The Journal of Systems and Software 100 (2015) 129–138

Contents lists available at ScienceDirect

The Journal of Systems and Software

journal homepage: www.elsevier.com/locate/jss

# A computer system architecture providing a user-friendly man machine interface for accessing assistive technology in cloud computing

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ARTICLE INFO

*Article history:*
Received 16 April 2014
Received in revised form
13 September 2014
Accepted 17 October 2014
Available online 27 October 2014

*Keywords:*
Cloud computing
Assistive technology
Human–computer interaction

ABSTRACT

Assistive Technology (AT) includes hardware peripherals, software applications and systems that enable a user with a disability to use a PC. Thus, when a disabled user needs to work in a particular environment (e.g., at work, at school, in a government office, etc.) he/she has to properly configure the used PC. However, often, the configuration of AT software interfaces is not trivial at all. This paper presents the software design, implementation, and evaluation of a computer system architecture providing a software user-friendly man machine interface for accessing AT software in cloud computing. The main objective of such an architecture is to provide a new type of software human–computer interaction for accessing AT services over the cloud. Thus, end users can interact with their personalized computer environments using any physical networked PC. The advantage of this approach is that users do not have to install and/or setup any additional software on physical PCs and they can access their own AT virtual environments from everywhere. In particular, the usability of prototype based on the Remote Desktop Protocol (RDP) is evaluated in both private and public cloud scenarios.



## 1. Introduction

Nowadays, cloud computing is an emerging paradigm and, at the same time, even a social reality. Scientific and commercial applications benefit from this new Information Technology (IT) paradigm. In such a context, remote pieces of software are delivered as a service and accessed by users using a thin client over the Internet, typically a web browser. This new form of application delivery is referred to as Software as a Service (SaaS) model. In addition, the virtualization technology allows us to deploy a traditional desktop environment, including the Operating System (OS) and applications, on Virtual Machines (VMs) without having to adjust programs, providing a personal desktop experience to end users through remote viewer technologies.

Assistive Technology (AT) includes hardware peripherals, software applications, and systems that enable a user with a disability to use a PC. Thus, when a disabled user needs to work in a particular environment (e.g., at work, at school, in a government office, etc.) he/she has to properly configure the used PC. In this paper, we discuss the possible impact of SaaS for using AT desktop applications (e.g., screen reader, screen magnification, keyboard accessibility tools, and so on) installed on web-accessed VMs, which are intended for users with disabilities, providing a software user-friendly interface.

Our solution aims to provide users with tailored VMs, each one running a standard OS and customized AT tools. In addition, we make available a complete interaction with each VM by means of an HTML5-enabled web interface. This approach does not require the usage of any additional thin client application to connect a remote VM. In fact, the networked physical client device (e.g., a traditional personal computer or a tablet) has to support just an HTML5-enabled web browser. Such an approach allows us to build a sort of adaptive user interfaces in a cloud computing environment.

In our previous work, we have already highlighted the advantages of using cloud computing for accessing AT tools installed on remote web-accessed VMs. In Mulfari et al. (2014), we discussed a cloud architecture for AT based on *noVNC* remote desktop client web application and proxy based on Virtual Network Computing (VNC) as technology for accessing remote VMs. In Mulfari et al. (2013), we discussed an alternative solution to noVNC, that is *Guacamole using VNC*. Both approaches highlighted poor performances in terms of usability for disabled users. Since, the VNC protocol does not support a native audio redirection, in both works, we

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http://dx.doi.org/10.1016/j.jss.2014.10.035
0164-1212/

implemented a system to play the sound effects of remote VMs in the web browser of the physical networked computer. As we discussed, both approaches made text-to-speech applications not so usable considering WAN scenarios.

The current work aims to enhance, in terms of performance, the system discussed in Mulfari et al. (2013). In order to achieve a better performance in using pieces AT software on web-accessed VMs, this paper discusses an approach based on Guacamole and the Remote Desktop Protocol (RDP) for controlling remote desktop environments. Differently from VNC, RDP supports both video and audio of remote VMs.

In particular, we present an open source cloud architecture including Guacamole, as HTML5 remote client web application and gateway, RDP as technology for accessing to VMs, Oracle VirtualBox, as virtualization software package (also called hypervisor or virtual machine monitor), and CLEVER as a middleware to build an Infrastructure as a Service (IaaS) cloud provider. Nevertheless, using AT tools in remote web-accessed VMs is not trivial at all. For this reason, we had to address several issues to make AT tools running on remote web-accessed VMs usable for disabled users. Finally, we discuss an in depth performance analysis considering both Intranet and Internet scenarios. The experimental results have shown the goodness of our system in both scenarios.

The rest of the paper is organized as follows. In Section 2, we discuss related works. Section 3 presents the cloud architecture for AT and it describes all the involved actors, components, and services. In Section 4, we focus on several issues in using AT tools on web-accessed VMs, discussing how we addressed them. Section 5 relates about several experiments aimed at evaluating the usability of AT tools on web-accessed VMs considering both Intranet and Internet scenarios. Conclusions and lights to the future are summarized in Section 6.

## 2. Related works

Differently from our approach, several works exist in literature, that do not consider VMs, but that aim to improve the web browser features for using AT tools. Augmented browsing systems aim to improve accessibility on any website (Mirri et al., 2011) and they work on additional plugins in order to make on-the-fly changes to web page content. These plugins provide end user with some accessibility tools, such as screen magnifier, text to speech, and virtual keyboard (Mangiatordi and Sareen, 2011). Another interesting solution is Firefixia (de Santana et al., 2013): it is a web browser customization toolbar and it is designed to support people with dyslexia by adapting the presentation of web content according to their preferences. WebAnywhere is a remote web-based screen reader application allowing people who are blind to access the web from any networked computer with a modern web browser and it includes a self-voicing web browser: in order to use the software, end users first browse to its web page. WebAnywhere speaks both its interface and the content of the web page that is currently loaded. So people who are blind can navigate using this web page to other web pages and the WebAnywhere interface will enable new pages to be spoken to the user (Bigham et al., 2008). These AT web-based tools are mainly intended to allow disabled users to access the Internet. Although functionality remains limited compared to equivalent desktop applications, the major benefit is to improve the accessibility of web sites when accessed from public PC in which users do not have the permission to install any customized software.

Currently, the combination of different web technologies allow to compose added-value cloud-based applications (Fazio et al., 2013). However, from the perspective of AT, cloud computing is at early stage. The Global Public Inclusive Infrastructure (GPII) (Vanderheiden et al., 2013) is an international collaborative effort aimed to build a sustainable cloud-based system with the purpose to help the creation of an ecosystem that enables the access to different digital technologies with an eye to AT. Cloud4all (2012) focuses on the key components needed to enable auto-personalization from user's needs and preferences. Cloud4all is an international consortium project funded by the 7th Framework Programme of the European Union and its main objective is to build the key components of the GPII around auto-personalization. Currently, the Cloud4all project is building the initial pieces of the infrastructure necessary to allow instant auto-personalization of software, devices, media, materials, and services based on user needs and preferences (stored in the cloud or on a personal device). This system includes a complex infrastructure that allows AT and mainstream product manufacturers (i.e., software, hardware, media materials and services) to create products that can automatically change their interface or format to accommodate the needs of each user with a disability.

Generally, the use of VMs in a cloud system, as advocated in our work, represents a new challenge, if we consider the great benefits that could be achieved. In Shu et al. (2012), a Desktop as a Service (DaaS) for FPGA (Field Programmable Gate Array) based cloud computing architectures is discussed. It works with a proxy able to reduce the amount of data exchanged between the thin-client and the cloud server that exposes the desktop. The results in terms of traffic reduction are relevant indeed, however the system they designed is rather complex. Another work on Desktop as a Service regards an educational cloud (Kibe et al., 2012). The authors looked at cloud computing benefits to significantly reduce the management costs of IT resources for a school or university. According to such a model, students can virtually own more than one PC in the laboratory, and they can configure them as they wish. The drawback of this work is the complexity of the overall architecture. Respect to this, the added value of our work is in using just a web browser for interacting with our system, simplifying the access.

## 3. A cloud architecture for AT

The basic idea proposed in this work consists in enabling a user with a disability to control his/her virtual environment running personalized particular AT tools and system settings by means of a remote desktop client web application. In this way, he/she can be able to display his/her virtual desktop environment within a specific dynamic web page displayed in a standard web browser running on a physical machine, without the need to install additional software or modify particular Operating System (OS) settings on the physical machine itself. The physical machine can be a standalone Personal Computer (PC) placed in an Internet point, a laboratory at university, in office at work, and so on.

Virtualization and AT may address many cloud computing scenarios involving people with disabilities. There is not limit to the number of possible application scenarios. Basically, these scenarios involve different type of user: System Administrator, Tenant, and Customer.

- *System Administrator*. He/she is responsible for managing the whole IaaS Cloud provider and the delivery of web-accessible virtual environments or Virtual Machines (VMs), configured with AT tools, to Tenants. VMs can be delivered either automatically by the cloud provider, according to the policies enforced by administrators, or manually by administrators themselves.
- *Tenant*. It can be considered as organizations supporting people with disabilities. A Tenant interacts, by means of its operators, with the IaaS Cloud provider to request customized