VU Entwurf und Programmierung einer Rendering-Engine

Organization

186.166 - WS 2.0

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Organization

- Vorlesung
  - Monday, 16:15 (s.t.) - 17:45
  - Seminarraum 186, Institut für Computer Graphik und Algorithmen
  - ECTS efforts: approx half/half

- Übung
  - As a project, implement a module for a rendering engine
  - Topics can be chosen by students

Student project

- Extra slides for “Übungsteil”
- Similar to previous years:
  - Rendering and optimization a scene. This includes:
    - Geometry processing (e.g. Terrain generation, Meshes,...) or model loading
    - Acceleration data structure or optimization algorithm
    - Rendering of the scene

Exam

- Hand in (per email) the project + a written report
  - Till 2 days before the exam date
  - Written report (2-4 pages)
    - Description of the project
    - Description of the used techniques
    - Analysis of the performance
- Oral exam
  - End of January till end of march
    - Email with 2 possible dates to rendEng@vrvis.at
  - Demo of the project
  - Two questions of the lecture content
    - Details not that important, but understanding of the topics.

Contact

Harald Steinlechner

- VRVis Research Center, Donau-City-Straße 11
- rendEng@vrvis.at
- Register in TISS
- When projects/team is fixed: write email with task description to hs@vrvis.at

VO Homepage

- https://www.cg.tuwien.ac.at/courses/RendEng/

The mission of a rendering engine….

- Provide easy to use software components...
- which can be used to solve rendering engine tasks (like a toolbox)

In order to accomplish this, we need:

- Algorithms and Datastructures
- Graphics API & Hardware Insights
- API design
- Domain specific languages (e.g. scene description)

After the lecture you are able to...

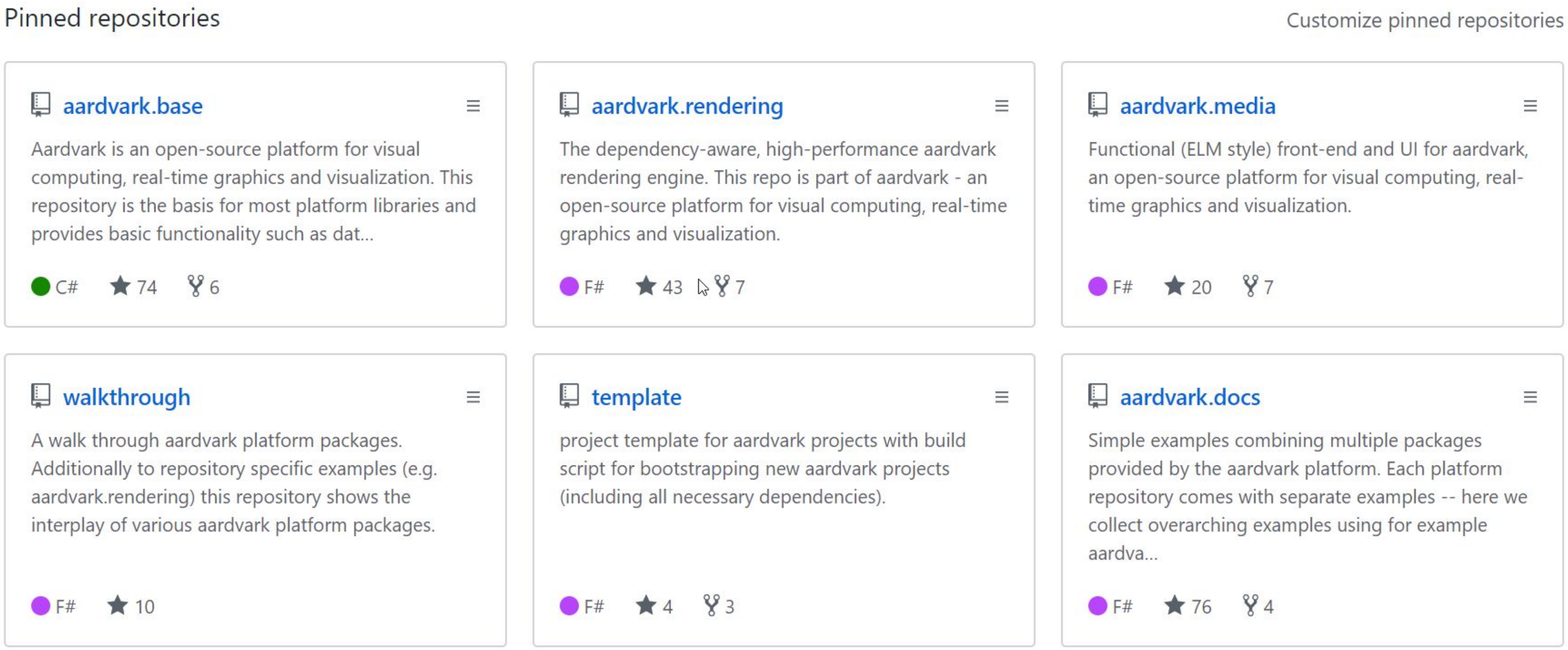
- Analyse specific use case for rendering engines
- Structure reusable parts of a rendering engine
- Evaluate techniques and their trade offs including benchmarks
- Apply lighting and global illumination techniques to applications

Content of this LV

- Requirements for the design of rendering engines
- Hardware and Graphics APIs (OpenGL, Direct3D, Vulkan,..)
- Scene Representation (Scene graphs, display lists, command buffers,...)
- Static and Dynamic Data (Incremental Update Techniques)
- Optimizations (Caching, Culling, Level of Detail, Bounding Volume Hierarchies, Just-In-Time Optimization)
- Resource Management
- Domain Specific Languages (HLSL, Spark, FShade, Semantic Scene Graph,..)
- Reusable Components/Design for Rendering Engines

About the LV team & Aardvark

- LV Team is basically the aardvark core development team.
- Active development of the aardvark rendering engine since 2006 with Robert F. Tobler.
- Roberts mission: easy to use but high-performance rendering engine.
- Aardvark - An Advanced Rapid Development Visualization and Rendering Kernel
    - Heavily used in research + industry projects



Pinned repositories

Customize pinned repositories

aardvark.base ≡

Aardvark is an open-source platform for visual computing, real-time graphics and visualization. This repository is the basis for most platform libraries and provides basic functionality such as dat...

● C# ★ 74 ⑂ 6

aardvark.rendering ≡

The dependency-aware, high-performance aardvark rendering engine. This repo is part of aardvark - an open-source platform for visual computing, real-time graphics and visualization.

● F# ★ 43 ⑂ 7

aardvark.media ≡

Functional (ELM style) front-end and UI for aardvark, an open-source platform for visual computing, real-time graphics and visualization.

● F# ★ 20 ⑂ 7

walkthrough ≡

A walk through aardvark platform packages. Additionally to repository specific examples (e.g. aardvark.rendering) this repository shows the interplay of various aardvark platform packages.

● F# ★ 10

template ≡

project template for aardvark projects with build script for bootstrapping new aardvark projects (including all necessary dependencies).

● F# ★ 4 ⑂ 3

aardvark.docs ≡

Simple examples combining multiple packages provided by the aardvark platform. Each platform repository comes with separate examples -- here we collect overarching examples using for example aardva...

● F# ★ 76 ⑂ 4

Seealso

https://aardvarkians.com/

Some of our projects

Live demo

Till approx 2002
Aart (Obj C)

Approx. 2002
Ave (C++)
Traditional Scene Graph

Managed language for rendering engine?

Approx. 2005
Aardvark (C#)

Clean Semantics for Rendering

Approx. 2008
Aardvark 2008 (C#)
Semantic Scene Graph [Tobler 2011]

Aardvark 2010
Lazy Incremental Computation
For efficient Scene Graph
Rendering [Wörister et al. 2013]

Performance!

Aardvark 2015
Composable Shaders
[Haaser et al. 2014]
Towards Incremental Computation,
Attribute Grammars for Incremental Scene Graph Rendering

Usability:

- **Domain Specific Languages**
- **Flexibility**

Approx 2016
aardvark.rendering
aardvark.base
General purpose incremental Computation,
Incremental Rendering VM [Haaser 2015]

Fast and flexible!

2017
Vulkan, ELM architecture,
Aardvark goes web

Usability, Remote Rendering,
Aardvark in the browser

Challenges

- Size of data-sets
  - Often requires out of core approaches
- Dynamic and static geometry
- Efficient graphics hardware utilization
- Support for special effects
  - APIs for accessing special hardware features
  - Provide mechanisms to specify for example shaders and post processing
- Many different application areas: Focus on real-time applications
  - Terrain, laserscan, reconstructed data, game levels
  - Architecture and planning
  - Light simulation (Global Illumination)
  - Games
  - Interactive Editing applications

Design Space

How to structure a rendering engine

- What interfaces and modules useful
- How to transfer data
- How to manage memory (we have GPU and main memory)
- How to store data in memory (e.g. for efficiency reasons)
- How to optimize, how to make use of multiple CPU cores

Graphics hardware specific questions

- What to compute in shaders
- What to compute on CPU (in what precision?)

What to expect

- Tools/Algorithms/Concepts to implement rendering engines
- Hardware/Graphics API insights
- How to structure rendering engine into modules
    - (Low cost) abstraction techniques
    - Compiler techniques
- Important data-structures in practise
    - k-d-Trees, Octrees
- Performance considerations
    - Optimizations (how to pack buffers etc)
    - Costs of programming language abstractions (e.g. can we afford virtual function calls?)
- How to manage large scenes (performance + memory)
- Approaches for implementing lighting/material systems

What to expect

- Dependencies and incremental computation for rendering engines
  - Efficient ways to handle dynamic data
- Scene representation
- Rendering of big scenes
  - Terrain-rendering, rendering precision, caches
- Parallelization for rendering engines

- **Not content of this LV:**
  - Graphics programming tutorial
  - How to use existing engines
  - How to implement concrete tooling (e.g. level editor, material editor)

Timeline

- 14.10.2019 - Organization, Introduction & Motivation
- 21.10.2019 - Scene representation
- 28.10.2019 - Optimization techniques for rendering engines
- 04.11.2019 - Data and rendering engines
- 11.11.2019 - Benchmarking, Representing fully dynamic scenes, Aardvark Tutorial
- 18.11.2019 - Optimization techniques for fully dynamic scenes
- 25.11.2019 - Domain Specific Languages for Rendering Engines, Composable Shaders
- 02.12.2019 - Materials and Lights for Rendering Engines,
- 09.12.2019 - Shading System and Global Illumination
    - Including lightmap packing, instant radiosity, deferred rendering techniques,..
- 16.12.2019 - Questions regarding the lecture/project

Questions