U.S. Army Research, Development and Engineering Command

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

A General Framework of Human Trust in Networks

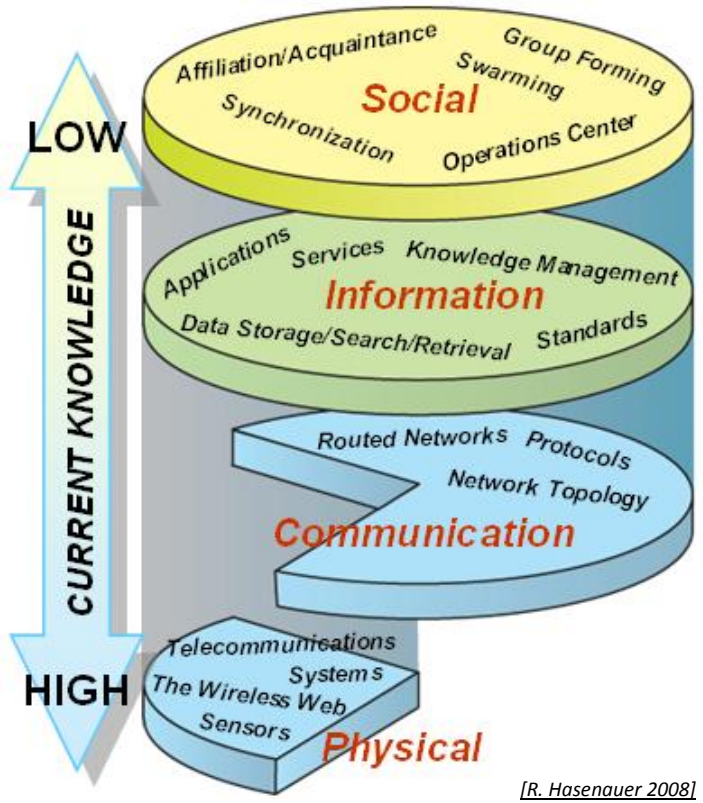
14th ICCRTS "C2 and Agility"

June 15, 2009

K. Chan, N. Ivanic, B. Rivera, E. Bowman

Motivation

- **Motivation:** Build tactical networks that maximize the capability/ability of the Soldier in performing mission objectives.
  - Presently, there is a lack in the understanding of the social/cognitive layers of the network science paradigm.
  - Furthermore, the interconnection of the communications, information and social/cognitive layers must be understood.



[R. Hasenauer 2008]

Challenges

- Specifically, networked devices and information services are a growing capability among the warfighter. However, several challenges arise despite advances in technology:
  - Information overload: The Soldier has access to many multimedia services (video, images, clips, http, chat, UAV feeds).
  - Transfer of information: The chain of command and the dissemination of information are potentially at odds.
  - Collaboration using the network: Soldiers need optimal and efficient capabilities to share and disseminate information.
  - Trust in network: Reliance and confidence in the battle command systems and networked devices is necessary.
- Trust as a metric to evaluate Soldier interaction with the network.

[www.spectrum.ieee.org]

Related Research Areas

- Dimensions of Trust: The ability of the user to gather information of its targeted environment and be able to make decisions based on these observations. The user and decision maker must possess a satisfactory amount of trust in this information.
  - Trust in Automation [Lee 04, Parasuraman 00]
  - Situational Awareness [Endsley 99]
  - Decision-making [Boyd 87]

- Trust Experiments: Validation of the models for human perception of video and dissemination of information is necessary.
  - Video perception studies [Ghinea 98, Chen, 06]
  - Collaboration Experiments [Moorman 93, Baba 99]

- Network Optimization: Many approaches for optimization of network performance using various metrics exist. Human trust in networks is a new metric for optimization.

Approach

Human Trust in Networks

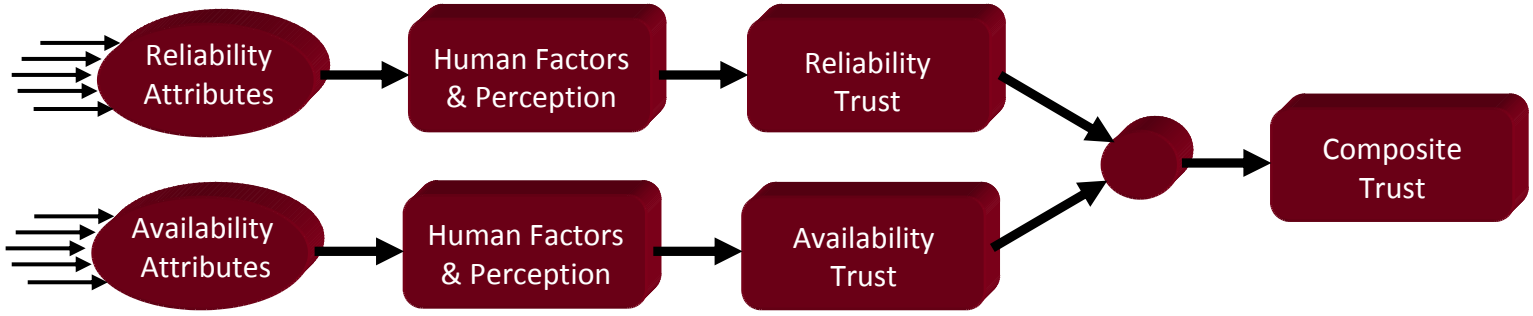
- Develop measurable models for human trust in networks (TiN)
  - Dimensions of trust : Network reliability, network availability
  - Composite trust
  - Quantifiable metrics of human trust vs. network parameters

- Experimental validation of trust models
  - Video tests for Human TiN
  - Preliminary results/analysis

- Determine approaches for network optimization
  - Routing layer: traffic rerouting, network topology optimization.
  - Application layer: information filtering, adaptive priority-based access control and delivery rate.

Human Trust in Networks Framework

General Framework of Trust in Networks



Availability

- → **Connectivity**: Routing protocols, servers in network, network topology, security/access control
- → **Channel Access**: MAC protocols, network traffic/congestion
- → **Data Latency:** MAC protocols, hop distances, node density

Reliability

- → **Data accuracy**: Synchronization of servers, data freshness/timeliness, signal-to-noise ratios,
- → **Data Security:** Data integrity, authentication, validation

Experimental Validation

- Validation using a video test
  - Determine the effect of degradation in the quality of video on the human performance to extract information.
  - Simulate a video stream from a unmanned aerial vehicle.

- One parameter of reliability in the network and its effect on the human trust in network using video.

- Measure objective vs. subjective performance and possible implications on network optimization.

- Preliminary Video Test
  - Varying frame error rate to simulate network QoS.
  - Experiment asked 2 questions/ mission objectives:
    1. Identification of the number of moving subjects, [0, 1, 2, …].
    2. Perception of the video being of sufficient quality, [Yes, No].

- Test Specifications:
  - 5 different video feeds with a variable number of people moving.
  - Range of 'frame' error rate for each video: {0%, 10%, … , 50%}.
  - Order of videos was randomly chosen.
  - Videos were only viewable once.

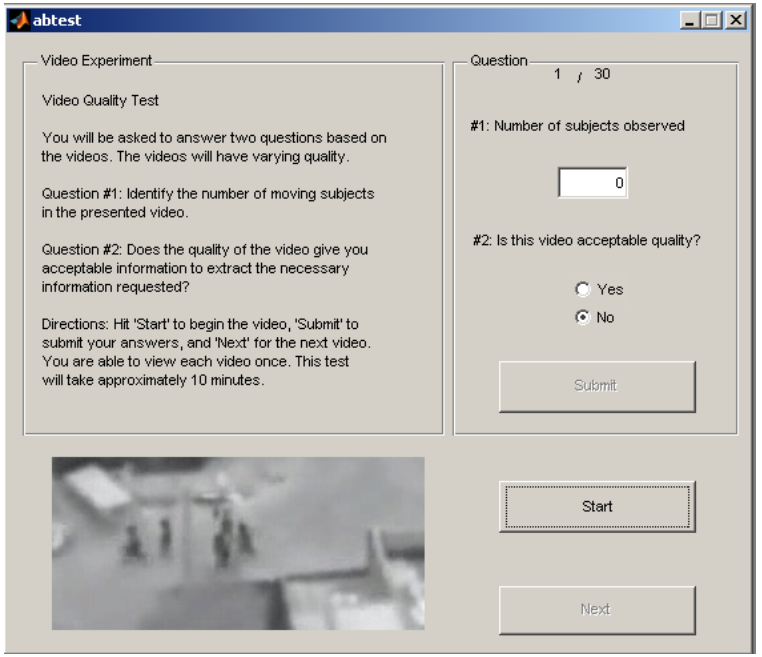
Observations

Experiential

- Learning from previously viewed video.
- Difficulty in identifying subjects that were not in the video for the entire duration.
- Distracting elements of video that were not part of the content (i.e. cross-hairs)

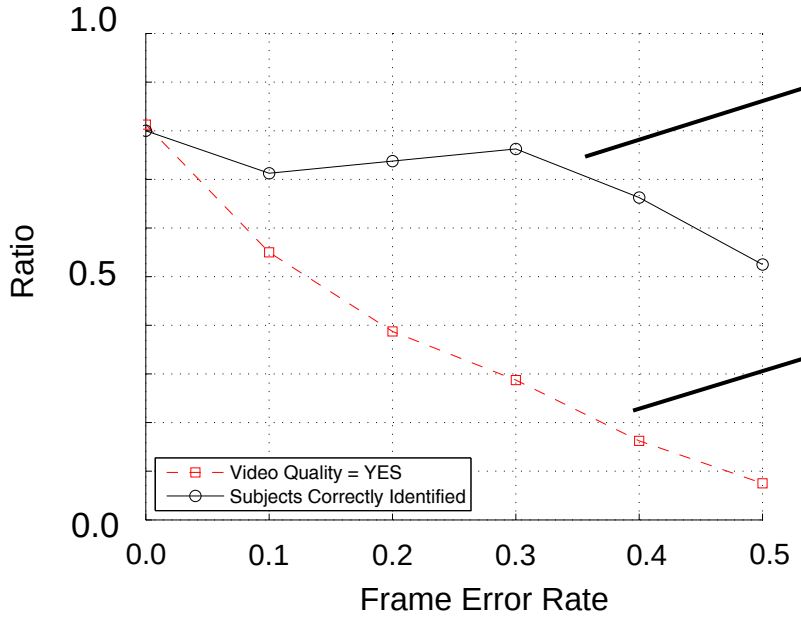
Implementation

- Training set to add familiarity to test.
- Answer submission methods:
  - Multiple choice, Text box
  - Allow user to submit the response “I don’t know how many subjects I see.”
- Increased video resolution.



Video Test Results I

- Results : Plot of the number of correct responses to question #1 and those answering YES to question #2 versus frame error rate.
- Objective measure of performance (subject identification) is maintained despite significant decrease in the subjective measure (acceptable video quality).
- Evaluating Human TiN metrics: Subjective vs. Objective measure.

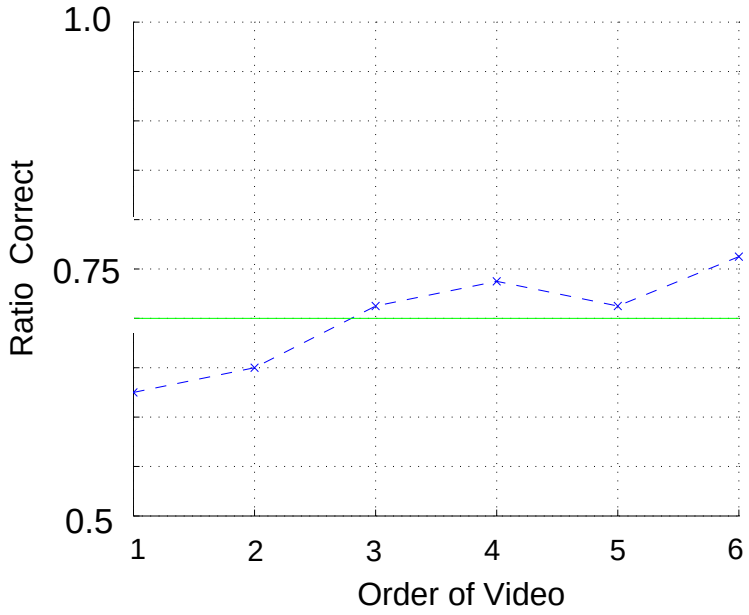


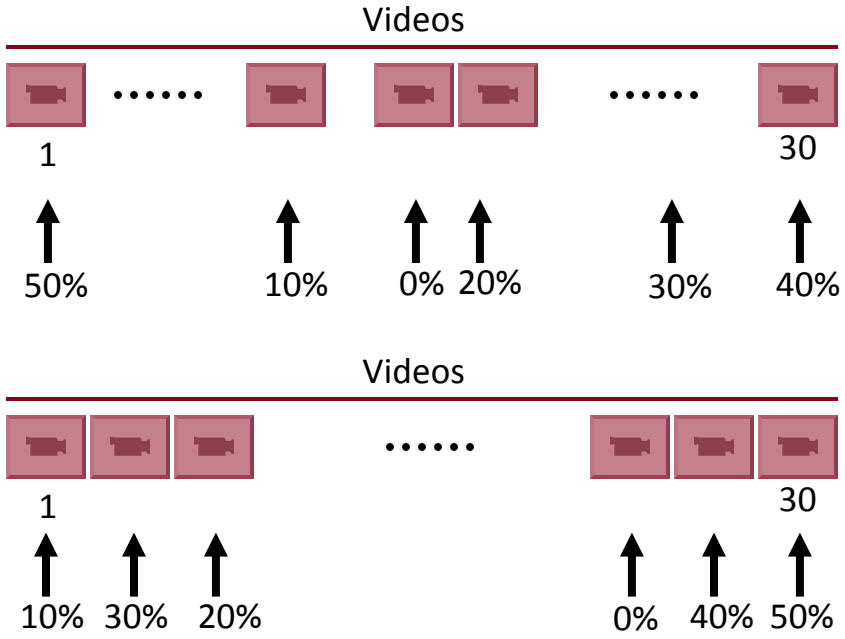
#1: Number of subjects observed: {Correct}

#2: Is this video acceptable quality? {YES}

Video Test Results II

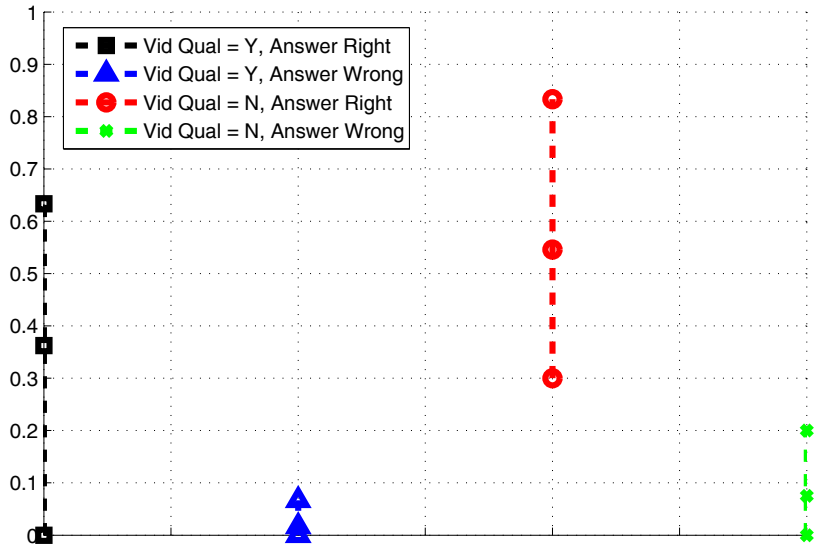
- The order of videos and error rates was randomly selected. Trends in responses exhibit a learning of the content of the videos based on order of viewing.
- From the first showing of the video to the last, there is a 13% (63%-76%) increase in percentage of correct answers.
- Mean of correct responses: 70%





Video Test Results III

- Distribution of the four combinations of responses:
  - {Yes} video quality, {Correct} response
  - {Yes} video quality, {Incorrect} response
  - {No} video quality, {Correct} response
  - {No} video quality, {Incorrect} response
- Statistics on these responses (max, min, mean, std. dev.).
- Results suggest and indifference to the frame error rate.



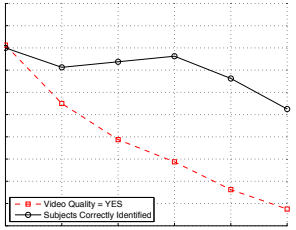
n = 25	Y, ✓	Y, ×	N, ✓	N, ×
mean( )	0.33	0.02	0.58	0.07
min( )	0.00	0.00	0.23	0.00
max( )	0.63	0.13	0.97	.20
σ^2( )	0.20	0.03	0.19	.06

Ideas on Network Optimization

- Network Optimization on Frame Error Rate (FER)
  - $Trust_{REL}(FER) = f (FER)$
  - Determine limits on FER to provide sufficient $Trust_{REL}$ for specific scenarios.

- Composite Trust:
  - Analysis using multiple attributes is necessary to establish a composite $Trust_{REL}$.
  - An overall Trust in Networks metric, $Trust_{TOT} = f (Trust_{REL}, Trust_{AVL})$.

$Trust_{REL}$(FER) vs. FER



Research Directions

- **Human Trust in Networks Models**
  - Consider dynamics of **composite trust** and the **time-varying** evolution of human TiN.
  - Establish a classification of mission objectives into the trust model. The **variation of mission objectives** have different requirements and affect associated trust models.
  - **Multiple networked users** and its affect on individual user TiN.

- **Experimental validation of trust models**
  - Build a comprehensive TiN Experiment environment with a multimedia (video/audio/image) database to allow for improved querying techniques

- **Network Optimization for a trusted, reliable and available network**
  - **Routing Layer:** Reroute traffic around a congested/failed node. Restructuring network topology to adapt to specific network environment.
  - **Application Layer:** Filter necessary information to soldier for optimal mission completion potential. Adapt network QoS and access to network services to individual soldiers based on mission completion requirements.

Summary

- A new general framework to measure human trust in networks that is based on network reliability and availability.
- Results of a video test to validate and illustrate the proposed trust framework.
- Possible implementation of the trust framework into network optimization approaches.