Human Factors in Developing Trustworthy IT Systems and Applications

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Outline

- Trustworthy IT Systems and Applications (ITSA)
- Challenges of Developing ITSA
- Human Factors in Developing ITSA
- Current State of Art
- Future Research

Evolution of IT Systems

- Mainframe (1950s)
- Personal Computer (early 1970s)
- Object-Oriented Computing (1980s)
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- Grid Computing (1990s)
- Services Computing (2001)
- Cloud Computing (2005)
- Internet of Things (2009)

Internet

Virtualization

Wireless

Smart Device

Current Trends of ITSA

- Based on ***service-oriented and cloud computing, and IoT paradigms with smart devices, large computing power, internet and big data***
- ***Standard interfaces*** for accessing capabilities offered by various providers
- Applications can be ***quickly composed*** of ***services*** to form ***workflows (business processes)*** for applications on IT systems.

Current Trends of ITSA (cont.)

- Consisting of **various heterogeneous components and smart devices**
- Relying ***public and private networks***
- Depending more on ***outsourcing services***
- ***More information and resource sharing***
- ***Adaptation*** to dynamic application requirements of users or environments (functional and QoS)
- ***Interoperation of heterogeneous services, components, and devices***

Trustworthy ITSA

- ***Trustworthy ITSA (TITSA)*** are needed due to
  - Over public or private networks, as well as mobile networks – more open to ***attacks***
  - Interactions involving ***unknown entities***
  - ***Dynamic*** and ***pervasive environments***
  - Large-scale and cross-domain ***service collaborations***
  - ***Distributed intelligence*** and ***control***
  - ***Dynamic QoS expectations*** for multiple workflows

Trustworthy ITSA ***(cont.)***

- Major aspects
  - ***Human***
    - Users and collaborators
    - Service and infrastructure providers
    - Insiders and outsiders
  - ***Devices, software, hardware, networks,*** and ***systems***
  - ***Dynamic user requirements and environments***
  - ***Dynamic security policies*** and ***enforcement***
  - ***Effective techniques***
  - ***Cost, usability*** and ***efficiency***

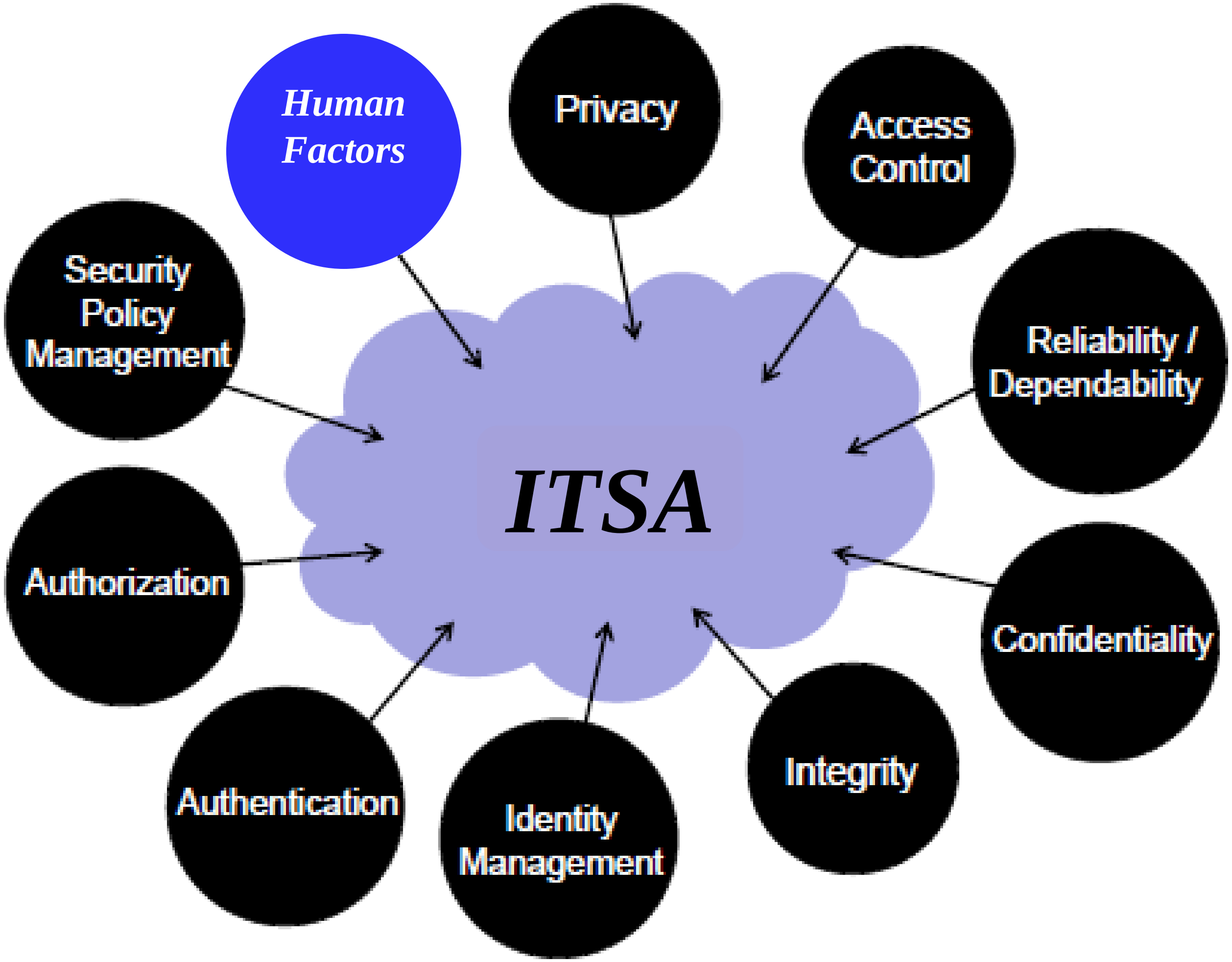
Trustworthy ITSA (cont.)

- Various system technologies needed for developing IITSA
  - Security
  - Trust management
  - Situation awareness
  - Runtime adaptation
    - QoS monitoring and analysis
    - QoS requirement trade-off
    - Resource allocation

Concerns of ITSA Users

- Most ITSA users are concerned with ***leakage of their sensitive data*** because their data is processed and stored on machines owned and operated by various service providers, not controlled by users.
- Due to severe limitation of resources available in mobile devices and characteristics of mobile networking, ***security*** issues is more severe for ITSA involving mobile devices and networking.

Challenges: Security for ITSA



Challenges of Developing TITSA

- ***Interactions among services*** in TITSA may have ***unforeseen consequence***s in trust, security, QoS, and risk
  - Untrusted/malicious services
  - Intermediate results generated during service interactions may reveal sensitive information
  - Trustworthiness of service providers, infrastructure providers and users

Challenges of Developing TITSA **(cont.)**

- ***Multiple QoS requirements*** from multiple users for various applications
- ***Runtime tradeoffs*** among expected QoS requirements
  - Example: Mechanisms providing ***security protection*** are often ***computationally intensive*** and require certain sacrifice in other QoS (e.g. service delay and throughput) with available resources
- ***Cost, usability*** and ***efficiency***

Challenges of Developing TITSA **(cont.)**

- ***Dynamically changing environment***
  - Make ***assessing trust and risk*** difficult
  - Need ***situation awareness*** due to dynamic trust and risk
  - Need ***adaptive enforcement*** of security policies
- ***Information needed*** for making decisions regarding trustworthiness usually ***distributed on multiple services and organizations.*** Need the following:
  - ***Cooperative decision making*** (e.g. delegation, policy composition with multiple organizations, collaborative QoS management, risk assessment, trust evaluation)
  - ***Pcient enforcement*** of ***distributed security policies***
  - ***Protection*** against various entities

Challenges of Developing TITSA ***(cont.)***

- ***Service selection*** and ***composition***
  - How to select ***more appropriate services*** and compose them to satisfy both functional and QoS requirements of various users, while ensure ***overall system trustworthiness*** and ***security***?
  - Need ***meaningful*** and ***quantitative metrics*** for ***trustworthiness, security*** and various attributes of overall TITSA
  - How to make ***service ranking*** to identify "better" services satisfying their requirements

Human Factors in TITSA

- In general, a ***human factor*** is a ***physical, psychological or cognitive property of an*** **individual or an individual in a community**, specific to humans and influencing technological systems as well as their applications.
- **Examples**: Influences, interests, relationships (collaboration/competition), opinions (positive/negative/neutral, support/against), knowledge (expertise), reputation, wisdom, physical and psychological factors (stress, fatigue, fear, happy).

Human Factors in TITSA (cont.)

- IT systems become more powerful, and their ***applications*** become more ***diverse*** and ***pervasive***
- ***Human factors*** are increasingly influential on the quality and efficiency of generating the results because
  - ITSA getting more ***embedded,*** increasingly involving ***multi-party collaborations*** and often more ***pervasive***
  - Applications must address multiple quality aspects expected by users, such as security, privacy, trustworthiness and performance

Three Levels of Human Factors

- Level 1. Direct Human-and-Human Relations
  - Collaboration of among ITSA users
- Level 2. Indirect Human-and-Human Relations
  - First-time collaborations among the users based on past data
- Level 3. Human in Communities
  - Influence among ITSA users
  - Knowledge sharing among the users
  - Matching ITSA users’ interest with applications

Direct Human-and-Human Relations

- Challenges:
  - How to quantify human factors in terms of the determinants, such as ***workload on the human, fatigue, learnability, attention, vigilance, human relations, human performance, human reliability, stress, individual differences, aging, safety, and results of decision making.***
  - How human factors affect humans themselves?

Indirect Human and Human Relations

- Example:
  - In ITSA, the providers upload their services/applications. The users search the service/application directory for the CBS and select the services/applications they need. Besides the quality of the services/applications, each user is concerned with the ***trustworthiness*** of the services.
  - Challenge: How can a user choose a ***trustworthy service***?
  - Related human factors: human relationships, stress, feedback, etc

Human in Communities

- Challenges:
  - How do the human factors from ***one person affect other persons in the community***?
  - How do the human factors ***from other persons in a community affect one person in the community***?
  - How do the human factors from ***one person in a community spread*** in the ***ITSA used by the community?***
  - …

Current State of Art

- **Incorporating human factors in developing TITSA**
  - Research has been mainly conducted by researchers in psychology and sociology, and few computer scientists and engineers.
  - Primarily focus on human-machine interactions, human-computer interactions, situation awareness, and human errors

Current State of Art (cont.)

- Automated service composition based on various formal specifications
- QoS-aware service composition in ITSA
- Tradeoffs among security and multiple QoS in ITSA
- Adaptive resource allocation in ITSA
- Design of ITSA for QoS Monitoring and adaptation
- Testing of ITSA

Current State of Art (cont.)

- **Trust estimation in SBS**
  - Flexible trust model for distributed service infrastructure (Z. Liu, University of North Carolina at Charlotte, S. Yau, Arizona State University)
  - Trusted computing platforms in web services (Nagarajan, et al, Macquarie University, Australia)
  - Trust management for context-aware service platforms (Neisse, et al, University of Twente, the Netherlands)
  - Improving trust estimation in CBS (S. Yau and P. Sun, Arizona State University)

Trust Estimation in TITSA

- **Trust management** needs to be incorporated in TITSAs to estimate service providers' trustworthiness so that users can decide whether to accept the services provided by the providers.
- Limitations of existing trust estimation approaches:
  - Only similarity of user profiles is considered
  - Based on pairwise trust relationship, which normally does not include the transitive property in the propagation of trust among service providers.

Trust Estimation in TITSA (cont.)

- Initialization
  - Initialize the trust values of all service providers of the CBS based on historic transactions using QoS profiles, collaboration and competition.
- Utilization
  - Update the trust values of the service providers in current transaction using QoS profile.
  - Update the trust values of all the other service providers using competition and collaboration.

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Effect of QoS Profile on Trust Estimation

- If the feedback QoS profiles of a selected service is **better** than its corresponding claimed QoS profiles, then the service user can decide the service provider is **more trustworthy**, and consequently **increase** the estimated trust value of the service provider.
- Otherwise, **decrease** the estimated trust value of the service provider.

Improvement of Trust Estimation Using QoS Profiles (cont.)

- **Rule 1**. ***Competition relationship*** increases the trust values of the participants in the competition group.
  - Competition limits free-ride
  - The more time one spends, the more one is likely to trust the people in this group.
- **Rule 2**. ***Successive collaboration relationship*** increases trust.
  - When two persons collaborate well with each other, they tend to solve problems together and help to build trust between them.
- **Rule 3**. ***Transitive property of trust***.
  - Whenever one service provider’s trust value changes, the trust values of his/her neighbors will also change accordingly.
  - The trust value of a service provider is uniformly propagated to all the other service providers he intends to compete or collaborate with.

Improvement of Trust Estimation Using QoS Profiles (cont.)

- Rules 1 and 2 show the positive correlation between trust and competition or collaboration.
- Rule 3 defines how the trust values should be propagated among the whole network of CBS.
  - The propagation of the trust values of service providers is similar to PageRank (a webpage reputation estimation approach).
  - The more people who intend to compete or collaborate with a service provider, the more trustful the service provider is.

Expertise Needed to Incorporate Human Factors in Developing TCBS

- Services and cloud computing
- Software and systems engineering
- Networking, including mobile ad hoc networks, intelligent devices, and social networks
- Information assurance and security
- Cognitive science
- Psychology
- Business
- Culture
- …

Future Research: Human Factors in Developing TICBS

- Develop meaningful ***metrics*** to quantify human factors and QoS aspects of CBS, including trust, security and others useful for developing TITSA
- Develop a general ***framework with necessary techniques and tools*** to effectively incorporate a variety of relevant human factors in developing TITSA
- Validation

Future Research: Human Factors in Developing TITSA

- ***Trust Management***
  - Existing definitions of trust are based on the assumption that the user to be evaluated is the one to be evaluated ***based on the user's account,*** i.e., the relationship between the user and the user's account, referred as the ***identity trust*** of the user, is ignored, but should be considered.
  - Identity trust for mobile smart devices users is extremely difficult. Possible research issues:
    - What characteristics does identity trust have?
    - What is the relationship between identity trust and commonly understood trust?
    - What need to be done to incorporate identity trust management in mobile clouds?

Thank you