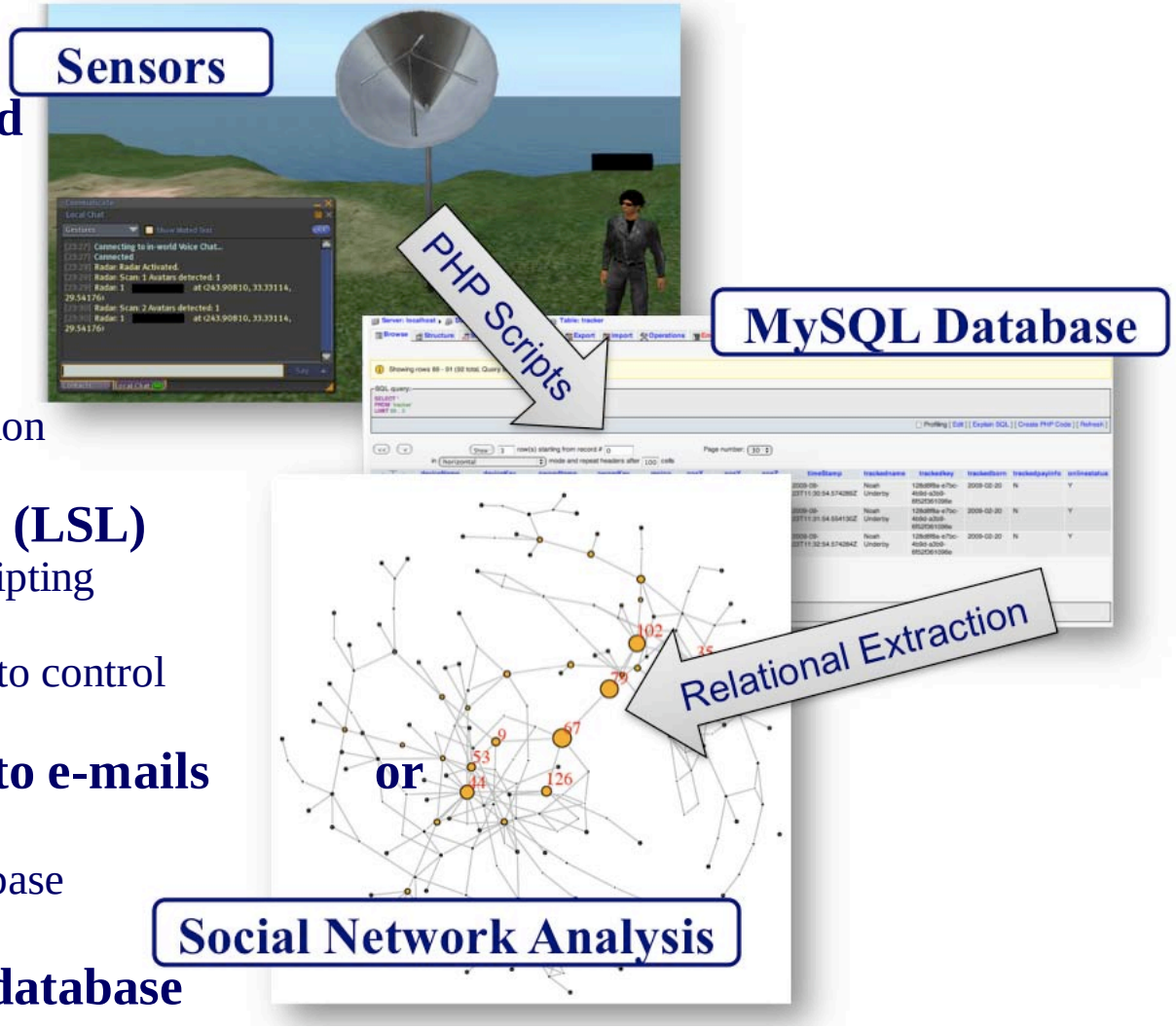


History & Initial Investigations



Sensing & Analysis Methodology

- **Non-persistent behavior and communications**
- **Types of information**
  - Avatar (and user) information
  - Communications and transactions (between users)
  - Region and location information
  - Object information
- **Linden Scripting Language (LSL)**
  - In-built state-event driven scripting language
  - Embedded within SL objects to control their behavior
- **Sensors automatically sent to e-mails or external database**
  - LSL -> PHP -> MySQL database
- **Analysis conducted on structured data within the database**
  - Social network construction
  - Social network analysis

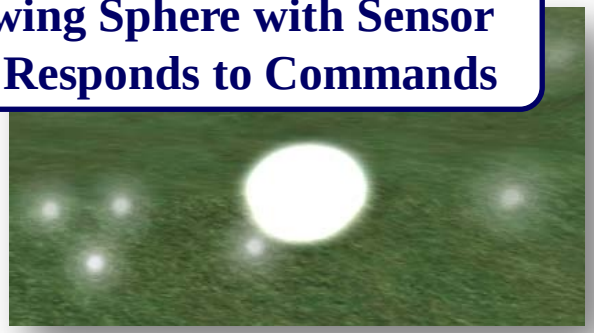


Sensing Objects

SPAWAR Systems Center ATLANTIC

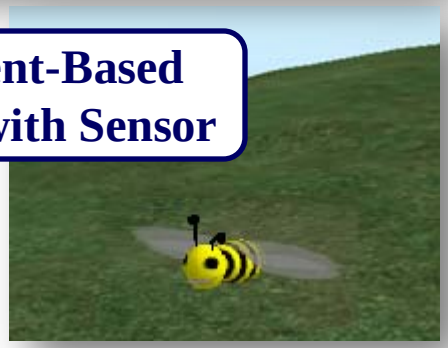
- **Physical appearance**
  - Sunglasses
  - Flying bee
  - Hovering sphere
  - Heads-Up-Display (HUD)
- **Movement**
  - Stationary
  - Wearable
  - Following
  - Patrolling
  - Agent-based
- **Visibility and solidity**
- **Sensor timing**
  - Regular intervals
  - User activated
  - Event triggered

Glowing Sphere with Sensor that Responds to Commands



Sensing Sunglasses

Agent-Based Bee with Sensor



- **Sensing capabilities**
  - Avatar names and profile information
  - Avatar location and proximity
  - Communication (chat) participants and content
  - Location/region information and coordinates
  - Group and object relationships
  - Online/offline status

Heads Up Display (HUD) Sensors with Data Sent to E-mail

Virtual World Sensor-Based Data

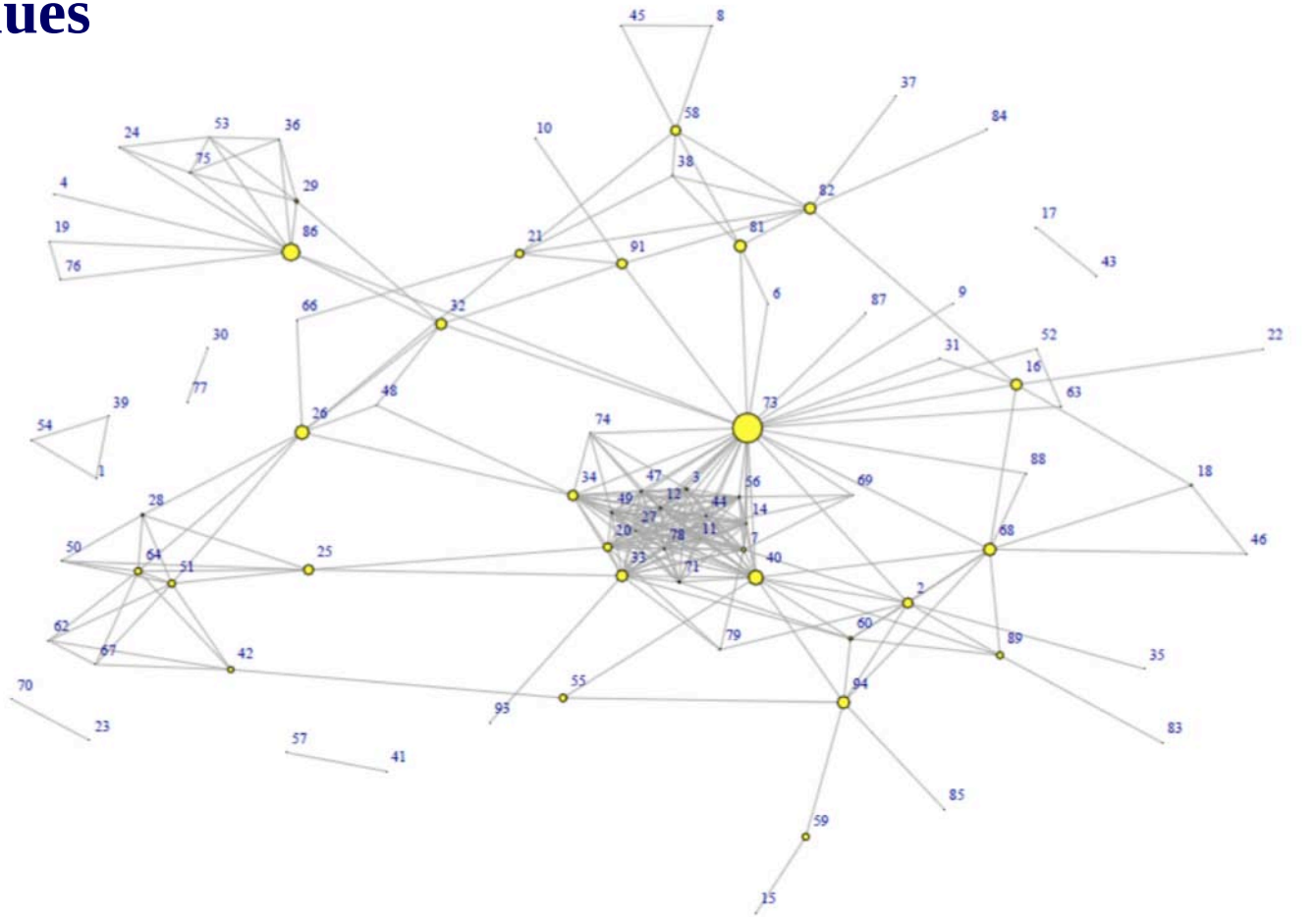
- **Avatar profiles**
  - Avatar name
  - Avatar description
  - Groups involved in
  - Avatar position and location
  - Sensing events (date/time/presence)
  - Online/offline
  - Birthdate (account creation date)
  - Payment information on file
  - Key ID
  - Chat events and messages
  - Avatars nearby at sensing events
- **Relationship profiles**
  - Avatars nearby
  - Groups
  - Visits the same region
  - Chats nearby
  - Direct chats
  - On friends list
- **Land profiles**
  - Region name
  - Region description
  - Region key ID
  - Owner or group owner
  - Region global coordinates
  - Region properties
  - Parcels and owners of parcels within regions
  - Events within region
- **Information that cannot be retrieved automatically using LSL**
  - Pictures (snapshots)
  - Video
  - VoIP chat
  - Instant messages
  - Animation information
  - IP addresses
  - Avatar locations outside a sim
  - Money transfers
  - Gender
  - RL information and location
  - Motivations for being in SL

Initial Test

- **Social network construction from virtual world data**
  - Communication-based
  - Group affiliations
  - Region and location affiliations
  - Manual approaches
  - Proximity-based
- **Initial test**
  - Sensing avatar position information within 96m range
  - Five uniformly spread locations within two regions of SL
  - Longitudinal data snapshots taken every 15 minutes
  - Relation information extracted based on proximity of avatars within data snapshots
  - 94 total avatars recorded over 48 hours

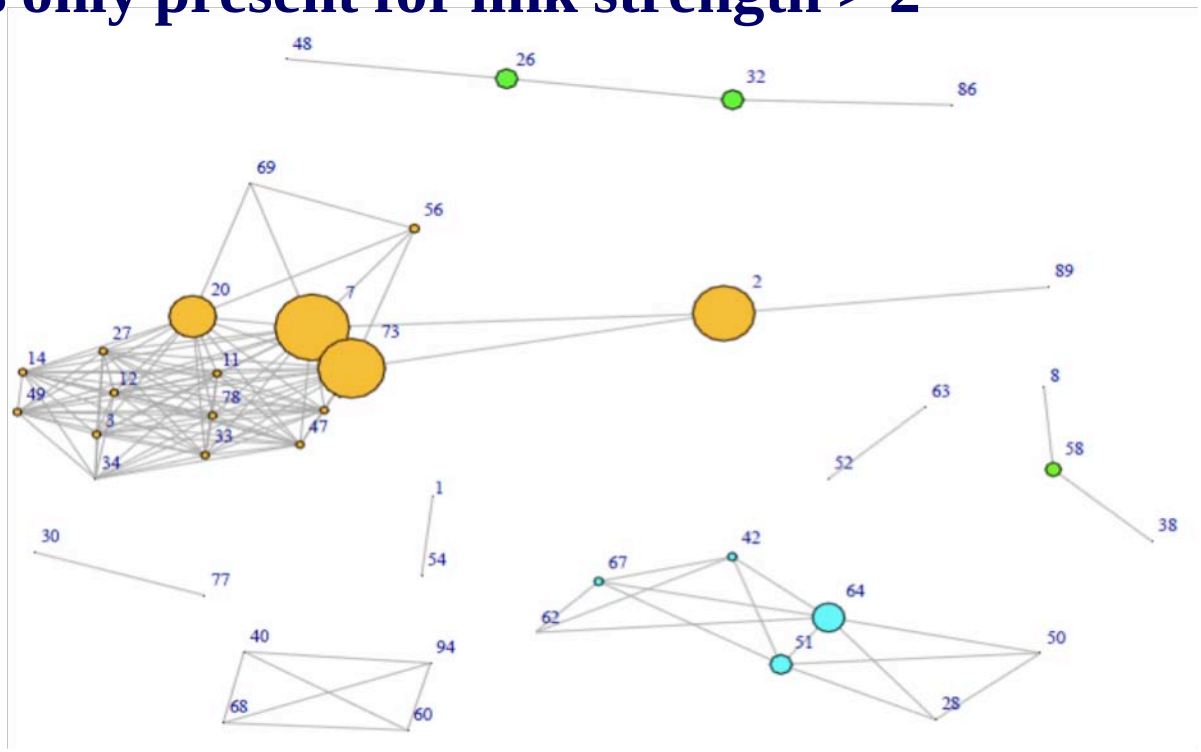
Results

- Undirected, unweighted social network graph
- Size of nodes is proportional to betweenness centrality values



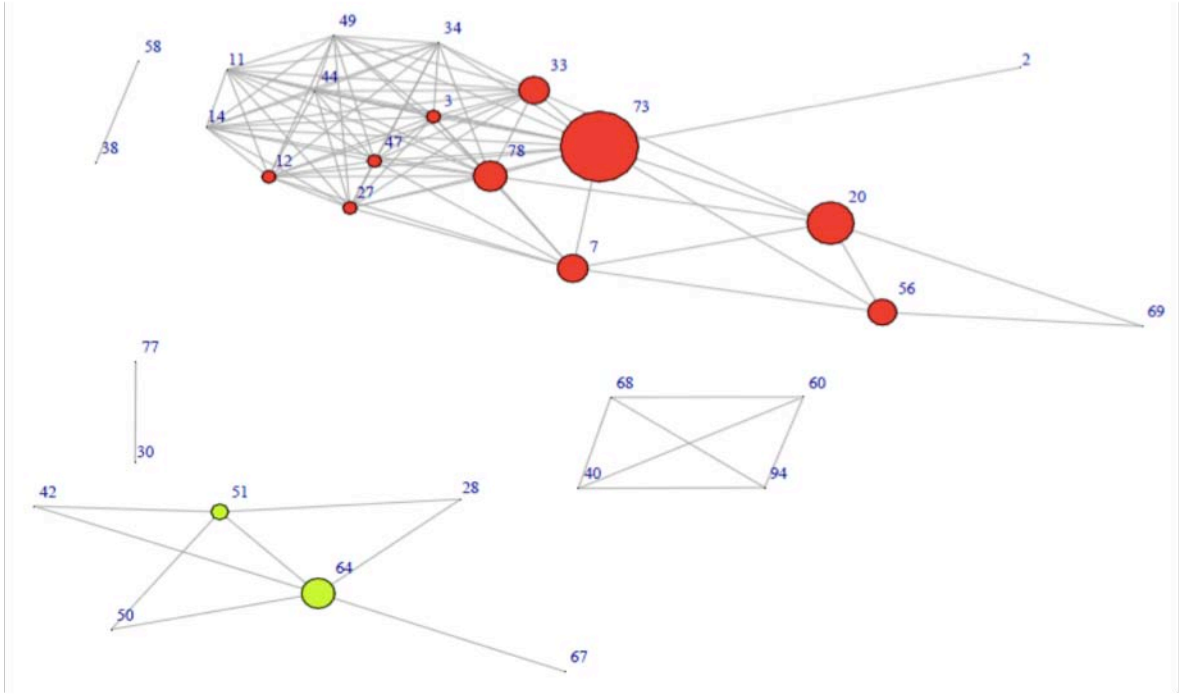
Results

- Undirected, unweighted social network graph
- Size of nodes is proportional to betweenness centrality values
- Colors correspond to connectivity within subgraphs
- Nodes only present for link strength > 2



Results

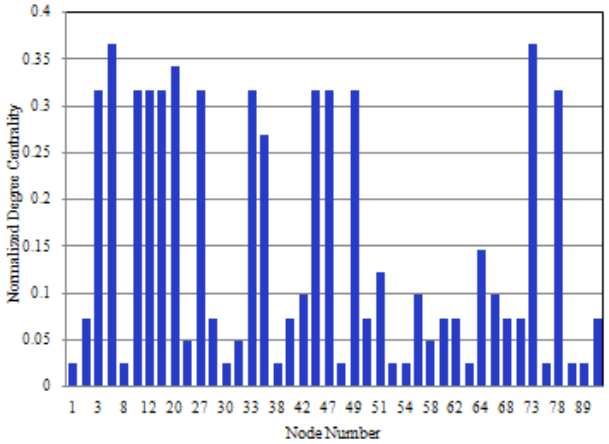
- Undirected, unweighted social network graph
- Size of nodes is proportional to betweenness centrality values
- Colors correspond to connectivity within subgraphs
- Nodes only present for link strength > 4

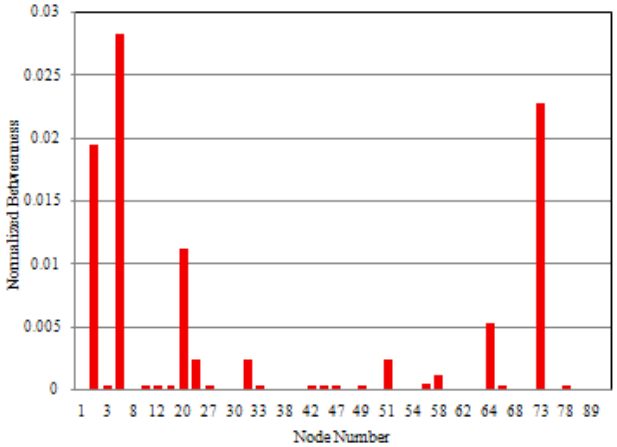


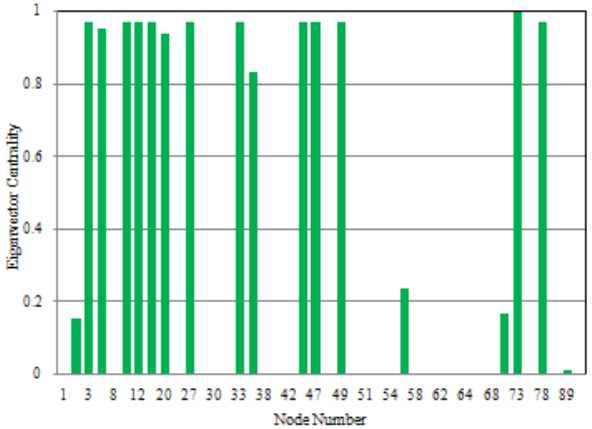
Results

- Undirected, unweighted social network graph
- Centrality distributions shown for graph with link strength > 2

Graph	Network Density	Clustering Coefficient
All links (Fig. 14)	0.075	0.686
Only Links with Strength > 2 (Fig. 15)	0.146	0.901
Only Links with Strength > 4 (Fig. 16)	0.211	0.867







Results

- Undirected, unweighted social network graph
- Centrality distributions shown for graph with link strength > 2
- Comparison between connected subgraphs with established SL groups

Connected Subgraph	SL Group	Percent Match
(1, 54)	(1, 54)	100.0%
(30, 77)	N/A	0.0%
(52, 63)	(52, 63)	100.0%
(8, 38, 58)	(8, 58)	66.7%
(26, 32, 48, 86)	N/A	0.0%
(40, 60, 68, 94)	N/A	0.0%
(28, 42, 50, 51, 62, 64, 67)	(42, 51, 62, 64, 67)	71.4%
(2, 3, 7, 11, 12, 14, 20, 27, 33, 34, 44, 47, 49, 56, 69, 73, 78, 89)	(3, 11, 12, 14, 27, 33, 34, 44, 47, 49, 78, 89), (56, 69)	77.8%

Summary & Future Work

- **Summary**
  - Combined sensing and social network approach
  - Initial test to extract network data
  - Compared persistent and non-persistent data in SL
- **Future Work**
  - More testing and analysis approaches
  - Current presence of terrorists or criminals in virtual worlds
  - Dynamics of behaviors in virtual worlds
  - Clandestine message passing
  - Identification of key nodes
  - Combined automated/manual intelligence approaches
  - Understanding physical characteristics of virtual users
  - The in-world context problem of virtual worlds