Design and Implementation of OpenDSA Interoperable Infrastructure

Hossameldin Shahin, Master Defense
Computer Science, Virginia Tech

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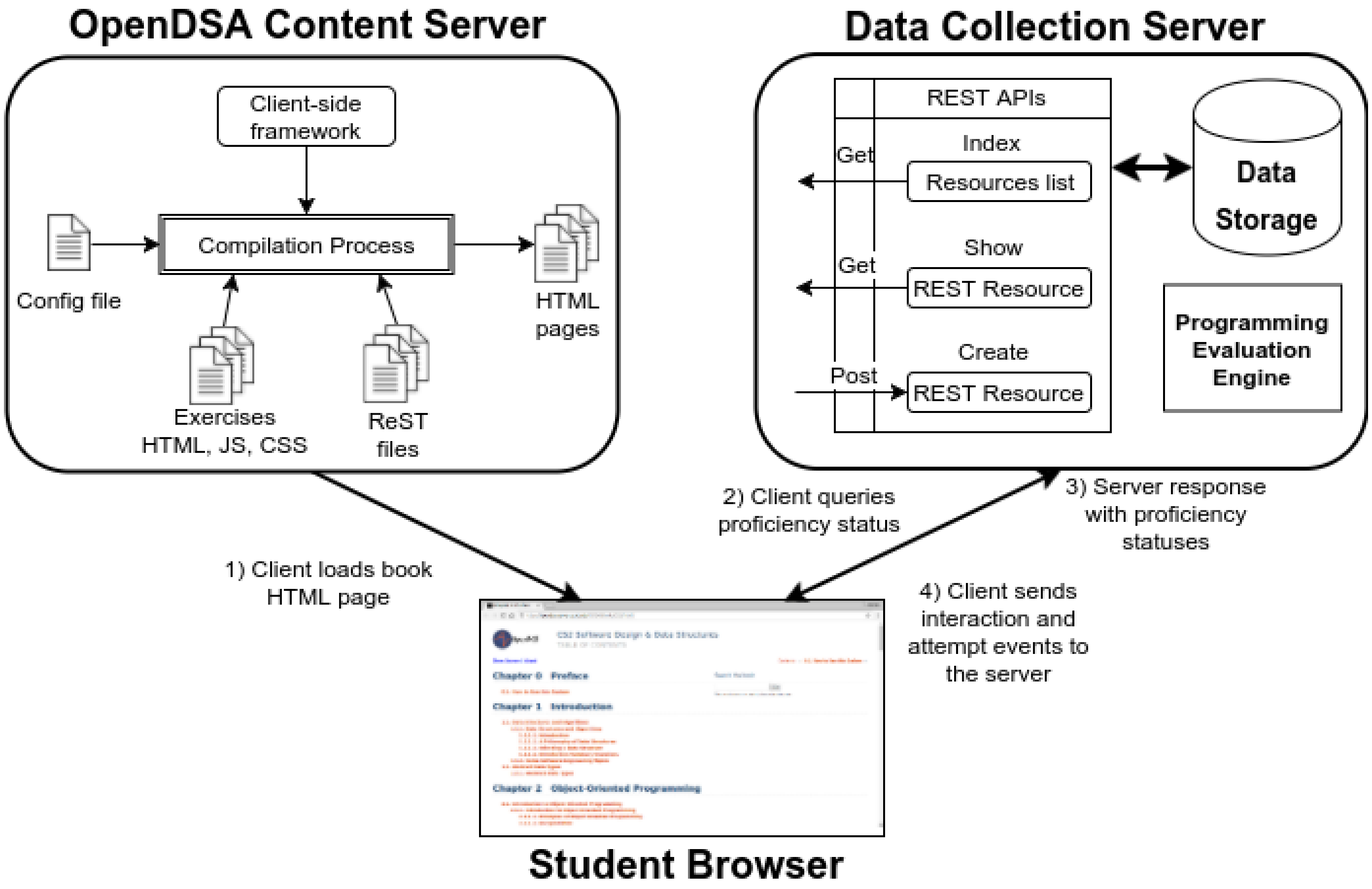
Blacksburg, Virginia

Outline

- Background
  - The First Generation OpenDSA Infrastructure
- Original Infrastructure: Challenges, Limitations, and Solutions
- OpenDSA-LTI
  - From a Monolithic System to an Interoperable Infrastructure
- Contributions
- Future Work

Background: OpenDSA Infrastructure

1. **OpenDSA content**
   - The prose → ReST files
   - Visualizations and Exercises → HTML5, CSS, and JavaScript
2. **Compilation process**
   - Generates complete books from content types
3. **Data Collection Server (DCS)**
   - Tracks student registrations, interaction data, and scores
4. **Client-side framework**
   - Managing the communication between the compiled HTML pages and the DCS



First Generation OpenDSA infrastructure

1- Original Infrastructure: Challenges, Limitations, and Solutions

Original Infrastructure Challenges

1. **OpenDSA content**
   - Outdated Khan Academy exercises framework
   - The “gaming” problem
2. **Client-side framework**
   - Buffering mechanism → Missing interaction data
   - Caching mechanism → Out-of-sync and gradebook problems
3. **Compilation process**
   - Manually prepared configuration files.
4. **Data Collection Server (DCS)**
   - Security concerns
   - Unstable automated assessment engine for programming exercises
   - No support for additional exercise types (e.g. CodeWorkout)

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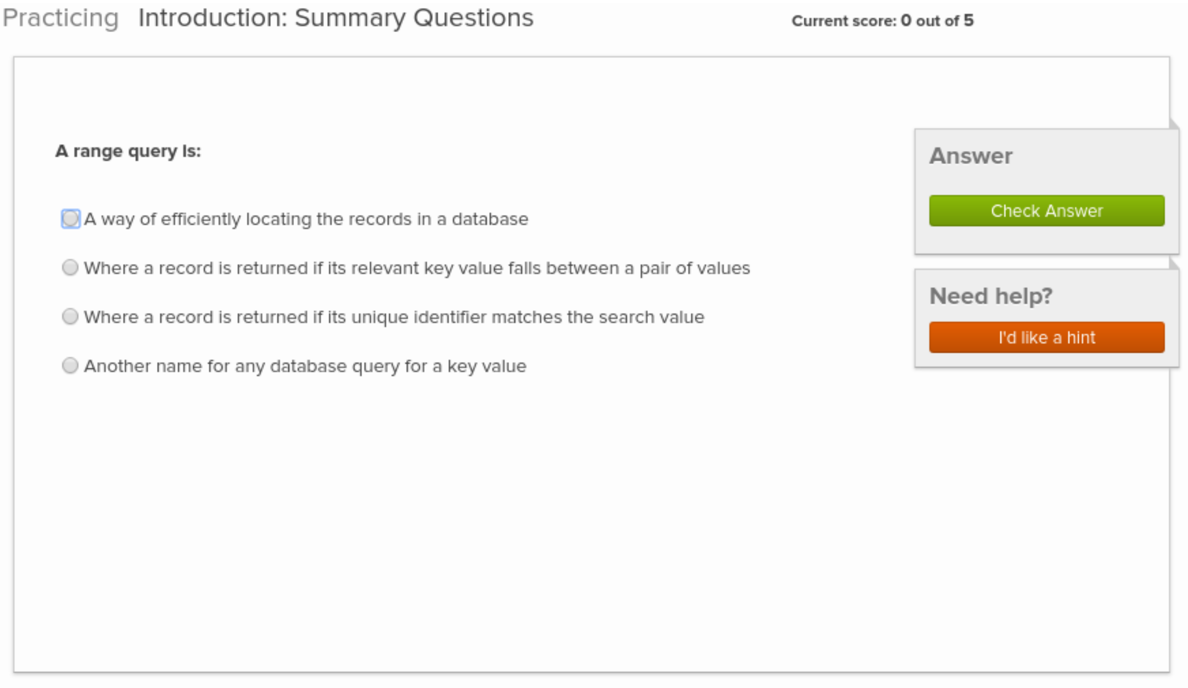
1.Mitigating Khan Academy Problems

KA summary exercise



Practicing Introduction: Summary Questions

Current score: 0 out of 5

A range query is:

○ A way of efficiently locating the records in a database

○ Where a record is returned if its relevant key value falls between a pair of values

○ Where a record is returned if its unique identifier matches the search value

○ Another name for any database query for a key value

1. Mitigating Khan Academy Problems (Cont.)

Technical problem: Outdated framework version

1. **Update or replace KA framework?**
   - Update the framework
   - Implement OpenDSA requirements as a layer that overrides some of the KA framework functionalities
2. **Latest KA uses RequireJS library**
   - Enhance user experience by reducing loading time
   - Help developers by separating JS code from HTML files
3. **Updated framework introduces new limitation!**
   - No native method to recursively load Summary exercises.

1. Mitigating Khan Academy Problems (Cont.)

Pedagogical problem: Students found ways to fool the framework

1. **How students game the system?**
   - Continuous refreshes to get an easy question
   - Misuse the hint system
2. **Preventing the gaming behavior**
   - Remember the “current” question
   - Remember when hint system is used
   - Remove correctly answered questions
3. **Proper handling for some use cases**
4. **Preventing gaming has direct impact on OpenDSA research**

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2. Mitigating Client-Side Framework Problems

1. **Missing interaction data**
    - Two students use the same browser
    - Students close their browser abruptly
    - Wrong mechanism for communicating interaction data
2. **An out-of-synch local proficiency cache**
    - Define the DCS as the ground truth for student grades
    - Side effect, Internet connection is required all the time

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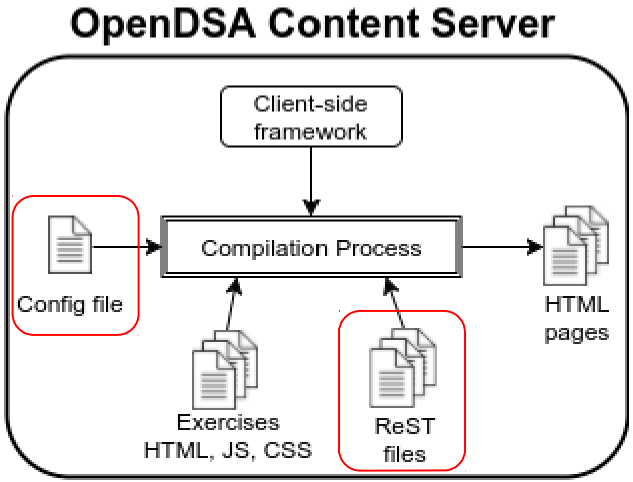
3. Mitigating Compilation Process Problem

- **Config files has to be aligned with the ReST files**
  - Manual, error prone process
  - The content keeps changing
  - Multiple config files need to be changed.

Solution: Automatically extract all the config files from the ReST files.



Original Infrastructure Challenges

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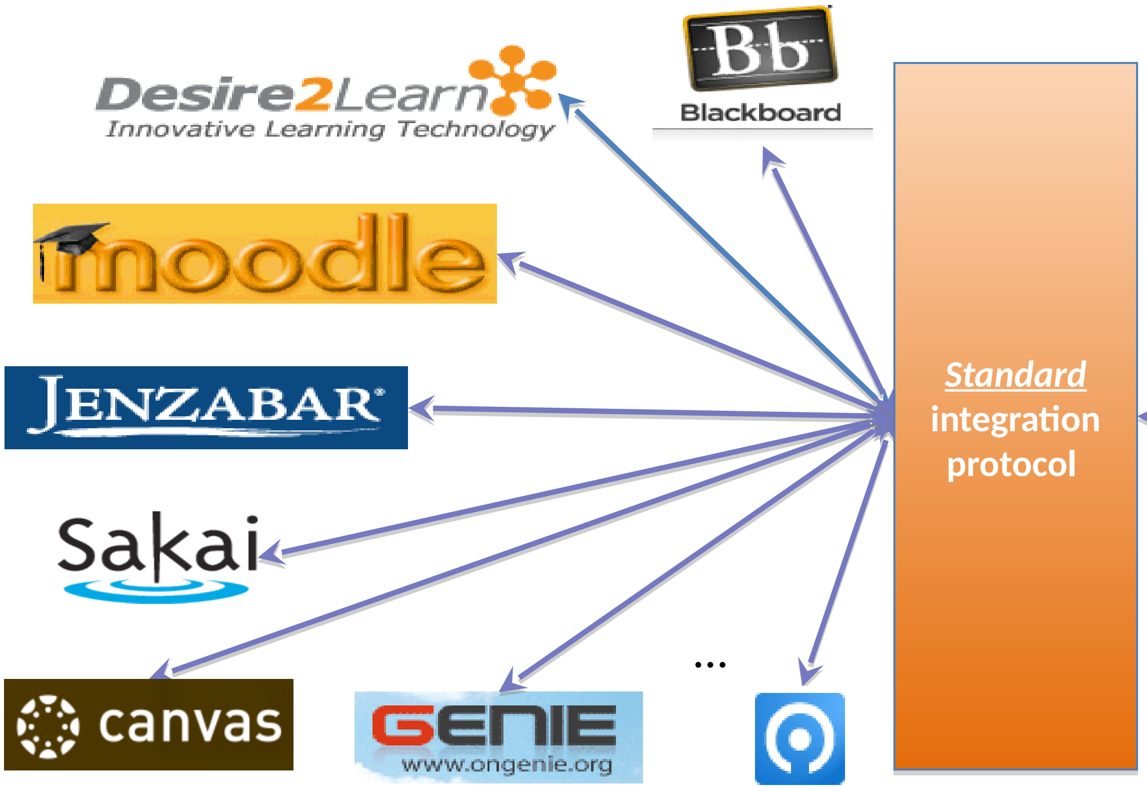
4. Data Collection Server

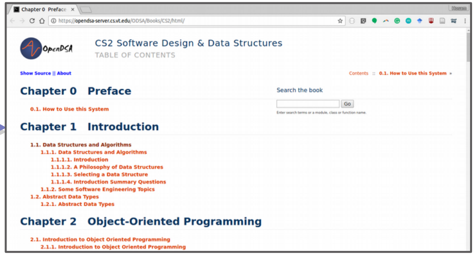
1. **Proprietary mechanism for handling session keys**
   - Modern Web framework provides full support for session handling
   - The secure approach is to use cookies to handle session data
   - Unfortunately, DCS didn’t use the standard, secure approach
   - Using proprietary mechanism:
     i. Insecure communication with client-side framework
     ii. Allowed only one session key per user
     iii. Complicated client-side framework code
2. **Automated assessment engine for programming exercises**
   - DCS contains embedded engine to store and evaluate students’ code
   - Students complained about slowness and instability
3. **No support for additional exercise types (e.g. CodeWorkout)**

Monolithic System vs. Learning Tool

1. **Original infrastructure**
   - DCS needs to be replaced
2. **OpenDSA is a monolithic system**
   - Students need to remember multiple usernames/passwords
   - Track their progress in multiple systems
   - Proprietary instructor tools (the gradebook)
   - Instructors have to create and maintain the same course across several systems.
3. **OpenDSA as a learning tool**
   - Keep instructors and students in one learning environment
   - Deliver OpenDSA through a trusted channel
   - Take advantage of the LMS robust instructor’s tools



Standard integration protocol



CS2 Software Design & Data Structures

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Chapter 0 Preface

0.1. How to Use this System

Search the book

Go

Enter search terms or a module, class or function name.

Chapter 1 Introduction

- 1.1. Data Structures and Algorithms
  - 1.1.1. Data Structures and Algorithms
    - 1.1.1.1. Introduction
    - 1.1.1.2. A Philosophy of Data Structures
    - 1.1.1.3. Selecting a Data Structure
    - 1.1.1.4. Introduction Summary Questions
  - 1.1.2. Some Software Engineering Topics
- 1.2. Abstract Data Types
  - 1.2.1. Abstract Data Types

Chapter 2 Object-Oriented Programming

- 2.1. Introduction to Object Oriented Programming
  - 2.1.1. Introduction to Object Oriented Programming

Ruby, Python
PHP, Java

OpenDSA Interoperability

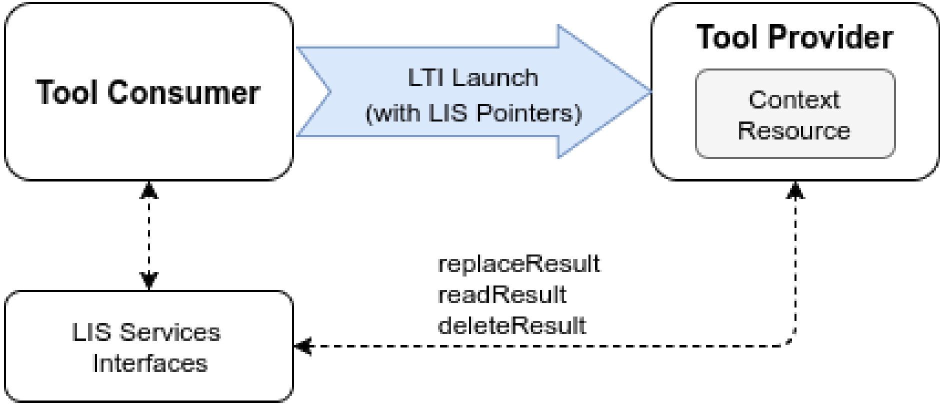
2- OpenDSA-LTI for Interoperability

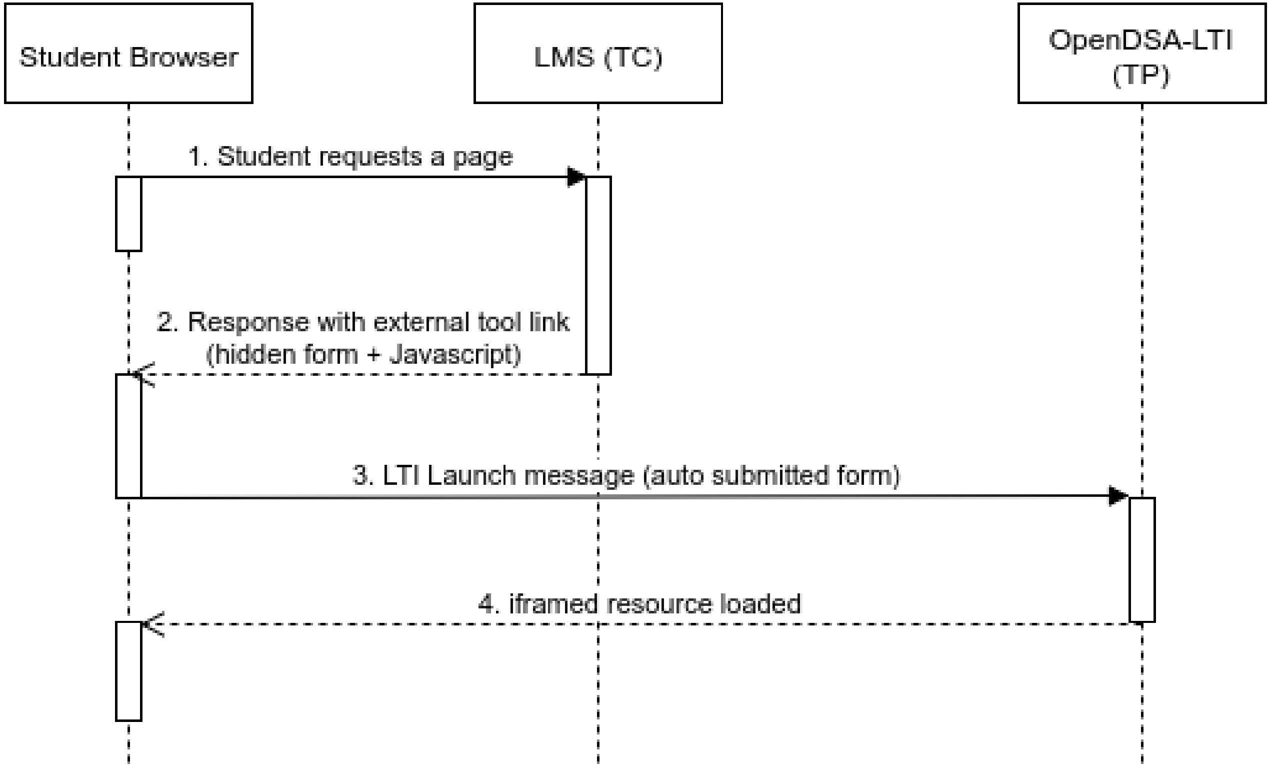
Interoperability Alternatives

1. **OpenDSA requirements and constraints**
   - Modifications required to OpenDSA content code base
   - The ability to integrate OpenDSA with a range of LMSs
   - Ability to augment OpenDSA with other learning tools (such as new exercise types) within an LMS
   - Community support and evidence for continuity
2. **Integration approaches**
   - A Component-Oriented Approach
   - Plug-In Architecture
   - Widgets
   - SCORM
   - IMS Learning Tools Interoperability (LTI)

How LTI Protocol Works

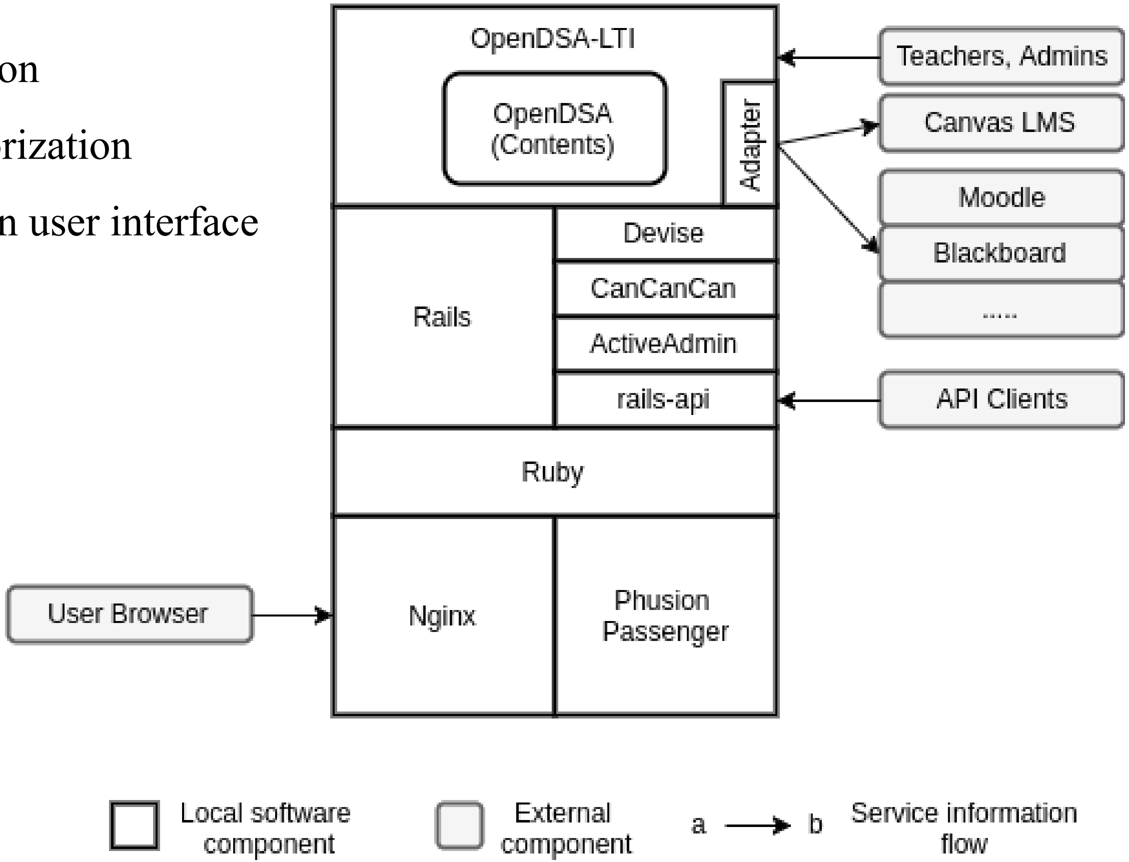
1. Terminology
   - Tool consumer/provider
2. IMS LTI v1.1 allows:
   - The outcomes services
   - IMS Learning Information Services (LIS)
3. Before the launch process
   - The Admin has to define the tool provider in the LMS
   - The instructor creates an activity that refers to the learning tool




Student Browser
LMS (TC)
OpenDSA-LTI (TP)
1. Student requests a page
2. Response with external tool link (hidden form + Javascript)
3. LTI Launch message (auto submitted form)
4. iframed resource loaded

OpenDSA-LTI launch function sequence diagram

- **Devise:** Authentication
- **CanCanCan:** Authorization
- **Activeadmin:** Admin user interface



OpenDSA-LTI Technologies Stack

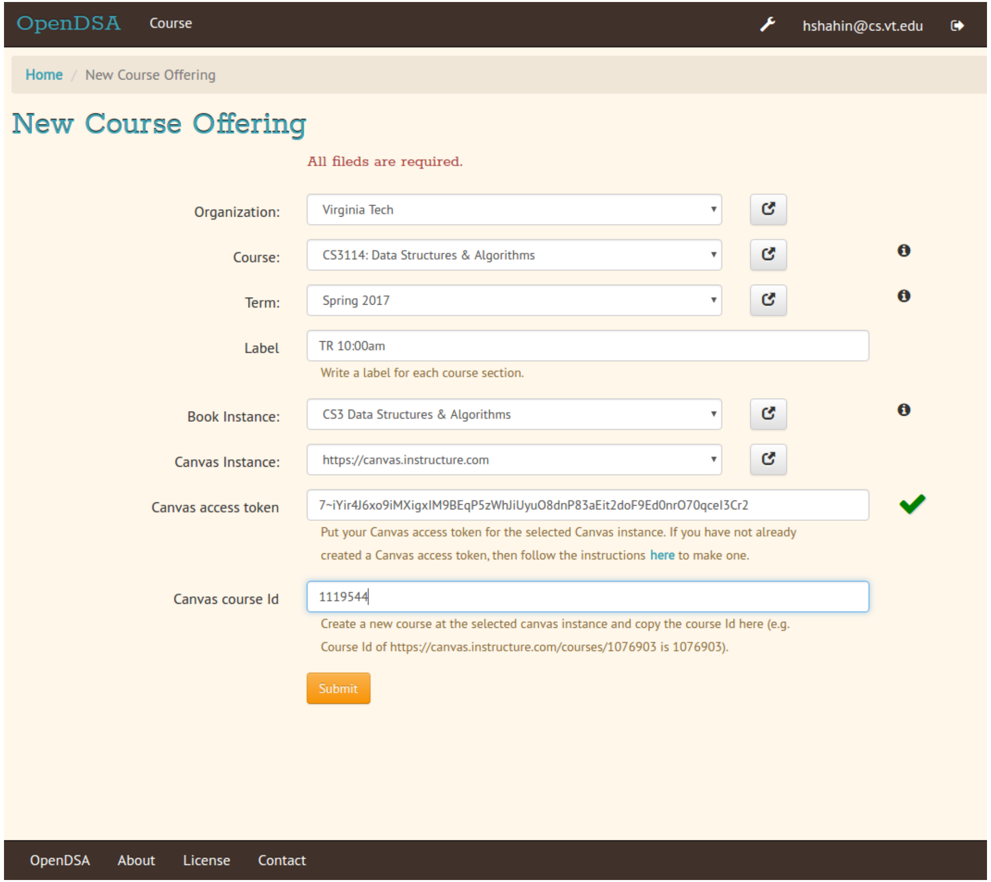
Identity Management

1. **Authentication**
   - Student’s automatic registration process
   - Instructor's manual registration, permission request, and access token update
   - Third-party authentication mechanisms
2. **Authorization**
   - Two roles permission model (global and course roles)
   - Instructor's privileges
   - OpenDSA-LTI Admins
   - Students are not aware of OpenDSA-LTI

User Interfaces

1. **Instructor Interfaces**
   - OpenDSA-LTI interface to configure and compile books within the LMS
2. **Student Interfaces**
   - The LMS interface
3. **Admin Interfaces**
   - OpenDSA-LTI provides comprehensive admin interfaces

Bootstrap library is used for a responsive and fluid layout. It scales to different screen sizes and resolution.



New Course Offering

All fileds are required.

Organization: Virginia Tech

Course: CS3114: Data Structures & Algorithms

Term: Spring 2017

Label: TR 10:00am

Write a label for each course section.

Book Instance: CS3 Data Structures & Algorithms

Canvas Instance: https://canvas.instructure.com

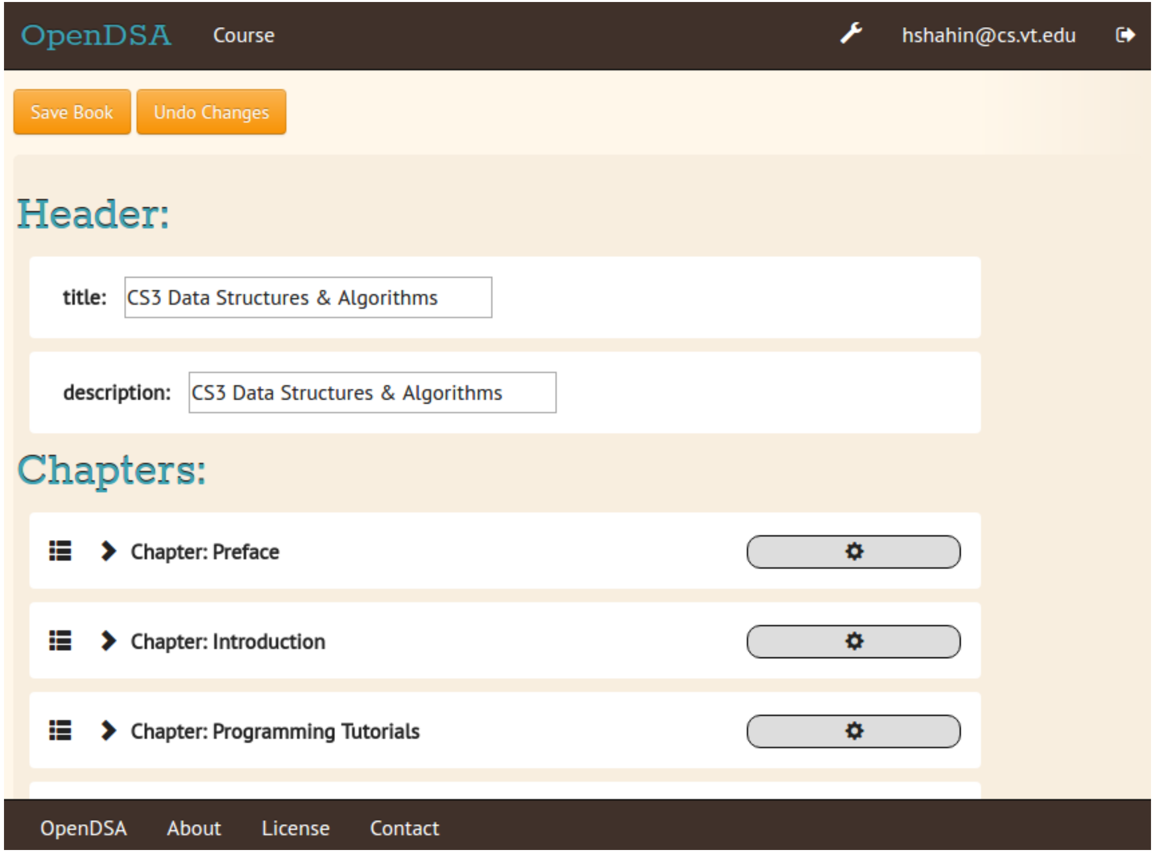
Canvas access token: 7~iYir4J6xo9iMXigxIM9BEqP5zWhJiUyuO8dnP83aEit2doF9Ed0nrO70qceI3Cr2 ✓

Put your Canvas access token for the selected Canvas instance. If you have not already created a Canvas access token, then follow the instructions here to make one.

Canvas course Id: 1119544

Create a new course at the selected canvas instance and copy the course Id here (e.g. Course Id of https://canvas.instructure.com/courses/1076903 is 1076903).

Instructors Interfaces: Create new course offering 1/3



Header:

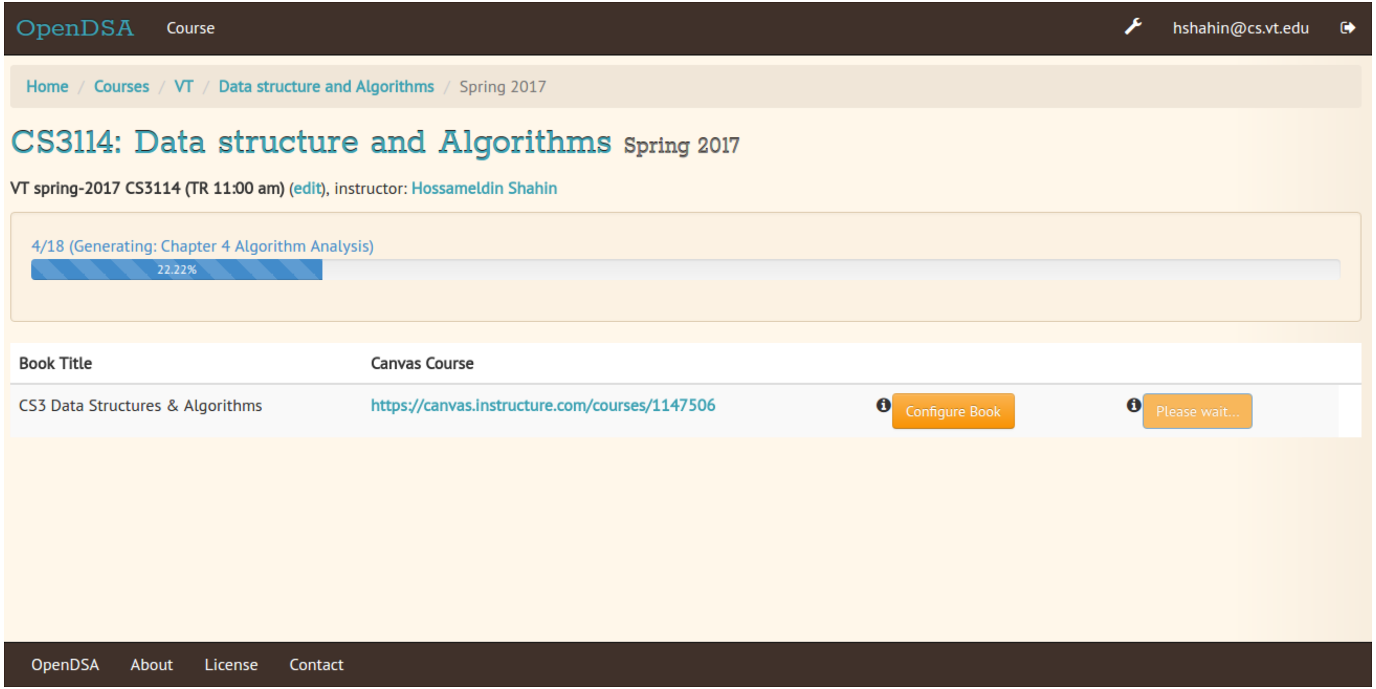
title: CS3 Data Structures & Algorithms

description: CS3 Data Structures & Algorithms

Chapters:

- Chapter: Preface
- Chapter: Introduction
- Chapter: Programming Tutorials

Instructors Interfaces: Book configuration 2/3


OpenDSA
Course
hshahin@cs.vt.edu
Home / Courses / VT / Data structure and Algorithms / Spring 2017

CS3114: Data structure and Algorithms Spring 2017

VT spring-2017 CS3114 (TR 11:00 am) (edit), instructor: Hossameldin Shahin

4/18 (Generating: Chapter 4 Algorithm Analysis)

22.22%

Book Title	Canvas Course		
CS3 Data Structures & Algorithms	https://canvas.instructure.com/courses/1147506	Configure Book	Please wait...

OpenDSA
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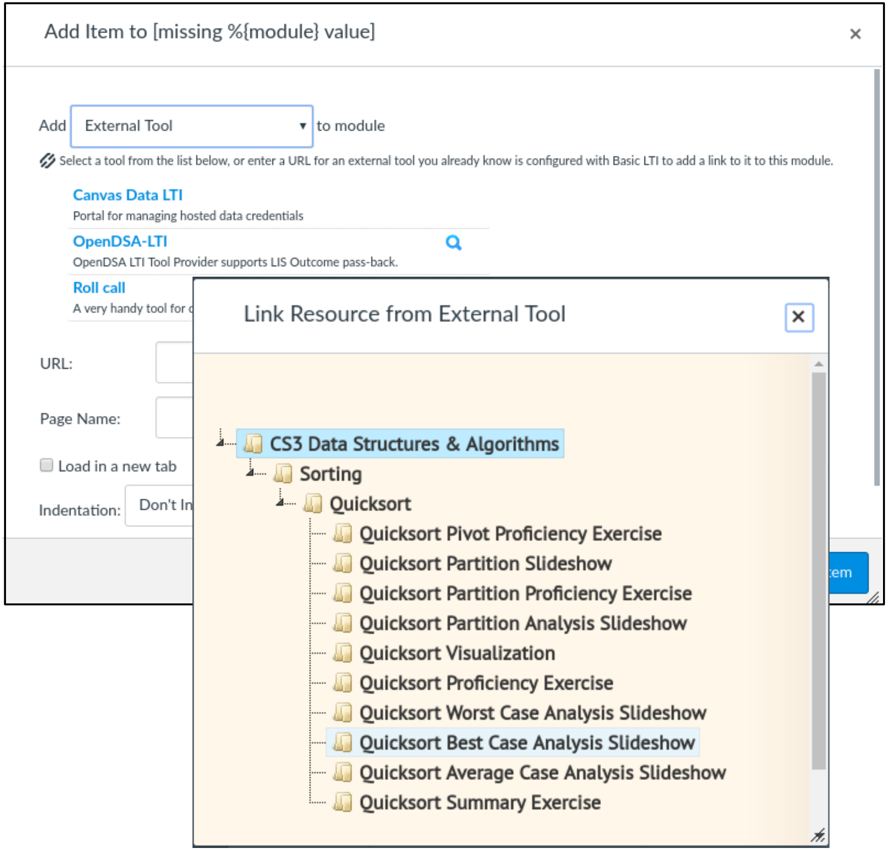
Instructors Interfaces: Course generation 3/3

1. Individual visualizations instead of a complete book.
2. Canvas implemented an extension to LTI v. 1.1 for resource selection.
3. The extension became part of v. 2.0.
4. Instructors have to manually define an LTI app in the course to be able to use this feature.
5. This feature still under active development.



Add Item to [missing %{module} value]

Add External Tool to module

Select a tool from the list below, or enter a URL for an external tool you already know is configured with Basic LTI to add a link to it to this module.

Canvas Data LTI
Portal for managing hosted data credentials

OpenDSA-LTI
OpenDSA LTI Tool Provider supports LIS Outcome pass-back.

Roll call
A very handy tool for c

URL:

Page Name:

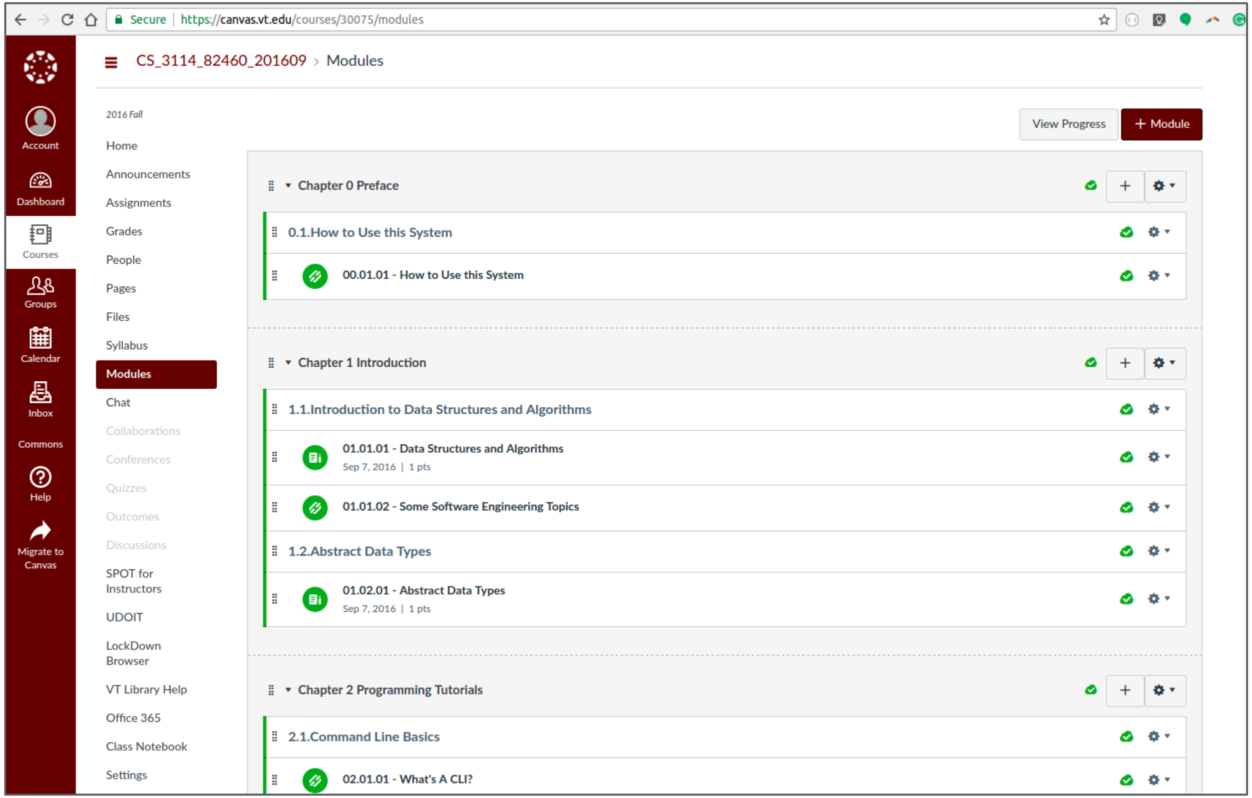
□ Load in a new tab

Indentation: Don't In

Link Resource from External Tool

- CS3 Data Structures & Algorithms
  - Sorting
    - Quicksort
      - Quicksort Pivot Proficiency Exercise
      - Quicksort Partition Slideshow
      - Quicksort Partition Proficiency Exercise
      - Quicksort Partition Analysis Slideshow
      - Quicksort Visualization
      - Quicksort Proficiency Exercise
      - Quicksort Worst Case Analysis Slideshow
      - Quicksort Best Case Analysis Slideshow
      - Quicksort Average Case Analysis Slideshow
      - Quicksort Summary Exercise

Instructors Interfaces: Resource Selection



Chapter 0 Preface

0.1.How to Use this System

00.01.01 - How to Use this System

Chapter 1 Introduction

1.1.Introduction to Data Structures and Algorithms

01.01.01 - Data Structures and Algorithms
Sep 7, 2016 | 1 pts

01.01.02 - Some Software Engineering Topics

1.2.Abstract Data Types

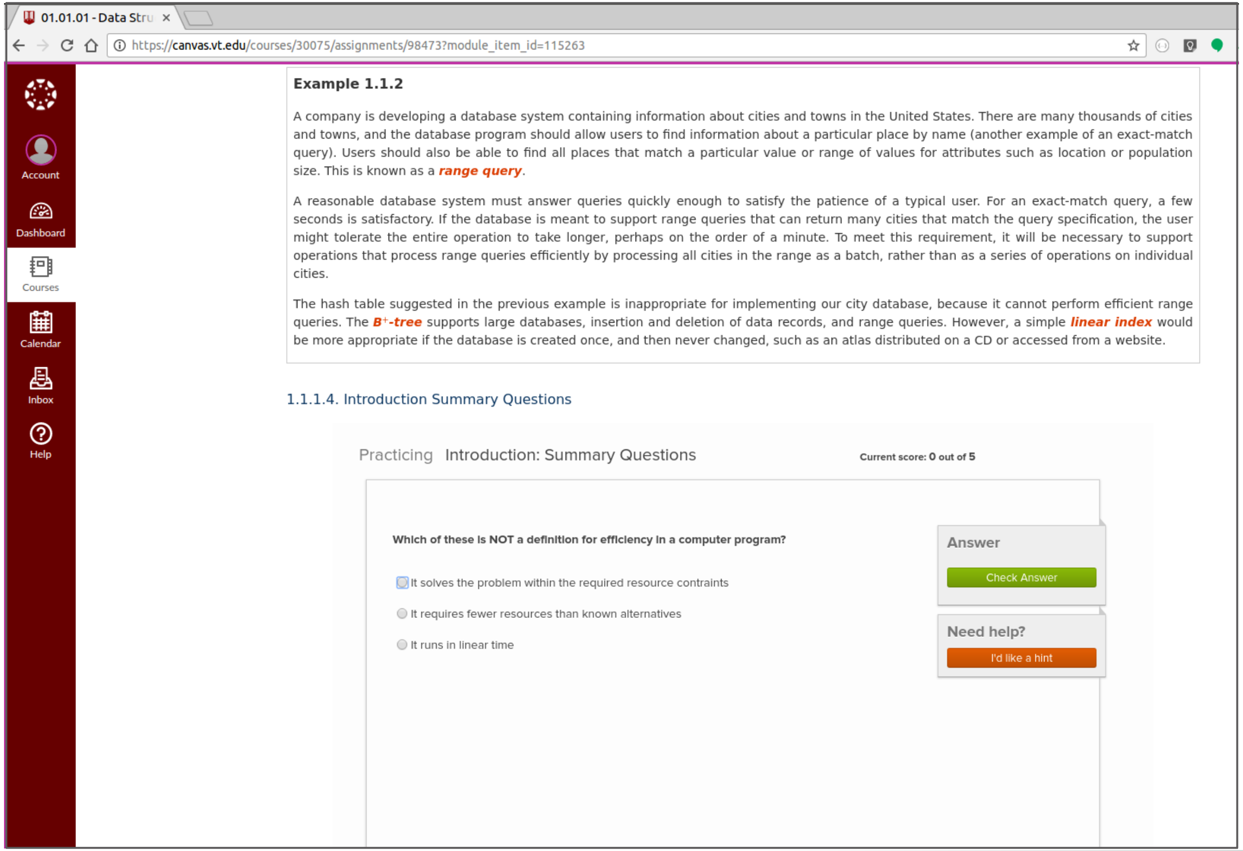
01.02.01 - Abstract Data Types
Sep 7, 2016 | 1 pts

Chapter 2 Programming Tutorials

2.1.Command Line Basics

02.01.01 - What's A CLI?

Students Interface: Main navigation page 1/2



01.01.01 - Data Stru
https://canvas.vt.edu/courses/30075/assignments/98473?module_item_id=115263
Account
Dashboard
Courses
Calendar
Inbox
Help

Example 1.1.2

A company is developing a database system containing information about cities and towns in the United States. There are many thousands of cities and towns, and the database program should allow users to find information about a particular place by name (another example of an exact-match query). Users should also be able to find all places that match a particular value or range of values for attributes such as location or population size. This is known as a ***range query***.

A reasonable database system must answer queries quickly enough to satisfy the patience of a typical user. For an exact-match query, a few seconds is satisfactory. If the database is meant to support range queries that can return many cities that match the query specification, the user might tolerate the entire operation to take longer, perhaps on the order of a minute. To meet this requirement, it will be necessary to support operations that process range queries efficiently by processing all cities in the range as a batch, rather than as a series of operations on individual cities.

The hash table suggested in the previous example is inappropriate for implementing our city database, because it cannot perform efficient range queries. The ***B$^+$-tree*** supports large databases, insertion and deletion of data records, and range queries. However, a simple ***linear index*** would be more appropriate if the database is created once, and then never changed, such as an atlas distributed on a CD or accessed from a website.

1.1.1.4. Introduction Summary Questions

Practicing Introduction: Summary Questions

Current score: 0 out of 5

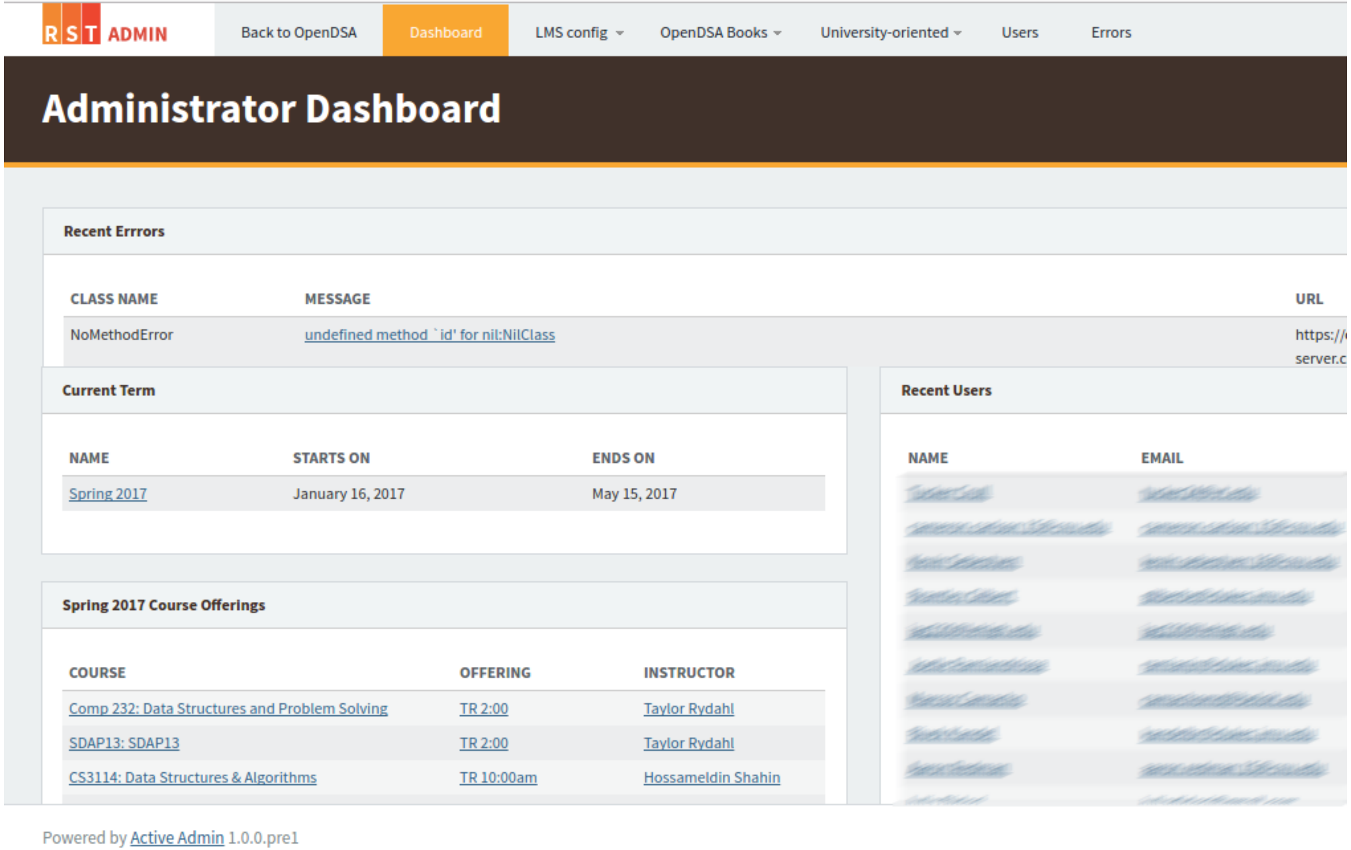
Which of these is NOT a definition for efficiency in a computer program?

○ It solves the problem within the required resource contraints

○ It requires fewer resources than known alternatives

○ It runs in linear time

Students Interface: OpenDSA page iframed in Canvas 2/2



Administrator Dashboard

Recent Errrors

CLASS NAME	MESSAGE	URL
NoMethodError	undefined method `id' for nil:NilClass	https:// server.c

Current Term

NAME	STARTS ON	ENDS ON
Spring 2017	January 16, 2017	May 15, 2017

Spring 2017 Course Offerings

COURSE	OFFERING	INSTRUCTOR
Comp 232: Data Structures and Problem Solving	TR 2:00	Taylor Rydahl
SDAP13: SDAP13	TR 2:00	Taylor Rydahl
CS3114: Data Structures & Algorithms	TR 10:00am	Hossameldin Shahin

Recent Users

NAME	EMAIL
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
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[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]

Powered by Active Admin 1.0.0.pre1

Admin Dashboard

Security

1. Students personal and class performance information are considered very sensitive (FERPA).
2. Security solutions such as SSL and firewalls are insufficient in protecting Web applications.
3. Top 10 threats, Open Web Application Security Project (OWASP)

- Injection
- Broken Authentication & Session Management
- Cross-Site Scripting (XSS)
- Insecure Direct Object References
- Security Misconfiguration
- Cross-Site Request Forgery (CSRF)
- Insecure Cryptographic Storage
- Failure to Restrict URL Access
- Insufficient Transport Layer Protection
- Unvalidated Redirects and Forwards

Contributions

1. Make OpenDSA more robust system
2. Integrate OpenDSA with the widest range of LMSs.
3. The OpenDSA-LTI makes it easier for instructors and students to use OpenDSA contents.
4. Transform OpenDSA from a monolithic system to a learning tool.
5. The OpenDSA-LTI infrastructure:
    - Hosts **36 active courses** offered by 25 different universities in 6 countries.
    - Used by **41 instructors** and **2,722 registered students**.

Future Directions

- Learning analytics is important to improve student performance and predict future outcomes
- Instructors can design all their activities to happen inside the LMS
- However, activities would be scattered across a range of tools
- Scattered learning tools means incompatible interaction capture mechanisms and data formats. (OpenDSA-LTI is an example)
- Caliper is a standard that enables interaction data with learning tools and LMSs to be collected, stored, and transported
- Make OpenDSA and encouraging other teams in the field to make more Caliper-compliant tools

Publications

- M. F. Farghally, K. Koh, H. Shahin, and C. A. Shaffer. "**Evaluating the Effectiveness of Algorithm Analysis Visualizations.**" *Exemplary Paper Award at the 48th ACM Technical Symposium on Computer Science Education (SIGCSE)*, 2017.
- K. Koh, E. Fouh, M. F. Farghally, H. Shahin, C. A. Shaffer. "**Experience: Learner Analytics Data Quality for an eTextbook System**", *ACM Journal on Data Quality*, 2017. (accepted)
- D. Altarawy, H. Shahin, A. Mohammed, and N. Meng. "**HYCAD: A Hybrid Approach to Categorize Software and Detect Similar Applications**", submitted to *IEEE International Conference on Software Maintenance and Evolution* (ICSME), 2017.
- S. Ha, D. Altarawy, H. Shahin, E. Dimitrova, D. Deb, R. Hilmer, J. Setubal, F. Katagiri, J. Glazebrook, B. Tyler, J. McDowell, S. Hoops, and R. Laubenbacher. "**PlantSimLab - A Virtual Modeling and Simulation Web Tool for Plant Biologists**", submitted to *BMC Bioinformatics*, 2017.

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- Dr. Clifford A. Shaffer
    - Advisor and committee chair
- Dr. Edward A. Fox and Dr. Dennis Kafura
    - Committee members
- OpenDSA and CodeWorkout developers
- NSF
    - Grant DUE-1432008
- My wife Doaa, and my kids Zeyad and Somaia

Thank you!
Questions?