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Intelligent Software Decoys: Presented at the Eiffel Summit

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Outline

- What is an intelligent software decoy
- Motivation for exploring the concept of a decoy
- Overview of related work
- Introduction to a software-decoy architecture
- Discussion of language and operating system support for software decoys
- Current work, other research, and funding status

Intelligent Software Decoy

- An abstraction for protecting objects from malicious attacks by mobile agents
  - We assume the attacker (i.e., rogue agent) will try to change the behavior of the targeted object
- Intended to deceive an agent into believing it is the object it advertises itself to be
- Provides a means for revealing the presence of an attacker

All Objects Can Serve as Decoys

- Decoy mode is triggered when the target object receives a message that violates the object-agent contract in one or more ways
- Decoy behavior is specified in an ante chamber
  - When the precondition fails, the object's interaction with the agent is controlled internally via a constraint language
    - The constraint language is an extension to the semantics of the Eiffel programming language

Concept Based on the Unified Power of Attack (UPA)

- One should try to neutralize one's opponent by means of, in the following order, reducing or eliminating the opponent's
  - Will to attack
  - Proximity of attack
  - Ability to attack
- Our conceptualization of intelligent software decoys is based on "software *jiu jitsu*"

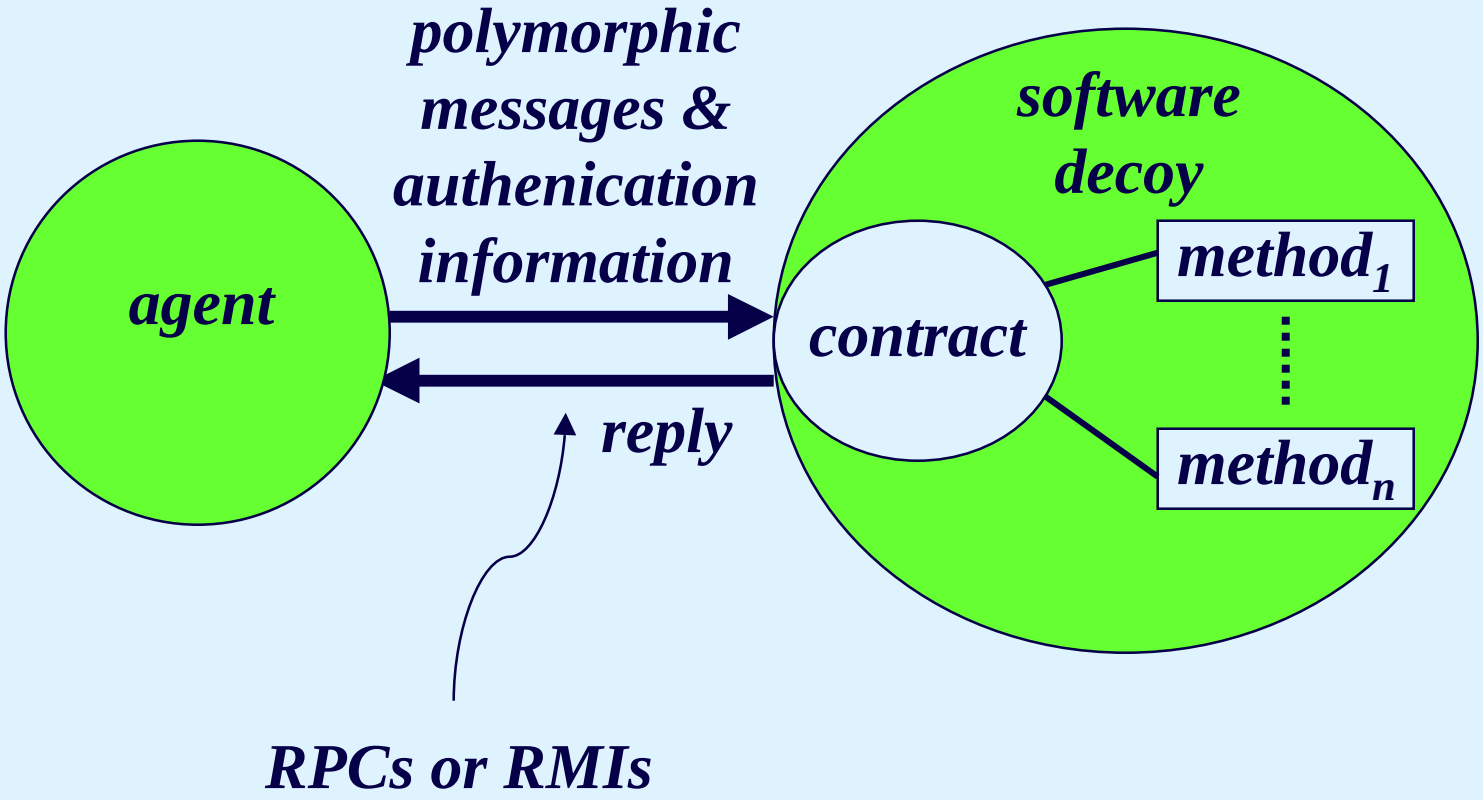
Properties of Intelligent Software Decoys

- **Intelligent**
  - **Adapt their behavior to changes in their operating environment**
- **Autarkic**
  - **Do not rely on the internal state of other objects to protect themselves**
- **Polymorphic (chameleon-like character)**
  - **Disguise themselves by altering their object-interface contracts at run-time**

Properties of Intelligent Software Decoys

- **Policy-governed**
  - **Behavior governed by pre- and postconditions, in addition to class invariants**
- **Self-replicating**
  - **Replicate themselves, either in an autonomous or cooperative manner**

Agent-Decoy Interaction



Motivation

- Software from which distributed systems are composed needs to be protected from malicious attack
  - Recent “Code Red” worm
- Some of the features of distributed systems make them tempting targets
  - for instance, dynamic patching schemes
- Explore the use of Meyer’s design-by-contract model to protect the components of distributed systems

Related Work

- **Concept of software-based deception is not new**
  - **Misrepresentation of an agent's true goal, for purposes of negotiating with other software agents**
    - **Reasoning with incomplete information**
    - **Byzantine Generals problem**
  - **Reasoning about the intelligent behavior of software-based systems**
    - **Turing's "imitation game" (a.k.a., Turing test)**
    - **Self-deceiving software-based systems**
  - **Software-based tools for constructing and maintaining deceptions in virtual worlds**
    - **for instance, Cohen's Deception Toolkit (DTK)**

Related Work

- **Information-theoretic techniques for detecting evidence of deception**
  - **for example, authentication-coding schemes**
- **Use of the "art of illusion" in the design of human-computer interfaces**
  - **Managing the virtual reality that the user of the interface perceives**

Novel Aspects of Our Software Decoys

- **Software contracts are used to**
  - **Specify security policy, and mediate the interaction under policy between the intelligent software decoy and the attacker**
- **Postconditions and invariants place fail-safe constraints on the behavior of the decoy**
  - **Contain and observe the attacker, while attempting to prevent the attacker from learning that the attack has been detected**
- **Class invariant makes it impossible for the agent to change the decoy's behavior via the interface**
- **Decoy can change its appearance via polymorphism**

Intelligent Software-Decoy Architecture

- Software decoys are objects within components
- Connectors between components are named interfaces
  - Name advertised to other components need not be unique
  - Consist of an ordered list of arguments
    - Primitive types or object classes (supporting polymorphic types)
- Each class is composed of its own arguments and behavior
  - Arguments are used to access methods of objects within a component

Intelligent Software-Decoy Architecture

- Modification of the software decoy's interface is supported by polymorphism
  - Change one or more of the
    - Arguments
    - Order of the arguments
    - Data type or class of arguments
    - Number and position of dummy arguments
- Component interaction is based on a contract that is controlled by assertions as well as a polymorphic type

Intelligent Software-Decoy Architecture

- An agent cannot modify the behavior of the decoy beyond the extent to which such modification is permitted by the parent class of the decoy
- Venus flytrap model
  - If the precondition fails, then the decoy does not thwart the attack, but rather contains the attacker
    - Invariant and postconditions defend the object
    - The decoy deceives the attacker into thinking its attack has not been detected, maintaining the interest of the attacker
    - Observe and try to determine intent and source of attack

Language and Operating System Support for Software Decoys

- Eiffel is a natural choice because it provides explicit support for
  - Design-by-contract
  - Inheritance of the assertions from ancestor classes by a descendant class
    - Needed to preserve the integrity of the software contracts
- Sombrero or StratOSphere distributed operating system are also a natural choices
  - Single address space operating systems support the naming conventions needed for implementing intelligent software decoys

Practical for Use with Legacy Systems?

- **Yes**
  - **One can wrap existing software objects with contracts, especially objects that are critical for the correct behavior and availability of mission-critical systems or the underlying information infrastructure**
- **Eventually, one would want to rewrite the software objects, such as the implementation of the File Transfer Protocol**
  - **This is costly, but one can gradually introduce contracts through the use of contract-wrappers**

Practical from a False-Positive View?

- Need to minimize the probability that a decoy will turn a false positive into a situation in which the object denies service to a legitimate user (or agent)
  - For example, a buffer overflow can be due to either
    - An egregious use of the interface (i.e., non-attack scenario)
    - An attack
  - In signature-based systems, the signatures tend to be general, and there are issues of temporal validity of the signatures
- Decoy provides the object time to assess the nature of interaction and signature

Potential Weakness and Solution

- **Relies on a strong foundation: the distributed operating system (e.g., 2K or Legion) along with the local network operating system (e.g., Windows NT)**
  - **If the operating system is not trusted, then the attacker will circumvent the contract interface of the object, preferring to instead attack the weak infrastructure**
- **Proposed solution**
  - **Incorporate the intelligent software decoys into the design of the operating system itself**
    - **Most modern operating systems are full of security holes that could be partially addressed with the use of software contracts**

Significantly Different from Other Approaches?

- Yes
  - Represents a major shift in security paradigm
    - Integration of formal methods (design-by-contract), deception techniques, and Unified Power of Attack, and actual application of software engineering principles
- Complementary to some other approaches
  - For example, it could be used in conjunction with the Return Address Defender (Chiueh and Hsu, State University of New York at Stony Brook)
    - Addresses the primary weakness of RAD: RAD itself is susceptible to attack via a buffer overflow
      - RAD could be wrapped with the decoy software (i.e., a contract)

Current and Proposed Work

- Developing a formal model of the intelligent software decoy architecture
- Exploring the use of various types of decoys
  - For instance, “volunteer” and “drafted” decoys
- Intend to investigating the technical feasibility of realizing the intelligent software decoy architecture by using the “Code Red” worm
  - The worm exploits the IIS Indexing Service DLL via a buffer-overflow technique

Status of Publications and Presentations

- Published an article on the concept in the Proceeding of the Workshop on Engineering Automation for Software Intensive System Integration (Monterey, Calif., June 2001).
- Several presentations at universities and research institutes within the United States

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