SmartVNC: An Effective Remote Computing Solution for Smartphones

Cheng-Lin Tsao, Sandeep Kakumanu, and Raghupathy Sivakumar
Georgia Institute of Technology

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Remote Computing from Smartphones

- Smartphones: mobile phones w/ advanced capabilities
  - Overtook PCs in global shipments in 2010 [source: CNN, Feb 2011]

- Remote computing from smartphones
  - Allowing users to access a remote PC, ex. VNC and RDP
    - Accessing applications and data in a PC when being away from it
    - Accessing a PC instance in VDI (Virtual Desktop Infrastructure)
    - Remote IT support for troubleshooting
  - Availability and popularity of remote computing clients
    - AndroidVNC, TeamViewer, etc: 2.5M+ downloads in Android

Knowledge workers spend 35% of time at their desks. [source: Harvard Business Review, Sept 2011]
User Experience Today

- Demo of remote computing from a smartphone
  - Client: AndroidVNC in Samsung Galaxy S Android phone
  - Server and PC application: MS Windows and Intuit QuickBooks
  - Task: generating a sales report and exporting it into csv format

- Real-user experiments
  - 22 users, 9 applications, 54 tasks of 3 complexity levels
  - Metric: opinion score (1=poorest, 5=best)
  - Poorer user experience with remote computing from smartphones
    - Consistent observation with Linux, iPhone, and/or RDP
  - More serious degradation from higher task complexity when using smartphones

![Graph showing mean opinion score for PC and Mobile VNC across easy, medium, and hard task complexities.]

4.45 3.12 4.30 2.57 4.09 2.20

- Graph showing mean opinion score for PC and Mobile VNC across easy, medium, and hard task complexities.
Understanding User Experience

- **Task effort**: number operations required for a task
  - Mouse clicks & keystrokes in PCs; touch actions in smartphones

- **Task effort inflation from smartphones**
  - Causes: the zooming, panning, keyboard, and error problems

\[
\text{TaskEffort}^{RCS} = \text{TaskEffort}^{PC} \times \text{Inflation}
\]

- **Correlation analysis**
  - Correlation between task effort and opinion score in remote computing from smartphones

![Graph showing the correlation between task effort and opinion score](image)

**Graph Details**:
- **x-axis**: Task effort in VNC
- **y-axis**: Opinion score in VNC
- **Data Points**:
  - Easy: +355%
  - Medium: +232%
  - Hard: +232%

![Bar chart comparing PC and Mobile VNC](image)

**Bar Chart Details**:
- **y-axis**: Average task effort
- **x-axis**: Task complexity (Easy, Medium, Hard)
- **Legend**:
  - PC
  - Mobile VNC
  - +355%
  - +232%
Core Construct: Aggregation

- Reducing task effort by aggregating repetitive sequences of operations in user activity

Q1. Does redundancy exist in user activity?
- Tracing user activity
  - Activity monitor tool
  - 10 volunteer users
  - Recording all operations in all applications
  - Average period: 12.5 days
- Analyzing activity redundancy
  - Average redundancy: 34.32%

Q2. How do we efficiently harness the redundancy?
- Macros: a recorded sequence of instructions
  - Application macros [Mickens ‘10, Leshed ‘08, Hupp ‘07, Bolin ’05, Excel]
  - Raw macros [Chang ‘04, AutoHotkey]

Q3. How do we design and realize a system for smartphone users?
SmartVNC

<table>
<thead>
<tr>
<th>Goals</th>
<th>Application macros (ex. Excel)</th>
<th>Raw macros (ex. AutoHotKey)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application agnostic</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>Robust</td>
<td>O</td>
<td>X</td>
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<tr>
<td>Extensible</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Task effort reducing</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Easy adoption</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Overview

- Creating robust, general, and extensible macros to aggregate operations on the PC
- Invoking macros easily in remote computing from the smartphone
- Generic design elements for any PC platform, smartphone platform, and remote computing protocol
Application-Agnostic Smart-Macros

Smart-macros: robustness of application macros and generality of raw macros

Key design
- Tapping into a GUI accessibility framework (ex. Microsoft UI Automation) for addressable GUI element information

Details
- Extracting the GUI element handle for each operation
  - FromPoint() for mouse clicks and FocusedElement() for keystrokes
- Retrieving an identifier as (name, auto_id, ctrl_type)

Raw macros
- Application agnostic
- Not robust
- mouse clicks
- keystrokes

Smart-macros
- Application agnostic
- Robust
- operating system
- event
- GUI element

Application macros
- Application specific
- Robust
- function call
- software component
Task Effort Reducing Front-end

- Easy and non-intrusive access to macros in remote computing from smartphones

- Key design
  - Tailored interface in reducing task effort from smartphones with seamless integration into the remote computing client

- Details
  - Collapsible overlay on the remote computing client
    - Showing macro playback progress via remote computing
  - Task effort reduction
    - Grouping macros by application
    - Automatic application opening
    - Automatic zooming and panning the front-end view to the focused GUI element
    - Fast playback that minimizes time on task
Parameterization and Extensibility

- Accommodating variations and extensions in macro playback
  - Parameterization: replacing certain operations
  - Extensibility: interrupting playback to add/remove operations

- Key design
  - Identifying parameter operations that only change the state of the associated GUI element

- Details
  - Automatically categorizing operations by the control type
  - Allowing the user to manually specify parameter operations
  - Providing choices for parameter operations in runtime
  - Allowing the user to add raw inputs to a macro or abort it
System and Prototype

- Two-ended enhancement solution on top of remote computing
- Prototyping Testbed
  - SmartVNC server
    - Dell desktop (2.8 GHz/3GB/19” screen/WinXP SP3)
    - Coexisting with unmodified RealVNC server
  - SmartVNC client
    - Samsung Galaxy S (1GHz/512MB/4” screen/Android 2.1)
    - Integrated with AndroidVNC
  - Access network
    - Local Wi-Fi 802.11g (54Mbps)

- Demo: exporting a sales report using SmartVNC System and Prototype

Performance Evaluation Methodology

- **Metrics**
  - **Macroscopic**: time on task and task effort
  - **Microscopic**: subjective opinion and system overhead

- **Experimental methodology**
  - **22 volunteers**
    - Students of ages between 20 and 30
  - **54 tasks of 3 complexity levels (easy, medium, and hard)**
    - 9 PC applications: Word, Excel, PowerPoint, Outlook, Quicken, IE, Visio, Project, and SharePoint
  - **Real-user experiments**
    - Using (after practicing) PC, mobile VNC, and SmartVNC
    - Pre-recorded macros for SmartVNC
  - **Trace-based experiments**
    - Evaluating achievable effort reduction in real user behavior
Macroscopic performance

- Mobile VNC inflates task effort by 3.32x to 4.55x (average 3.73x).
- SmartVNC reduces task effort from smartphones by 83% to 86%.
- SmartVNC requires less effort than PC in certain tasks (average 0.61x).
- Time on task is similar to task effort.

Subjective opinion

- Lots of users have poor experience with mobile VNC.
- Almost all users give good or best opinion to SmartVNC.
- Task effort reduction improves UX.
Performance (2/2)

- **Overhead analysis**
  - **Server (measured w/ MS perfmon)**
    - CPU: higher usage due to fast playback
    - Memory: unoptimized code but sustainable
  - **Client (measured w/ SystemPanel)**
    - CPU: lower usage w/ less interaction
    - Memory: efficient integration

- **Trace-based evaluation**
  - Split operations in the collected traces
    - Repetitive or non-repetitive
  - Calculating total effort in smartphones
    - Repetitive: reduced effort (0.61x)
    - Non-repetitive: inflated effort (3.73x)
  - Average reduction from VNC: 37.71%
Summary

- Poor user experience and high task effort in remote computing from smartphones
- Propose SmartVNC to reduce effort with operation aggregation
  - Application-agnostic smart-macros
  - Task effort reducing front-end
  - Parameterization and extensibility
  - Offline macro recommendation
- Prototype and evaluate SmartVNC in testbed
  - Significant performance improvement in task effort, time to task, and subjective opinion score
  - Minimal system overheads at the client