

# Design of an Executable Solutions Management Platform based on Virtual Machine Snapshots

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## Abstract

Annually, dozens of software solutions are developed by students as part of the mandatory requirements for them to be awarded their respective degree qualifications. However, most of these potentially groundbreaking solutions tend to be stored away and forgotten upon completion. This then gives rise to the current predicament where universities produce multiple graduates but do not yield a proportional number of usable innovative software solutions. The aim of this paper is to design a platform that enables the storage, indexing, retrieval and execution of these developed solutions. This will be done through the design of a user-friendly interface as the front end, a database of virtual machine snapshots for each executable system running at the backend and a querying engine to interface the two. This will go far in ultimately aiding universities to become recognized hubs of innovative and marketable technologies.

**Keywords:** Virtualization, projects repository, virtual machine snapshots, information retrieval

## 1. Introduction

Cloud computing has ushered in a lot of revelations in e-learning. Many universities and colleges to date have managed to create repositories for past exams, lecture notes, project documentations and theoretic assignments (DSpace). (Ramshirish et al. 2006) This development facilitates for students to reference to past educational materials and analyze the trends a particular course has been following over the years.

However, since much progress has been made in digitizing and centralizing these materials, little or no progress has been made in centralizing student projects in executable form. Study (with a bias towards Information and Communication Technology) has shown that, student projects (mainly software based projects) are handed over and stored in CD format after completion. Some of the products will not conform to the expectations of project submission i.e. no environment setup to run the project, students submitting only the source code only not the executables etc. To that cause, current students cannot allude to past projects for the purposes of research, literature review and improvements on these projects as there is no proper evidence of existence of such projects.

These challenges necessitated for the development of a cloud based platform to allow improvement and modification of past projects. The researchers propose to develop a centralized repository of projects in executable form. The repository has a backend running on a cloud platform. Every student project being an individual Virtual Machine, snapshot taken in the executable format of the project with the virtual machine environment tailored for each project. Front end access for the purposes of uploading, installation and viewing is done via a web GUI.

## **2. Literature Review**

### **2.1 Definitions**

Mell et al ( 2009) defines Cloud computing (hereinafter: CC) as “*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.*”

Virtualization is one of prerequisites for the realization of CC (Dong et al. 2009), the concept of virtualization, is essentially method of dividing a single machine into smaller virtual machines by running multiple operating systems and giving the impression to an end user that his or her job was running on a separate, dedicated machine.

### **2.2 Challenges**

The concept of automation when it comes to student-developed projects or programs is not a new one. In the past, it has been focused on a number of aspects including the grading of student programs (Jones 2001). The problem was rooted in the management of large classes of students who were taking a programming course. Jones goes on to give a detailed report in the paper on how the automation of grading student programs impacted both the author and the performance of the students. Not only did automation of a typically manual task save time, but it also improved the fairness of the grading process too. This effectively led to the overall improvement of student-developed programs.

There were some shortcomings however which included the instructor having to spend more time preparing assignments that met the specifications of the testing system and also developing the grading program (Jones 2001). This basically proves that automation of student-developed products will most probably lead to an improvement not only to the faculty members who are supposed to evaluate the projects but to the students as well. Examiners will be better able to review and properly analyze student projects through the use of this platform as opposed to the old model of relying on student project demonstrations on a once-off final presentation.

For our use case most student projects are very volatile and require very specific hardware to successfully execute. In the University we face the challenges of student project being hard to replicate or reconfigure once projects have been submitted, which counteracts the purpose reproducible research in higher education.

Previously E-learning research focused on the reuse of learning material, but not on IT infrastructure, services and applications. Many universities’ ICT driven policies focus on traditional Learning Management System, such as BlackBoard, Moodle etc.

### 2.3 Related Work

Boettiger (2015) explores common reasons that code developed for one research project cannot be successfully executed or extended by subsequent researchers, he further summaries the challenges as a result of; i) Problems of dependencies in code ii) Imprecise documentation iii) software updates iv) Barriers to adoption and reuse in existing solutions to solve said problems. He goes further to highlight the current paradigms on solving the issue of reproducible research as workflow systems and virtual machines.

Dong et al. (2009) propose the BlueSky cloud framework which allows use of cloud computing as a base for modern e-Learning applications, within it physical machines are virtualized and allocated on-demand.

CloudIA (Sulistio et al., 2009) a system developed within Hochschule Furtwangen University is a comprehensive private cloud solution infrastructure that provides IaaS, SaaS, PaaS with respect to requirements and needs of e-Learning and collaboration. The IaaS system enables the creation of a VM by choosing a base image and post-installing software packages selected by the user on the fly. CloudIA's implementation model can be utilized to realize our needs. Vouk, et al also propose a similar solution where students are offered predefined VMs.

**Table 1:** Overview of research on private cloud in University Setting

Paper	IaaS	PaaS	SaaS	LMS
Wenhong, et al (2010)		X		
Dong, et al (2009)	X			
Doelitzscher, et al (2011)	X	X	X	X
Vouk et al (2008)		X	X	
Di Costanzo et al (2009)	X			
Rajam, et al (2010)			X	
Liang et al (2011)	X		X	

The private cloud serves as a real world test-bed for deployments, benefiting students, researchers and faculty as wells as providing needed relief for currently strained education budgets. (Mircea et al, 2011) A private cloud model enables educational institutions to have a complete control of identity management, services, data security, applications, and resources.

By leveraging CC, we aim to provide students with the appropriate tools for application development, reuse and archival purposes of student projects. Given the survey of literature related to our problem, a private cloud solution would enhance realization of research and educational reproducibility of students' projects. Table 1 gives an overview of our research on private cloud in a university setting.

### 3. Design

#### 3.1 Architecture Design

The full architecture design of the platform is illustrated in Fig 1. Considering its design from a basic point of view, it is comprised of four main components. These are the web interface, the database querying module, the database itself as well as the server on which everything is housed.

The web interface acts as a front-end where the user enters commands for processing. These are then fed to the database querying module which is effectively an interface between the database itself and the web interface.

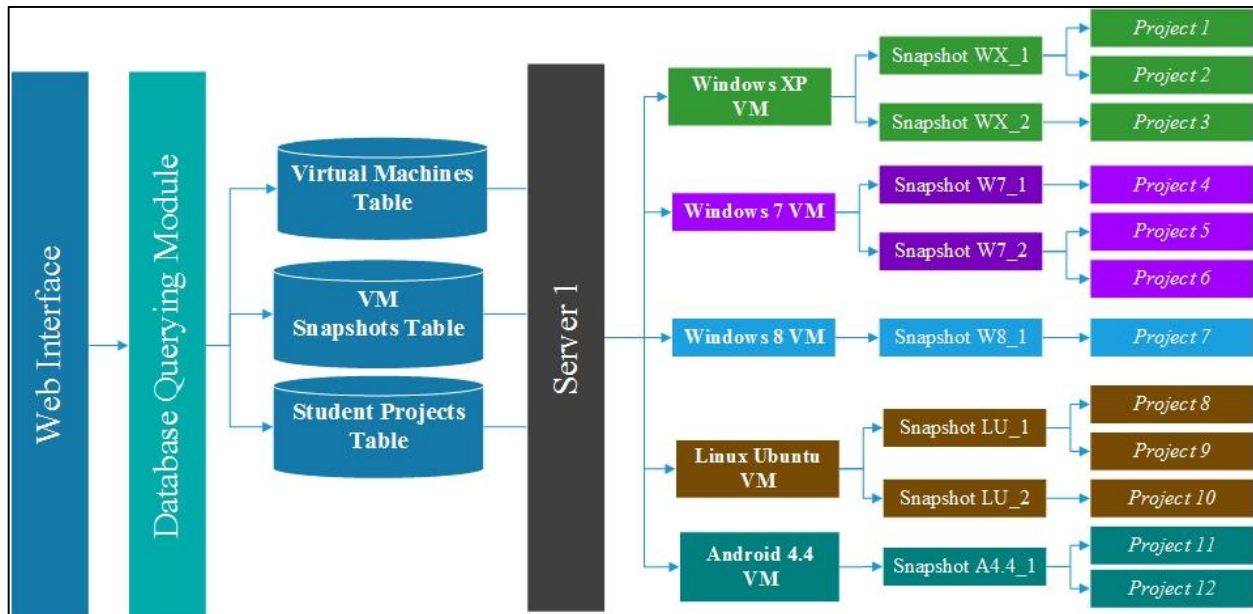


Figure 1 Architecture Design

The database is basically comprised of three main tables; the Projects table, the Virtual Machines (VM) table and the VM snapshots (Kalmbach et al 2015) table. The projects table contains all the projects available on the platform. The VM table contains all the Virtual Machines on the platform as well as the operating system running on each VM, the number of snapshots associated with it and so on. The VM snapshots table is comprised of the titles of the projects running on the snapshots, the configurations, installed applications/add-ons and other hardware and software specifications associated with the snapshot. A snapshot can have more than one project running on it. Also, a virtual machine can have more than one snapshot associated with it (Pearce et al. 2013). However, a project can only be run/stored in one snapshot.

The database, the various virtual machines as well as the snapshots will all be stored on a server. It is imperative that this server is of a very high quality since it is the backbone of the whole platform. Understandably, due to the growth in popularity of distributed computing as a concept, future developments of the platform may result in there being more than just one server as the backbone. However, for demonstration purposes for this design, the aspect of distributed computing was not taken into consideration.

### 3.2 Submission Module

The operation of the submission process where a student uploads and installs their project onto the platform is illustrated in Fig 2. The student, upon completion of the project, is then asked to use the platform and upload/install their project. The student logs into the platform and is then prompted to select the operating system on which they developed their project.

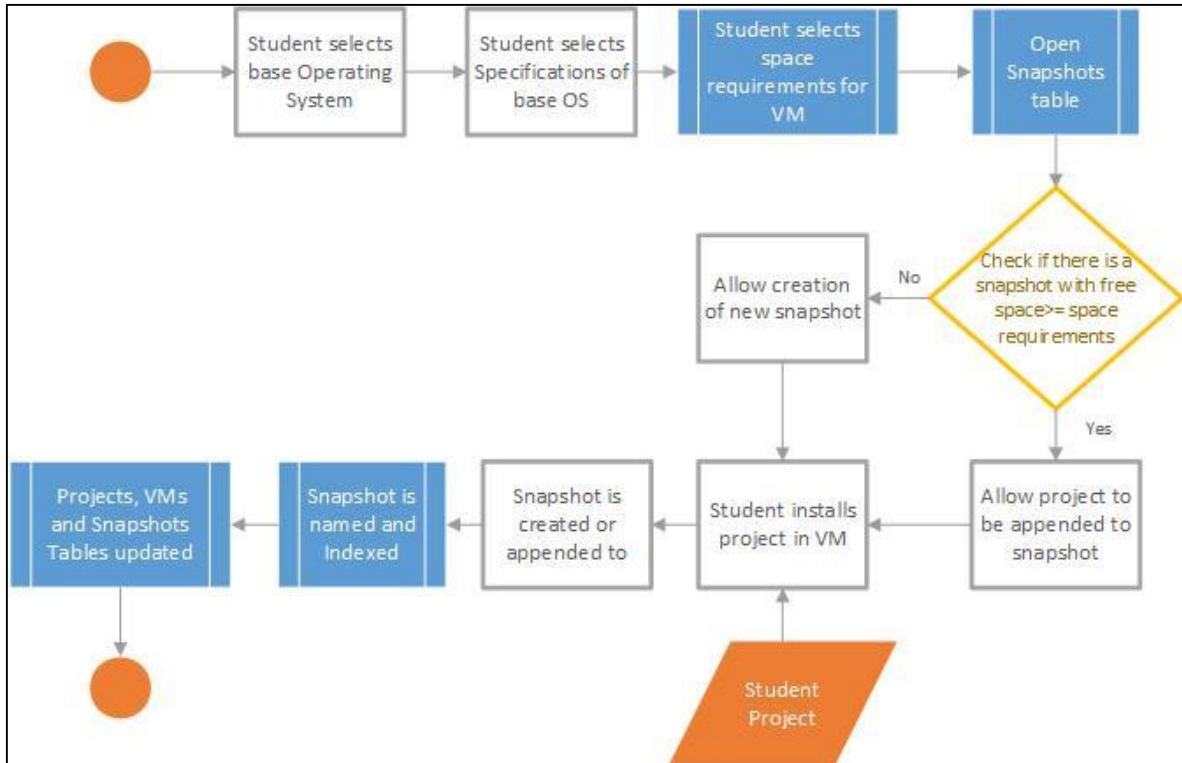


Figure 2

As show in Fig 1, the platform will accommodate more than one operating system including Windows, Android as well as some distributions of Linux. The student selects the operating system they used and then they proceed to outline the specifications that their project needs to operate ideally. These can be programs such as the Microsoft Visual C++ runtime libraries or a flavor of Microsoft SQL Server to mention a few examples for Windows. In addition to that, the student also states how much memory and hard disk space their project will require.

This captured information is then used when parsing through the Snapshots table to see if there is any (VM + snapshot) instance available that meets the criteria highlighted in the student's specifications. If one is found, the system then checks if there is enough space to accommodate the student project. If there is, that snapshot is loaded and the student is given permission to upload and install their project onto the snapshot. However, if there is no VM + snapshot instance that meets the requirements, then a new snapshot is created that allows the student to install and configure their project as they see fit.

After the installation is completed, the student is then prompted to commit the changes they have made to the snapshot. The snapshot is then immediately saved and the Projects, Snapshots and VMs tables in the database are updated accordingly.

### 3.3 Retrieval Module

This is with respect to a scenario where the user of the platform would like to retrieve and view/use a student project that has already been uploaded and installed onto the platform. Fig 3 highlights the flow of this process in the form of a diagram. The user logs onto the platform and then proceeds to enter the title of the project they would like to view. Alternative methods of selection include entering keywords such as “inventory management” which would lead to the displaying of some student projects that dealt with the various facets of inventory management.

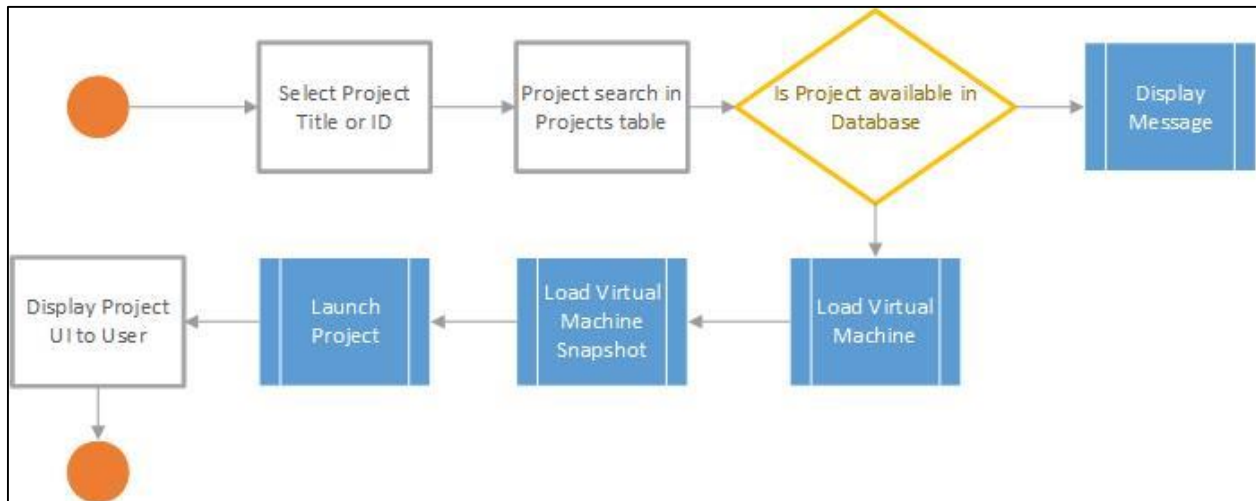


Figure 3

After entering the name of the project, a search is then done in the Projects table of the database. If the project does not exist, an error message informing that to the user is then displayed. However, if the project does exist, then the selected virtual machine running the project is loaded. It is then followed by the loading of the VM snapshot and then the automatic launching of the project for use or testing by the user.

### 4. Discussion

The design of this prototype is mainly based on the concept of snapshots in virtual machines. A snapshot has the capacity to capture the state of memory as well as the hard disk's and the state of various devices on a selected virtual machine. The virtual machine in question may either be shut down or running when the snapshot is captured or restored. The snapshot then goes on to record the state differences between the original state of the virtual machine and the time when the snapshot was taken.

Due to this capability, snapshots that would have been captured earlier can then be restored very quickly. This would also mean a lot more space and time is saved as compared to the alternative of installing every project on a completely new virtual machine which would inevitably hog resources on the host machine. In addition to that, using snapshots also adds another identifier to the set of projects in that groups of projects can be referenced using the snapshot as a grouping characteristic/identifier.

An alternative to the use of snapshots would have been to install all the student projects with an operating system in common onto one virtual machine. This would have involved installing all add-ons and additional software onto one VM and ensuring that its specifications accommodated

The projects with the highest requirements. Granted, this would save a lot of space as compared to the concept of using snapshots, but the challenges faced would ultimately outweigh the benefits. This is because it would result in a single point of failure for all projects. This means that in the event that the VM crashes, this would negatively affect all the functioning of the projects housed on that VM. This goes on to highlight the benefit of having multiple snapshots of VMs as opposed to having just one VM for everything.

Another problem that would be faced if the single VM approach is used is regarding backward compatibility and selection of the ideal add-on/program version that can accommodate all the student projects installed on a single operating system. Say, one project requires Add-on version 1.1 while another requires Add-on version 3.2. If version 3.2 has no backward compatibility with 1.1 this would mean that any project that runs on version 1.1 will not be able to run successfully. The solution to this would ideally be to install projects 1 and 2 on two different machines.

This problem is resolved by the use of snapshots in that each snapshot can be set up to have all the necessary requirements pre-installed without worrying about compatibility with the requirements of other projects.

In order to accommodate most, if not all the student projects to allow them to be placed on the platform, the most common operating systems were used in the design of the prototype. These included Windows 7 and 8, Linux Ubuntu 14.10 as well as Android Kit Kat version 4.4. Other operating systems such as the various Linux distros and Mac OS flavors were not included but may be added in future as the platform has the capacity to accommodate more VMs.

There are a number of other benefits that are associated with the implementation of this platform as well. One of them is that the installation of multiple projects on a single snapshot also allows efficient usage of space. Also, in the long run, it will not only help ensure only working prototypes are submitted by students, but it will also allow individual modules of previous student projects (possibly from a preceding academic year) to be used as case studies in Secure Programming or security courses in the degree programme's curriculum. To add to that, this will allow there to be more diversity in project ideas by students since there will be a common repository to reference and evaluate the originality of a project proposal before it is even started.

## **5. Conclusion**

Considering the volumes of student projects generated per year at any university, the number of business solutions, patentable and innovative projects the university in question will produce should be equally huge in number. However, that is not the case since in many cases there is no standard system or platform is in place to harness all these generated products and ideas for further improvement. The platform being suggested in this paper proposes to solve that challenge. This is done through the implementation of cloud computing concepts in order to not only better manage resources and components associated with the platform but to also use them efficiently. Ultimately, this will lead to the production of more unique and innovative student projects and also allow for the progressive improvement of previous student projects to come up with more industry-ready solutions and systems in the long run.

## 6. Future Work

### 6.1 Containerization vs Virtualization

Whilst virtual machines provide a readily available solution without a steep learning curve, current trends are moving towards the use of containers with cloud computing. Solutions such as Docker provide a novel remedy to our problems, the main challenges pose are the learning curves. Other universities are using containers to provision assignments and enable uniform platforms for computer science related practical courses. We aim to integrate both virtualization and containers with our infrastructure(Scheepers 2014).

### 6.2 HitCloud

We aim to develop further on our solution to provide a fully-fledged private cloud infrastructure (HitCloud) based on existing resources which offers IaaS, SaaS and PaaS within the learning environment.

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