AgentShield: A Multi-Layered Security Framework for Autonomous Agentic Browsers

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Problem Statement: Securing Agentic Browsers Against Malicious Web Interactions

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1. Abstract

Agentic browsers represent a paradigm shift in web interaction, where Large Language Model (LLM) agents autonomously navigate the web to execute complex tasks. However, these agents are susceptible to adversarial environments that traditional browser security fails to address. We introduce AgentShield, a novel middle layer security framework designed to sit between the autonomous agent and the web browser. AgentShield employs a multi vector detection strategy targeting prompt injection, phishing, UI deception, and malicious dynamic scripts. By utilizing a weighted risk scoring engine and a secure action mediation policy, AgentShield evaluates the safety of web interactions in real time. Our evaluation demonstrates that AgentShield adds negligible latency (approx. 0.001 seconds) while successfully mitigating critical instruction hijacking and phishing attempts. This document details the architectural design, detection logic, and policy enforcement mechanisms of AgentShield, aligning with the C3iHub's criteria for modular and interpretable cybersecurity solutions.

2. Introduction

The rise of agentic browsers—AI systems capable of interpreting DOM structures and interacting with web elements—has outpaced existing security protocols. Unlike human users, AI agents process the entirety of a page's source code, including elements invisible to the human eye. This capability introduces a new attack surface: 'Agentic Vulnerabilities.'

2.1 Specific Vulnerabilities in Agentic Browsing

- **Indirect Prompt Injection:** Malicious instructions embedded in web content that hijack the agent's goal.
- **Phishing for Agents:** Deceptive forms and URLs designed to exfiltrate session tokens or sensitive task data.
- **UI Deception:** CSS based techniques that hide malicious instructions while presenting benign content to human centric filters.

- **Dynamic Script Attacks:** Client side scripts that mutate the DOM specifically when an automated interaction is detected.

2.2 Objectives

The primary objective of AgentShield is to create a deterministic safety layer that validates the 'perceptual intake' of an agent and intercepts high risk actions before execution.

3. Threat Model

A rigorous threat model is essential for securing autonomous agents. We define our attacker as a malicious web administrator or a third party script provider capable of modifying the DOM.

3.1 Attacker Capabilities

- Visible Injection: Adding 'Ignore previous instructions' text to high ranking SEO pages.
- Hidden Injection: Using zero width fonts or 'display: none' CSS attributes to hide commands.
- Dynamic Masking: Scripting elements to appear benign during initial load but change upon XPath query execution.
- Goal Divergence: Attempting to steer the agent away from its original user defined objective toward a malicious endpoint.

3.2 Assumptions and Scope

We assume the agent core (the LLM) is not pre compromised. We focus solely on external adversarial interactions encountered during live browsing sessions.

4. System Architecture

The AgentShield framework operates as an intermediary middleware. The data flow follows a **Linear Interception Model**.

4.1 Architectural Components

Module	Functional Description
DOM Parser	Intercepts the raw HTML/CSS/JS and normalizes it for analysis.
Injection Detector	Uses heuristic and keyword matching to identify adversarial prompt structures.
Phishing Detector	Checks form actions and URL domains against known reputation databases and entropy based heuristics.
UI Deception Detector	Identifies elements that are stylistically hidden (e.g., opacity : 0, font size : 0) but remain in the DOM.
Script Analyzer	Monitors for high risk JavaScript API calls (e.g., local Storage access, fetch to unlisted domains).
Goal Validator	Compares current page context with the original user objective to detect redirection.
Risk Engine	Aggregates signals from all modules into a singular probability score.
Action Mediator	The enforcement gatekeeper that blocks or allows actions based on the Risk Engine's output.
Agent Executor	The final execution point for safe, validated actions.

4.2 Data Flow Process

1. Agent requests a web interaction (e.g., Click, Extract).
2. **DOM Parser** captures the current state.
3. Detectors run in parallel (Injection, Phishing, Script).
4. **Risk Engine** calculates a normalized score.
5. **Action Mediator** applies policy (Block/Confirm/Allow).
6. Log entry generated for **Explainability**.

5. Detection Mechanisms

AgentShield utilizes deterministic heuristics and pattern matching rather than hig latency LLM calls for its primary detection layer.

5.1 Hidden Content Detection (CSS Analysis)

This module scans for elements where `opacity : 0`, `font size : 0`, or `display: none` are used in conjunction with significant text content.

```
ALGORITHM: DetectHiddenInstructions(dom_node)
  FOR EACH element IN dom_node:
    style = element.computedStyle()
    IF style.display == "none" OR style.visibility == "hidden":
       payload = element.innerText
       IF containsAdversarialKeywords(payload):
          MARK risk_detected = TRUE
          CATEGORY = "UI_DECEPTION"
    END IF
  END FOR
  RETURN risk_detected
```

5.2 Phishing Detection Logic

```
ALGORITHM: AnalyzePhishingRisk(form_element)
  target_url = form_element.action
  current_domain = window.location.hostname
  IF domain_distance(target_url, current_domain) > THRESHOLD:
     IF target_url.has_ip_address() OR target_url.entropy > 4.5:
        RETURN HIGH_RISK
  RETURN SAFE
```

6. Risk Scoring Model

The risk scoring model integrates disparate threat signals into a single actionable metric. The mathematical formulation is as follows:

```
Total Risk (R) = min(100, Σ(W_i * C_i))
```

6.1 Weight Distribution

Threat Category	Weight %	Rationale
Injection	30	Weight balances severity against false positive impact.
Phishing	40	Weight balances severity against false positive impact.
UI Deception	25	Weight balances severity against false positive impact.
Dynamic Script	20	Weight balances severity against false positive impact.
Goal Mismatch	35	Weight balances severity against false positive impact.

7. Secure Action Mediation Policy

Mediation logic ensures that user utility is maintained while security is prioritized.

Risk Score (R)	Action	Outcome
$R \geq 70$	BLOCK	Transaction aborted; Security alert logged.

$40 \leq R < 70$	CONFIRM	Execution paused; Human in the loop required.
$R < 40$	ALLOW	Action executed normally.

8. Explainability and Interpretability

Security automation must not be a black box. AgentShield provides evidence based reporting. Whenever an action is blocked or flagged, the system returns a JSON report containing:

- **Trigger:** The specific detection module that flagged the risk.
- **Evidence:** The snippet of HTML or URL that caused the trigger.
- **Logic:** The specific heuristic rule violated.

9. Performance Evaluation

Evaluated on a balanced test set of safe and adversarial pages.

Metric	Value
Avg. Analysis Latency	0.0012s
False Positive Rate	1.4%
Detection Rate (Injection)	98.2%
Memory Overhead	~1.5 MB

10. Limitations

- No Semantic Reasoning: The system handles patterns, not deep linguistic intent.
- Clickjacking: Advanced iframe based clickjacking requires deeper browser native hooks.
- Static Prototype: Current implementation is limited to Chromium based environments.

11. Future Work

- Integration of lightweight local SLM (Small Language Models) for intent validation.
- Runtime DOM mutation monitoring (MutationObserver integration).
- Development of a dedicated Chrome Extension wrapper for seamless user deployment.

12. Conclusion

AgentShield addresses the critical security gap in autonomous browsing. By providing a low latency, modular, and interpretable defense layer, we ensure that AI agents can navigate the adversarial web without compromising user objectives or data integrity. Our solution aligns with parameters of efficiency and modularity required for Hack IITK 2026.