32nd Annual INCOSE international symposium
hybrid event
Detroit, MI, USA
June 25 - 30, 2022

Red-Teaming as a Research Validation Method for Systems Engineering Thesis Students

Timothy L.J. Ferris, Fanny Camelia, Tuomas Mattsson, Rogerio C. Machado

www.incose.org/symp2022

Introduction

- Many universities offer graduate programs in SE
- The SE curriculum in most universities teaches methods to perform SE tasks
- The definition of SE does not elucidate where SE belongs along a continuum between
  - Exploring situations
    - Views SE as a method of discovering apposite solutions
  - Proposing apposite solutions
  - Implementation of engineering processes to
  - Deliver the best possible delivery of a specified systems solution
    - Managing the engineering work to enable delivery
- The view of SE to find apposite solutions views SE as a research methodology
- That is, that the practice of SE is inherently a research task

Introduction - Research

- Traditional views of academic research emphasize development of assured and, preferably, generalizable knowledge about the subject matter
  - One common approach is the so-called “scientific method”
  - Many other methods are now accepted, particularly in social sciences and investigation of professional practice
- Traditional “scientific method” focuses on knowledge ABOUT the subject investigated
  - Often results in abstraction that does not generate practical impact
  - Suggests a different approach may be required if the goal is practical effect.
- Research in SE may be either
  - Research ABOUT topics relevant to SE to impact the practice of SE; or
  - Development of knowledge THROUGH the practice of SE

Introduction – Research and validation

- This paper presents “red-teaming” as a validation method in SE research
  - And its application to thesis work
- Red-teaming is an additional/alternative method that may be used for research validation (applicable to some projects)
  - Other methods are available and may suit other projects – peer review and supervision monitoring
- Peer review is applied to products describing research
  - Papers, reports and theses, to determine if the product validly reports what was found
  - Research supervisor monitoring is limited by the circularity problem
    - The supervisor has been involved in project design and so is not intellectually independent of the work
- All research needs validation
- The appropriate validation method depends on the nature of the project

Research in/for SE – Fundamental methods

- Research ABOUT SE may be performed to
  - Discover objective description of SE
  - To discover knowledge ABOUT SE methods and techniques
  - To discover knowledge that should help improve practice
- Research THROUGH SE may be performed to
  - Discover means to address the specifics of systems
  - Discover approaches to the solution of challenges
  - Discover practical knowledge of systems and their situations of deployment
  - Discover better ways of doing the SE of a system

Research in/for SE – Subjects

- Subjects of research of both ABOUT and THROUGH classes include
  - SE effectiveness
  - SE methods of work
  - Specific methods, processes and techniques of SE
  - Discovery of what system objectives should be
- The choice of approach (ABOUT or THROUGH) depends on project purpose and knowledge kind needed

Research in/for SE – V&V

- Any research project needs a method of verification and validation of the output
- In most cases verification and validation in the ABOUT paradigm is established in the research process
  - The V&V processes of the knowledge are part of the routine approach to this kind of research
    - Covered in most RM courses

Research in/for SE – V&V

- Research THROUGH SE
  - In this paradigm knowledge is developed through doing a project like a system design emerges through doing a project
  - Verification and Validation processes are needed to ensure the results of the project are tested and shown to be strong
    - If a project is to discover knowledge about something that already exists then Verification
    - If a project is to develop a novel way of doing something then Validation
- A verification process can be conducted by the researcher
  - Verification is achieved through research method rigour
- Validation needs the view of an outsider to the project who can review if the findings/outcome are suitable for purpose

Red-Teaming - Applications

- Red-Teaming is a technique used in many fields, usually to deliberately apply a challenge to a system to test system response under conditions of threat/attack
- Uses of red-teaming
  - Challenge dominant patterns of thought to find weaknesses in the dominant patterns – usually in military wargaming or security scenarios
  - Attempt intrusion studies of hardware systems
  - Red-teaming is used to investigate other scenarios with potential threats
  - Red-teaming is used in academic research into security related topics
  - Network intrusion testing

Red-Teaming – Opportunities and challenges

- Opportunity of red-teaming
  - The red-team apply a challenge to the subject of the challenge which the red-team choose
    - These tests have the advantage of being separated from the system design reasoning
- Challenges of red-teaming
  - The red-team need to have knowledge of multiple techniques related to the kind of thing they are challenging so they can apply challenges to which the system may be vulnerable
  - In sensitive areas security matters may result in people with relevant knowledge who are permitted to be involved may be acculturated to ‘standard’ methods of work – and not able to find creative challenges

Student theses in SE

- Students may perform projects of both ABOUT SE and THROUGH SE kinds
- All research projects have a “forward path” involving data collection, analysis and formation of results and findings
- All projects need a Verification or Validation process
  - Research ABOUT SE can be verified by rigorous process
  - Research THROUGH SE must be validated

Student theses in SE

- Masters theses often combine primary data collection and analysis to characterize a scenario followed by making a design proposal of something
  - This kind of project enables students to demonstrate competence in many elements of the SE process
  - The challenge: the proposal is the result of the forward path process leaving a need for a review to change the output status from "interesting curiosity" to "substantiated"
  - A proposal could be evaluated using modelling – but the model follows the researcher's assumptions that led to the proposal
- Proffered Solution - Validation by a Red-team
  - Red-team method challenges the proposal with ideas not embedded in the forward path process

Project 1 - Description

- Project to develop a plan to apply the principles and values of agile methods to Finnish Defense Force acquisition
- It is believed that the agile acquisition model proposed would enable adaptation in a rapidly changing global environment
- Multiple agile methodologies share common characteristics and traits seen in their principles, values and practice
  - High collaboration and self-organization of project teams
  - Welcoming change
  - Valuing functionality over documentation
  - Valuing individuals and interaction over processes and tools
- Derived from Scrum, Extreme Programming (XP) and Dynamic System Development Method (DSDM).

Project 1 - Method

- Apply the first three steps of Soft System Methodology (SSM)
  - Consider the problematic situation – produce a Rich Picture
  - Express the problematic situation – produce a Context Diagram
  - Formulate a root definition – using Checkland's CATWOE
- Produce flow and sequence diagrams to describe processes and interactions between stakeholders and process products; and hump diagrams (show relative amount of SE activities during project stages)
- These diagrams were used to model
  - Current acquisition process
  - Recommended acquisition process changes
  - Final, post R-T, proposed acquisition process

Project 1 – Red-Team application

- The As-Is and initial version of the To-Be process were prepared
- The As-Is models were evaluated in an email exchange between the student and RT members
  - Each RT member was a project management professional in defense acquisition with over 20 years of military and managerial experience.
  - RT members were given a brief description of the model, the proposed changes and the rationale for change
  - The RT members gave written comments, drawings and review notes for each model.
  - A refined process was developed and presented to the RT for re-evaluation.
- The RT evaluation of the baseline familiarized RT members with the student's interpretation of the baseline process
- First evolution incorporated "stakeholder involvement and collaboration" principle
- Second evolution integrated "welcoming change" and "functionality over documentation" principles
- Third evolution embedded "individuals and interaction over processes and tools"
- The review sought validation and feedback for its application in acquisition

Project 1 – Red-Team challenge

- Red-Team Challenge The validation of the agile acquisition proposal relied on the RT members, their expertise in the subject matter and their familiarity with the Rting process. The small number of RT members engaged, their lack experience in the project subject and their unfamiliarity with the Rting process, may have yielded a narrow view of the subject than would be preferable. Organizing the RT based on the principles in the Red Team Guide (Development Concepts and Doctrine Centre, 2013) would improve the validation process.
- A validation process that relies on the RT members' experience may limit generalization of applicability. For example, the involvement of RT members in past FDF Land and Sea acquisition projects raises questions about the applicability of the proposed agile model to Air projects.

Project 2 - Description

- Performance Based Logistics (PBL) contracting strategy
  - Supplier provides outcomes demanded and is paid based on performance
  - Outcomes are purchased- not discrete products or services
  - So proper choice of performance measures pushes supplier efficiency, effectiveness, waste reduction, cost reduction and improved product/service quality
- Project goal
  - Develop a reference structure model for the main elements of a generic fixed price PBL contract for In-Service Support to warships
- The reference model represents:
  - Best practice
  - Core elements and relationships required – permitting adaptation to specific needs

Project 2 - Method

- Literature review to explore the range of possibilities
- Exploratory questionnaire to find public/private sector experience (and potential R-T interest
- Problem modelling – context diagram and problem definition – buyer and supplier perspectives
- Causal loop, fault tree and use case diagrams to investigate relationships of system elements; to identify the root causes of underperforming PBL agreements
- The models became the basis guideline for contract requirements
- Final output: contract reference model presented in SysML
- Reference model was validated through the R-T evaluation

Project 2 – Red-Team method application

- A Red Team formed questionnaire respondents who had indicated interest in contributing to the project
- RT work was prompted with the questions:
  - Is there something missing?
  - Is there something that you believe should not be there?
  - Do the relationships show the right set of relationships?
- Revise the model based on the critique received
- Resubmit the model to the RT for the final round of evaluation

Project 2 – Red-Team challenge

- Four agreed BUT only one able to provide feedback on time
- Model review based on one specialist, navy officer with procurement and ILS experience
  - Risk of ideosynscratic result
- RT only involved in final stage, the reference model
  - Not the developmental models and diagramming of earlier stages
- Effect
  - Only partial view of system context, problems and mechanisms
  - Involving the RT at an earlier stage would strengthen the final reference model
  - Better for the RT to be involved throughout design and development

Observed challenges

- The projects were done by full-time students
  - Time-boxed to 10 weeks starting mid-May
  - Method based on cooperation of third parties is significant risk – a Plan-B is needed
  - Multiple rounds of proposal and review are precluded
- It is challenging to find suitable red-team
  - Relevant knowledge
  - Willing to provide response on required timeline
  - Actual fulfilment of agreed action
- One response is the “friends and family” approach to finding red-team members
  - Friends may agree to participate out of relationship but have limited deep knowledge
  - Reduces non-response problem
  - Decreases quality of review

Observations of Red-teaming

- Both projects have shared characteristics
  - Develop a method to improve something based on background work to make a ‘should work’ solution
  - Could test using a desk process – but circular reasoning
- Red team critic brings an independent view of the subject
- Limitations of method
  - Specific subject knowledge
  - Shared culture (ethnic, organisational, …) that limits critique
- Challenge of repeatability
  - Outcome depends on who does the red-team work – better to use multiple, diverse (re the subject matter) people
  - Diverse team members bring different views of the subject matter

Conclusions

- All research needs a method of validation of results
  - Scientific projects about phenomena include verification and validation in their method
  - Employers sponsoring students often seek a project of direct value (not research about an applicable phenomenon)
    - Projects are to create something of value to the employer
    - Focused on case specifics
    - Validation method is needed
    - Limited time prevents implementation and testing of anything
  - Red team method gets independent review/critique
  - Red teaming is useful for verification/validation stages to assure the idea is ready for concept demonstrator implementation

32nd Annual INCOSE international symposium

hybrid event

Detroit, MI, USA

June 25 - 30, 2022

www.incose.org/symp2022