SmartVNC: An Effective Remote Computing Solution for Smartphones

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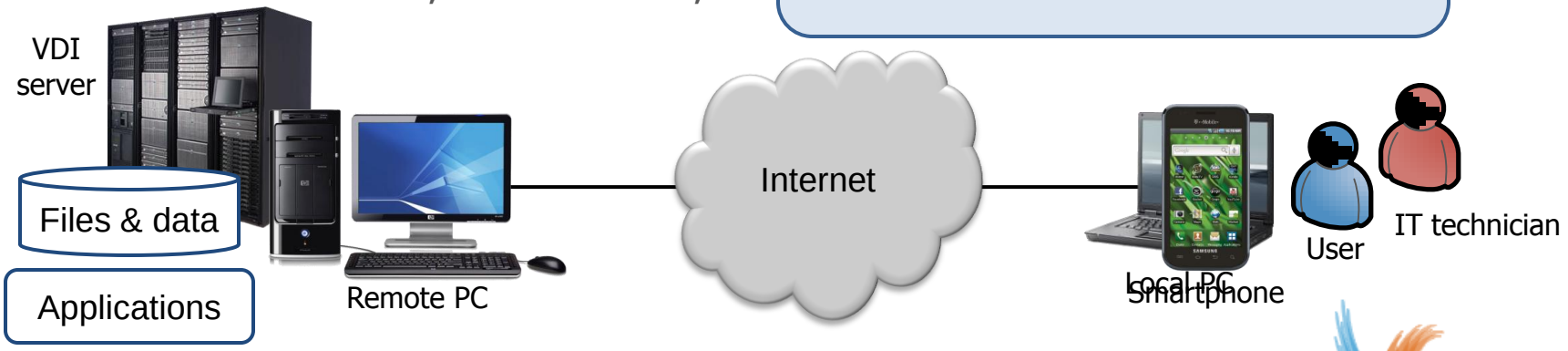
Remote Computing from Smartphones

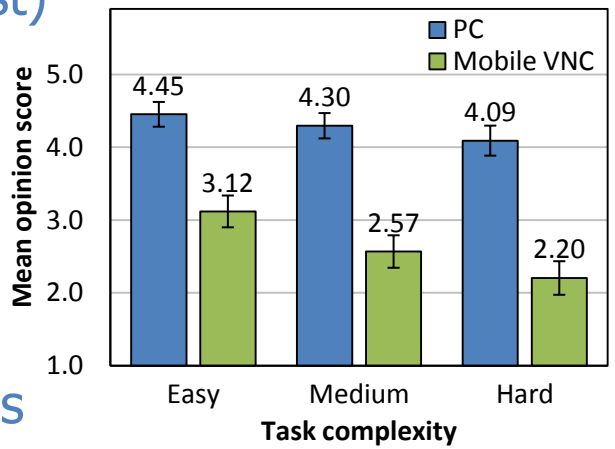
- Smartphones: mobile phones w/ advanced capabilities
  - Overtook PCs in global shipments in 2010 [source: CNN, Feb 2011]
- Remote computing from smartphones
  - Allowing users to access a remote PC, ex. VNC and RDP
    - Accessing applications and data in a PC when being away from it
    - Accessing a PC instance in VDI (Virtual Desktop Infra cture)
    - Remote IT support for troubles
  - Availability and popularity of re
    - AndroidVNC, TeamViewer, etc

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

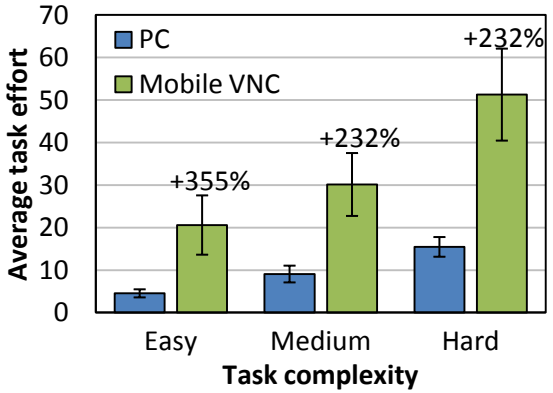


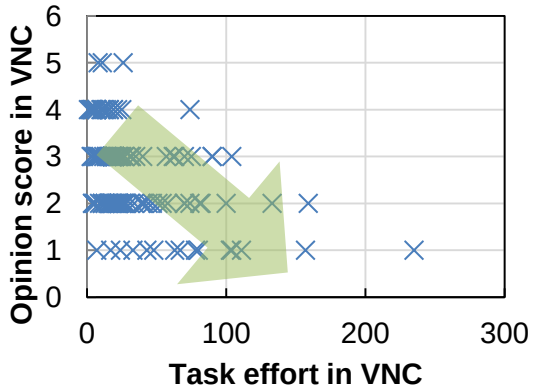
Understanding User Experience

- 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

$$TaskEffort^{RCS} = TaskEffort^{PC} \times Inflation$$

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





Core Construct: Aggregation

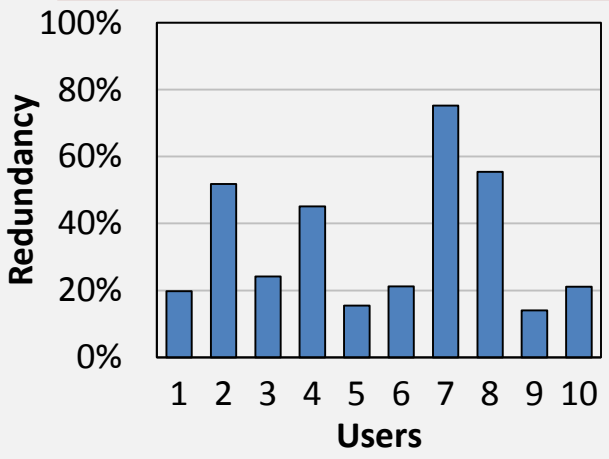
- Reducing task effort by aggregating repetitive sequences of operations in user activity

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%

Yes

Operation Aggregation



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

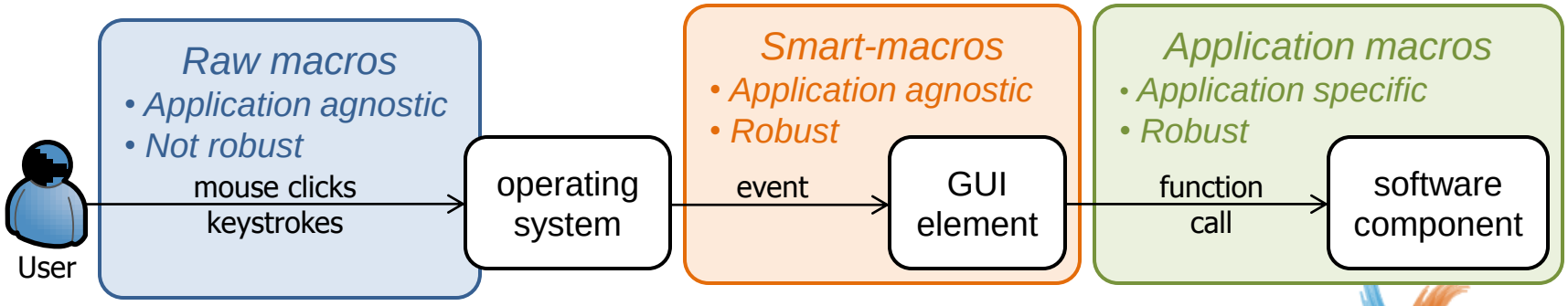
Goals	Application macros (ex. Excel)	Raw macros (ex. AutoHotKey)
Application agnostic	X	O
Robust	O	X
Extensible	X	X
Task effort reducing	X	X
Easy adoption	X	X

- 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)

Smart-macros
Effort reducing frontend
Parameterization
Offline recommendation



Task Effort Reducing Front-end

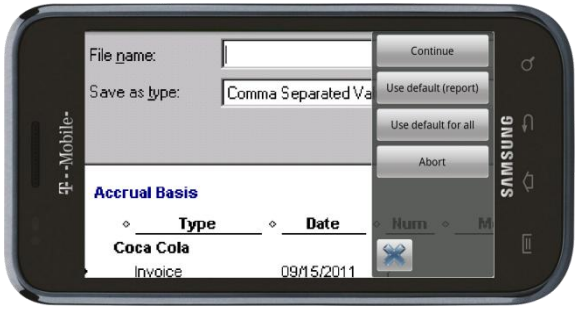
- Easy and non-intrusive access to macros in remote computing from smartphones
- Key design
  - Tailored interface in reducing task effort from smartphones with seamless integration into the remote
- Details
  - Collapsible overlay on the remote co
    - Showing macro playback progress via
  - Task effort 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

Smart-macros
Effort reducing frontend
Parameterization
Offline recommendation

Parameterization and Extensibility

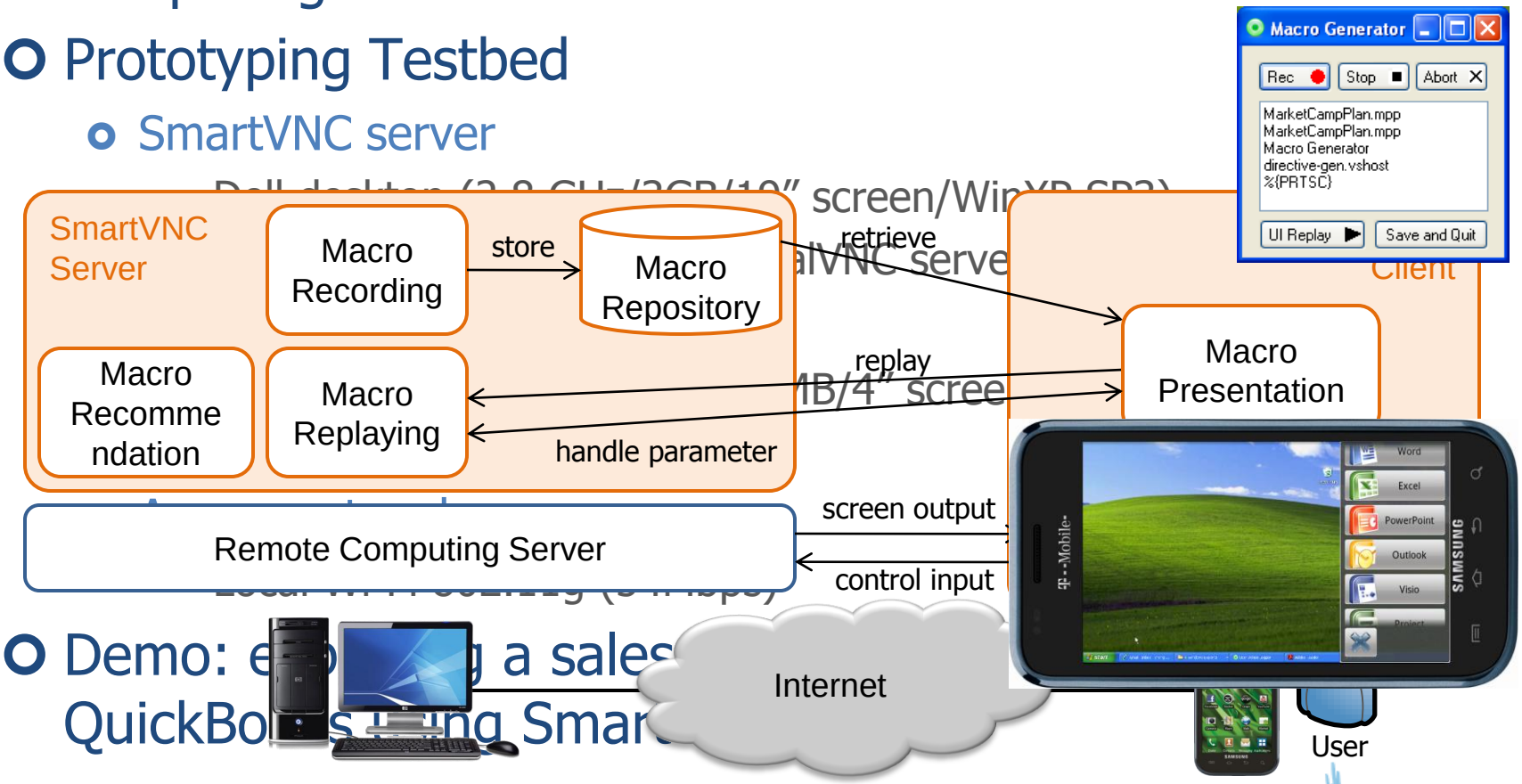
Smart-macros
Effort reducing frontend
Parameterization
Offline recommendation

- 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
- Demo: e… a sales… QuickBo… using Smar…

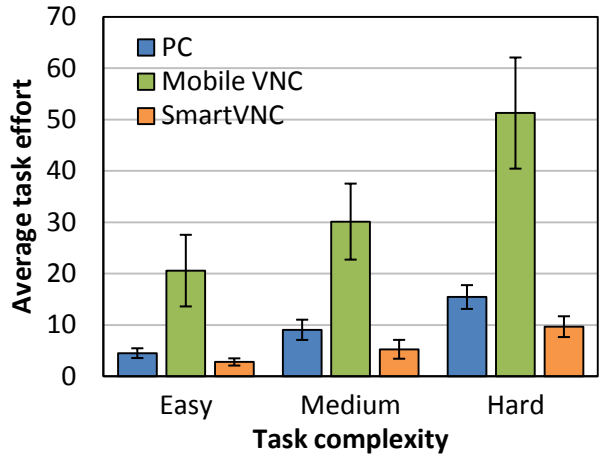


Performance Evaluation Methodology

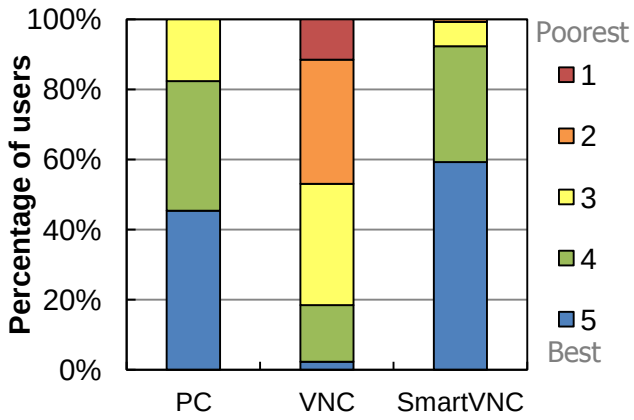
- Metrics
  - Macroscopic: time on task and task effort
  - Microscopic: subjective opinion and system overhead
- Experimental methodology
  - 22 volunteers
    - Students of ages between 20 and 30
  - 54 tasks of 3 complexity levels (easy, medium, and hard)
    - 9 PC applications: Word, Excel, PowerPoint, 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

Performance (1/2)

- 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.

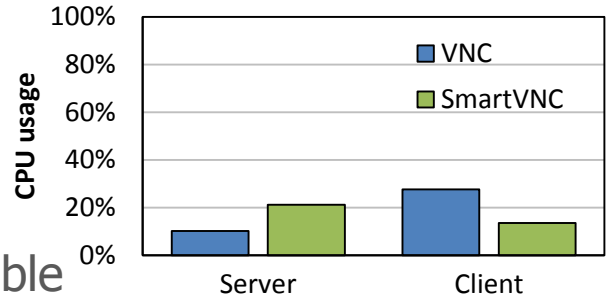


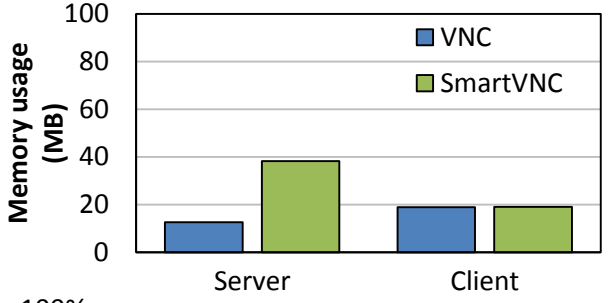
Error bar: 90% confidence interval

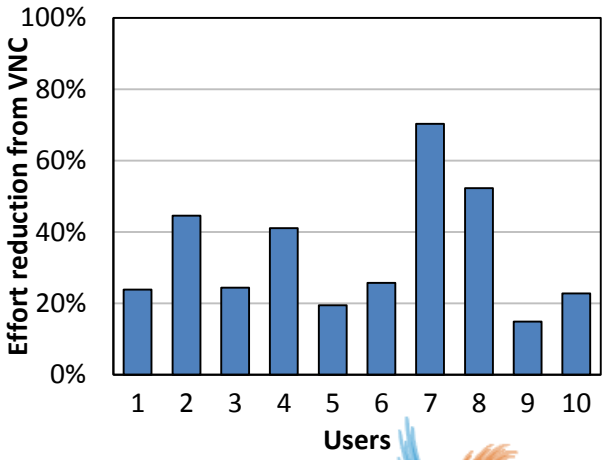


Performance (2/2)

- 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