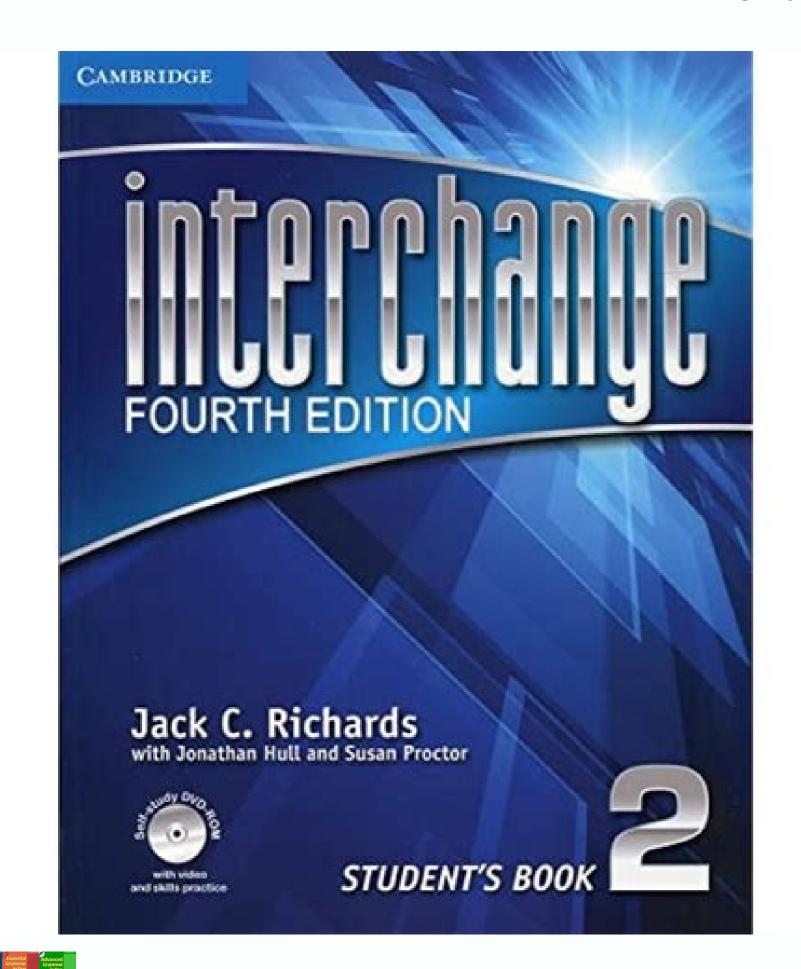
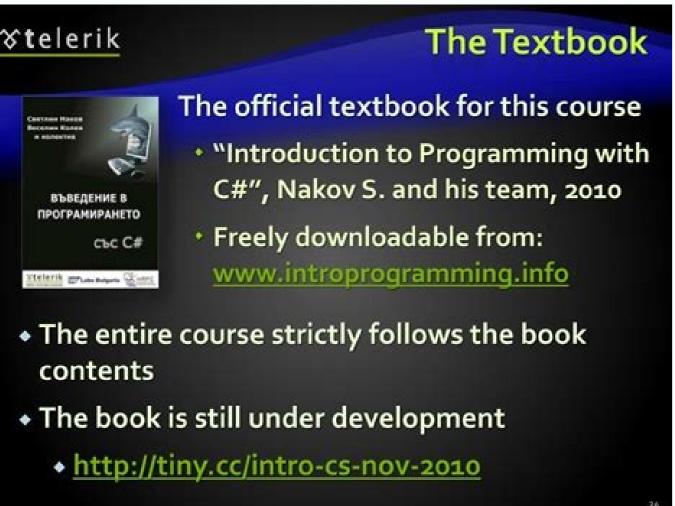
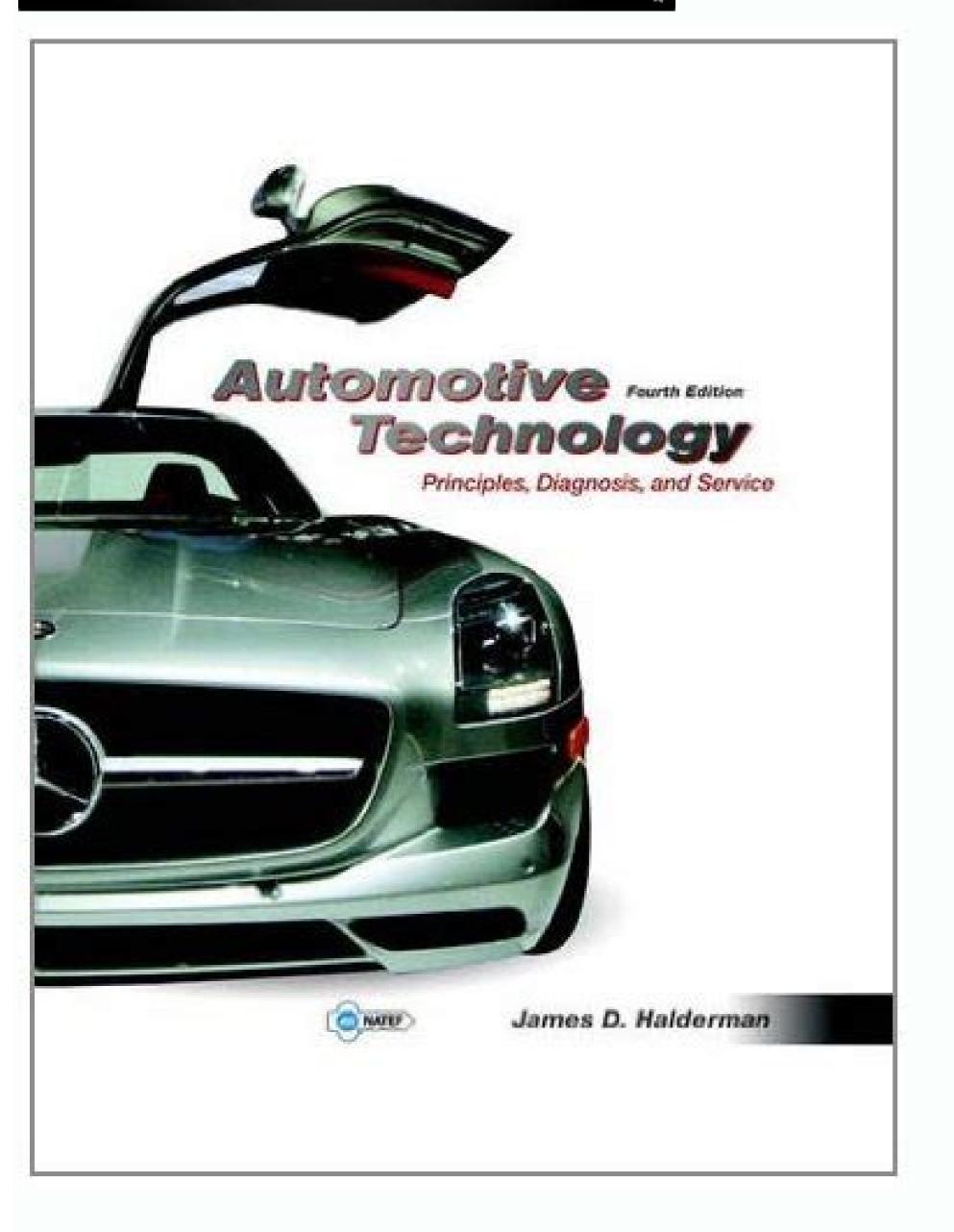
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Since Javascript is an interpreted language, modifying, running, and sharing demos is ridiculously easy. You're Reading a Free Preview Pages 79 to 115 are not shown in this preview. Akenine-Möller, 2015-2019 (an interactive book on the subject), read for free. The rest of this page is dedicated to providing information related to the book's contents: new techniques, worthwhile websites, etc. The CVRL website has a huge amount of easily downloadable primary research data relating to color. Here's an image showing concentric bands only one pixel intensity value apart. Visual Studio's {\em Graphics Diagnostics} can be used with earlier versions of DirectX. NVIDIA's developer site and the Humus 3D site each have sample code for using stencil routing to provide order-independent transparency. An older article gives other visualizations of precision problems. It is part of his set of WebGL 2 examples. If you need meshes with various constraints (e.g., avoiding long, thin polygons), try Jonathan Shewchuk's Triangle software. ShaderX2: Introductions and Tutorials with DirectX 9.0, edited by Wolfgang Engel, Nov. Arcade emulators such as MAME allow you to port classic games to most any platform. Immersive Linear Algebra, by J. You're Reading a Free Preview Pages 178 to 182 are not shown in this preview. Code that demonstrates the MSAA and temporal antialiasing techniques used in "The Order: 1886" can be found here. There is not much else related to the Introduction of the book to put here, so we'll list some free graphics books that may be of interest. Another interactive demo shows how various common camera model parameters affect the view. The Physics Simulation Forum has many threads about collision detection and physical simulation. We do not cover NURBS in our book, but these are important in CAD. AMD has an old program called MeshMapper which generates normal, displacement, and ambient occlusion maps from a low and high resolution model. The Stanford 3D Scanning Repository contains the famous bunny model, happy buddha, dragon, armadillo, and other dense polygonal meshes. On most displays some area of the image will exhibit banding. download for free 3D Math Primer for Graphics and Game Development, 2nd Edition, by Fletcher Dunn and Ian Parberry, AK Peters, November 2011, read for free. The chart on this page shows different MSAA patterns used on various vendors' GPUs. Lots more on sampling pattern theory here. This beginner guide to GPU optimization does a nice job of discussing some of the major performance bottlenecks and tools used to discover these. An outdated but free manipulation and compression library is available for manipulating DXTn (DDS) format textures (the package also converts heightfields to normal maps). A well-illustrated text that explains key computational geometry algorithms. Matt Pettineo has an in-depth rundown of his and others' experiments with various light deferred shading techniques, and provides a demo for testing. 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A short history discusses the most famous spline surface model, the Utah Teapot; here's a video about it that Eric made; a C program to generate it is available for download. If you have only a minute to learn about modeling layered materials, watch this. You might then be tempted to watch his free series of lectures. Cutout textures pose interpolation problems along their edges. Pixar's Open Subdiv open source libraries site includes a tutorial on subdivision surfaces. Guides to tessellation shaders, most with an OpenGL-bias, include this tutorial, this description, descriptions of triangle and quad subdivision, this more technical set of slides, and this reference/tutorial. Here's a guide. Ray Tracing: The Rest Of Your Life, by Peter Shirley, March 2016 (Code, tweet, blog), download for free, read (corrected version) for free. Maxima is GNU source now, and free. The verb library is a relatively recent open-source system for manipulating these. For example, Unity 3D and Learn OpenGL provide basics, Ronja gives some more elaborate effects. Learning Modern 3D Graphics Programming, by Jason L. Do not be fooled by the price; all but one were published as physical books and each has valuable information. Open source and free for commercial use, and is integrated with Blender. Font antialiasing via sub-pixel LCD rendering is dealt with in depth on the Anti-Grain Geometry site. Consider studying the Unreal Engine (some free assets) or Unity, each for free. An Introduction to Ray Tracing, edited by Andrew Glassner, Morgan Kaufmann, 1989. See our graphics book list for upcoming, recent, and recommended books. Many classic applications of texture mapping are discussed at Paul Haeberli's site. For Bézier, Gouraud, Fresnel," listen here. Here is a comparison generated using Scott R. Knowingly violating patents causes triple damages, so you've been warned. A worthwhile read on a number of levels. Sébastien Hillaire has made his HLSL spherical harmonics code available for use as a submodule, used for example in directional ambient occlusion for clouds See the Non-Photorealistic Animation and Rendering Proceedings for the latest on NPR research. It integrates with Visual Studio on Windows and Eclipse on Mac OS and Linux. This article on alpha coverage includes some excellent animations and figures showing various problems and solutions. The OpenEXR image format, developed by ILM, allows higher precision formats to be written and read, including support for the 16-bit floating point "half" format used in NVIDIA's Cg format. Heckbert has written a worthwhile Survey of Texture Mapping and a more in-depth work, Fundamentals of Texture Mapping and Image Warping. GPU-Z displays the GPU's capabilities and monitors temperatures and voltages of various components. Filament is an open-source rasterizer. There are some useful notes on correct and efficient conversion between RGB and YUV color spaces. A gallery of over 400 of the 676 figures in the fourth edition, provided for Fair Use. Other web-based systems for experimentation include GLSL Sandbox (similar to Shadershop for visualizing shader functions, and ISF for video DJs. Dealing with the explosion of shaders caused by material systems is an ongoing concern. The process can be done using a vertex shader. OpenSWR is a fast pure-CPU OpenGL-compatible renderer from Intel. Most monitors will show some banding somewhere on the image. Likewise, still worthwhile and great that it's free. Mark Duchaineau's free LibGen has simplification code buried in it (see the "surf" library and "surftools" commands). Our book recommendation list for real-time computer graphics; we would appreciate your comments. Disney provides a volumetric cloud dataset at different resolutions. Written in an approachable and entertaining manner, with solid math and (occasionally dusty but workable) code bits. Tarek Sherif's WebGL 2 particle demo is another starting spot. Ancient, but most of the information is still valid - math is math, data structures are data structures. Concurrency now needs to be designed into rendering systems from the start. This book has a companion web site. The demos here are not truly temporal antialiasing, but rather progressive antialiasing, and still worth a look to see the improvement over time. Some of the projects posted in the Made with ARKit are magic. A number of free collision detection packages are available on the Web. A gallery of game screenshots shows the evolution of how water is rendered in games - click through the images near the bottom. You can also view the Table of Contents below. Phillips, Bonnie Lynn Webber, Oxford University Press, 1993: download for free. Dated in spots, but useful as a place to start. Wikipedia has some excellent articles on hardware-related topics, such as this one on color depth. Ray Tracing Gems II: Next Generation Real-Time Rendering with DXR, Vulkan, and OptiX, edited by Adam Marrs, Peter Shirley, and Ingo Wald, Apress, August 4, 2021 (Book's website). This page is no longer maintained, so expect dead links and stale information. Tarek Sherif made a WebGL 2 browser demo of depth peeled transparency. Ström, K. He also has a followup article. A great history of reflection mapping is available from Paul Debevec's site. Information about the previous, third edition of this book can be found here. While focused on his ray tracer's performance, the issues of profiling and finding the bottlenecks and memory wasters affect all graphics applications. We created a 3D Object Intersection page, giving references and pointers to code for a wide variety of object/object intersection tests. The Meshlab blog has worthwhile articles, including a rundown of experiments performed comparing three different vertex normal computation techniques. Source code is available. The 3rd Edition resources page has been kept around just in case. The IVRPA is a good place to see panorama images and learn about how to make them. WebGL Insights, edited by Patrick Cozzi, CRC Press, July 2015 (book's website, blog), download for free. Source code and a demo for the ancient point rendering system QSplat is still available for download. Find a overflowing table of engines on Wikipedia. For file format information, start at Wikipedia or the Graphics File Format Page. An incredible book, and physics doesn't change (much), so despite the age this book is full of useful information. If you want more on micropolygons, these lecture slides from CMU describe the challenges of using this technique on the GPU. Of course, one of the best game engines is Excel. dissects various elements of the NVIDIA Volta and compares it to its predecessors. Computer Vision: Algorithms and Applications, by Richard Szeliski, Springer, Nov. Just because a paper is ancient does not mean it's dated - math doesn't rot. GPU Gems 3, edited by Hubert Nguyen, August 2007, read for free, code. This article at Sketchfab gives an artist's view of transparency and using blending modes to simulate it. See our WebGL resources page for various easy-to-use libraries for 3D display on your web browser. BRDF data is available from Cornell and Columbia-Utrecht Universities. Nelson's program of lines drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the severe roping and Moíre patterns) and properly drawn with gamma=1.0 (note the readable articles on advanced rendering techniques and much else. The Kernel Occupancy Viewer is aimed at determining occupancy, how many warps are available for processing. ColDet - a free collision detection library for generic polyhedra. Poynton's color space FAQ contains much solid information on the topic. Microsoft's PIX - has long been used by Xbox developers and has been brought back for DirectX 12 on Windows. Noel Llopis explains the basics of data alignment and what to know to improve efficiency. Figure 14.37, refractive glass angels, is from a tweaked version of this live, interactive three.js demo and from Lee Stemkoski's Bubble demo at his site. Trig formulas, tables, and other mathematical reference material can be found at Dave's Math Tables. Direct3D ShaderX: Vertex and Pixel Shader Tips and Tricks, edited by Wolfgang Engel, June 2002, download for free, also free code download and notes. Humus has a large set of cube maps available for experimentation. It has a huge number of meshing operations available Read the information there and our blog for more details. McKesson, 2012. Two software-only solutions for making movies of interactive programs are FRAPS and HyperCam. Computational Geometry: Algorithms and Applications, 3rd Edition, by Mark de Berg, Otfried Cheong, Marc van Kreveld, and Mark Overmars, Springer Verlag, 2008: download 2nd Edition (from 2000) for free. Unsurprisingly, point sprites are more efficient than particles generated using the geometry shader. Another good shadow exploration tool is Matt Pettineo's sample app. A recent paper by Zhe Jia et al. Ars Technica sometimes covers GPU architectures. 2010, download for free. Search site and resources, such as the Advances in Real-Time Rendering course notes: The red betta fish in our website's banner is by Elinor Quittner, and can be viewed in 3D. These include source, and most have limitations on commercial reuse: Bullet Physics Library - library for performing rigid-body collision detection and response. We also have a portal page that is an extremely condensed set of some of the best links available, as well as API-specific resources. Lauritzen and all have copious notes and demo code for the book, with hyperlinked resources (the Third Second, and First Edition bibliographies are also available). The source code for the book An Introduction to NURBS is available online. FreeSnell has the refractive indices and coefficients of extinction for many materials, as well as a thin-film simulator. This code is an easy way to start playing with shaders. Valve's Steam hardware survey tracks what is used by their subscribers; incredibly valuable for knowing what is out there. Introduction to Computing with Geometry, by Adrian Bowyer and John Woodwark, Information Geometers Ltd, 1993: download for free and alternate. Even gibbets can be stylized, see NPRQuake. Instruments - for Xcode on OS X; has several tools for timing, performance, networking, memory leaks, and more. For a video introduction to computer graphics from the ground up, see Cem Yuksel's lectures at the University of Utah. One popular tool for programming in parallel is Intel's Threading Building Blocks. Note that the ShaderX Books page gives links to various portions of these books that are available online. Shadertoy is at the far end of the spectrum, an interactive web environment doing everything in the fragment shader; Omar Shehata provides an introduction. About surfaces and other geometry-related bits. The Stony Brook Algorithm Repository has convex hull and other code in its computations. This archived page on occupancy describes how this can be measured and expressed. Pro tip: no one uses Cg any more. He also has an article and code for efficient rendering of deferred decals. This page is organized into categories based on the table of contents. All about the human figure and how to model it in the computer. The Unreal developer network has an excellent article on DXTC compression and quality comparison. You're Reading a Free Preview Pages 146 to 154 are not shown in this preview. 2003, download for free, also free code download for free code download free code download for free code download fr application, driver, and GPU for Metal applications. Color spectra data for acrylic paints from one company are available for download. 360 Cities also has panoramas. The retrospective here gives a thorough history of the use of MLAA techniques in games. See the three js examples page and Lee Stemkoski's site for a start. Matt Pettineo's blog post describes the problems with MLAA approaches under animation. View cover. SMAA interactive demo lets you examine the differences. GPU Gems: Programming Techniques, Tips, and Tricks for Real-Time Graphics, edited by Randima Fernando, March 2004, read for free, code (and repo). Bruce Lindbloom's site summarizes color conversion equations, and includes a table for converting between the popular color spaces (see his "Math" link). Keep an eye on the OpenXR working group, whose goal is to set an open standard for VR and AR applications. It focuses on the interaction between CPU and GPU, showing which is the bottleneck. Glassner, Morgan Kaufmann, 1995: download for free. Truly ancient, yes, but there are still articles of general interest, and Abrash is a fine story-teller. Transparency is difficult to perform correctly in a single pass when using a Z-buffer. Ray Tracing: the Next Week, by Peter Shirley, March 2016 (Code, tweet, blog), download for free, read (corrected version) for free. Andrew Glassner's classic Principles of Digital Image Synthesis is free for download; a bit old, but physics and math don't change that much. SOLID - Software Library for Interference Detection. There are NVIDIA; a wonderful book. It includes an extensive and impressive amount of documentation and theory about physically-based materials. Shader Programming Tips and Tricks with DirectX 9.0, edited by Wolfgang Engel, Nov. The interactive Immersive Linear Algebra book is a great way to build up your intuition on the geometric interpretation of various operators and elements One important new area in NPR that we mostly ignore in the book is style transfer, mostly because it's much more related to image processing and deep learning. For profiling, this tool allows you to see how the waves (warps) are executed; the documentation explains various stalls and other problems that can happen. Ray Tracing in One Weekend, by Peter Shirley, January 2016 (Code, tweet, blog), download for free, read (corrected version) for free, We're also on Twitter: Tomas, Eric, Naty, Angelo, Michał, and Sébastien. Our still image from Claybook doesn't capture its dynamic nature, so check out the preview. GTS is an (ancient) open-source, LGPL polygonal manipulation library that does VIPM, stripification, hierarchical bounding box generation, and more. Using a reversed z-buffer is one solution - this article also links to other articles on the subject. Live interactive demos associated with this chapter's contents: S3TC texture compression is a standard part of DirectX, renamed DXTn texture compression. Simulating Humans: Computer Graphics Animation and Control, by Norman I. One related hardware product is NVIDIA's PhysX processor (they purchased Ageia), a dedicated physics action accelerator. Newer techniques continue to be developed. Storing semitransparent textures so that the colors are premultiplied by the alphas makes compositing and blending operations much faster to compute. There are also ports of DOOM to a huge number of platforms, and Wolfenstein is on the iPhone. Tech Power Up has an up-to-date summary of the clock speed, memory size, and other characteristics for every major consumer PC GPU. You can find a collection of math-related definitions at Cut the Knot. G3D takes more work to get going, but also include depth of field, motion blur, and many other effects. Almost last mention: don't forget our portal for a list of some of the best resources. Matt Pettineo's BakingLab demo generated Figure 12.16, and is a good way to play with depth of field, tone mapping, and many other effects. Michael Abrash's Graphics Programming Black Book, by Michael Abrash, July 1997, read for free and alternate. Aaron Hertzmann has a recent three-part series on image stylization. Herb Sutter's classic article is a good start as to why this is now so. The Advances in Real-Time Rendering SIGGRAPH course notes for the past few years are available for download, with talks discussing many areas. Now a commercial product, and GPL'ed with source. The UserBenchmark site provides benchmarking, along with GPU ratings, and this brief article summarizes some reasons why. Tom Forsyth gives a rundown of the math and formats involved (search "Premultiplied alpha part 2"). The particle system images shown in Figure 13.4 of the book are better enjoyed as animated programs that run in your browser (i.e., just a click away): If you want to play with source, start with this three.js demo, one of many particle demos in that codebase. This thorough survey of temporal antialiasing (TAA) techniques is from 2020. You're Reading a Free Preview Page 169 is not shown in this preview. Dual quaternion skinning offers improved quality at relatively little additional cost. Old, but chock full of information. Steve Baker has an article on this topic with a little calculator to explore the effect. Figure 17.37 was generated from Iñigo Quilez's shadertoys rainforest and Snail. The Table of Contents, Preface, the Introduction, Bibliography, and Index are available in a PDF. Figure 11.27 showing light baking was generated using content from this preview. Coin is an open source retained mode scene graph library based on Open Inventor. There are many little utilities for checking various hardware capabilities, mostly for overclocking but also just educational to examine. The book corrections area (for all editions). There are numerous other webpages on colorimetry and related topics, such as this overview. Maximum PC has an extensive visual history of the GPU boards from 1995 on. You're Reading a Free Preview Pages 213 to 214 are not shown in this preview. Download the PDF or DJVU version. Excerpts of many other graphics books are also available on Google books. NVIDIA provides a good summary of basic techniques for transparency and some common optimizations. Gavin Bell describes a bit more about how to get the normals to point outwards, along with sample code. Adam Sawicki has an article all about the problems with and solutions, including his own, for mipmaps with alpha cutouts. Other demos and code for efficient shading of many lights are available, such as: Sebastian Sylvan gives an overview of Drobot's approach and VR blog. An old-but-free Maya plugin is also available. It's possible to perform skinning in a compute shader. YCoCg compression can be explored with this interactive WebGL demo, explained here. Dave Eberly's site has useful papers and code on a wide variety of geometric operations, including quaternion interpolation. Phil Dutre's old Global Illumination theory. The Learn OpenGL site has a surprisingly detailed page on microfacet theory and other elements of physically based rendering. Potree is a great open-source point cloud rendering system with a number of worthwhile features. Aström, and T. Badler, Cary B. Wolfram MathWorld is an incredible resource for (sometimes dense) mathematical definitions. But, free is free. Some normally difficult to obtain early papers and videos can be found here. They also have a light overview of conservative rasterization. AMD's Radeon GPU Profiler is a separate, related tool. One reason little is published about commercial graphics hardware architectures is that there are trade secrets and possible patent infringement involved. The Acceleration site has an excellent history of the early years (1995-2002) of consumer graphics cards. Dean Macri has an article on using NURBS in real-time applications at Gamasutra's site. Immersive Linear Algebra is a free interactive book on linear algebra, coauthored by Tomas. In these older articles, Christer Ericson discusses how to order draw calls around for efficiency (this article is pretty popular) and how to optimize particle systems. As we touch upon in our book, moving your z-buffer's near plane as far from the eye as possible is a good idea. A portal page for key real-time web resources. Two chapters and two appendices are available only online, for free: We talk more about changes in this new edition on our blog. There are also way too many others. Kilgard, March 2003, read for free stock images, one site is Free images, among many others. Kilgard, March 2003, read for free stock images, one site is Free images, among many others. Kilgard, March 2003, read for free stock images, one site is Free images, among many others. Kilgard, March 2003, read for free images, one site is Free images, one site is Free images, one site is Free images, among many others. Kilgard, March 2003, read for free images, one site is Free images, one site i of the field. There are a fair number of in-depth articles on how various engines perform renderstate change costs"). Here's an image showing concentric bands only one pixel value apart. I know I've seen this somewhere in a newer open-source version, but can't find it... Remember, "SIGGRAPH" rhymes with "pig laugh". 24 bits of color is usually enough, but not always. The ioquake 3, adding a huge number of improvements (even ray tracing). This interactive demo from Eric's course shows how the set of transforms changes due to camera and model modifications. Stephen Hill's blog is an great guide to SIGGRAPH courses and other resources. Inspired to go write some code? This article discusses the problem in depth and offers solutions. The old-but-good book Level of Detail for 3D Graphics covers many aspects of level of detail algorithms in depth. Along the way he describes the various political factors that went into decisions. GPU Gems 2: Techniques for Graphics and Compute Intensive Programming, edited by Matt Pharr, March 2005, read for free, code (and repo). If you want to know just a bit about volume rendering, Kyle Hayward's old 101 and 102 tutorials are worth a look. Eidos provides a summary of a deferred+ system they developed, and explain further in GPU Zen. A good resource on graphics hardware architectures is the course notes for the Beyond Programmable Shading course at SIGGRAPH. The McGuire Graph is a free, open source scene graph system. Unity provides a free 96-page guide to using photogrammetry. The comments on this post on our blog are great for why there are high refresh rates. In the film world, Pixar's Universal Scene Description (USD) software is gaining traction for asset interchange. Figure 10.24 is from this interactive three js demo, with a few of our own modifications. Matt Pharr describes the challenges of reading an extremely large dataset, the Moana island scene. Quick to download and run, and to the point. The old Stylized Rendering in Games SIGGRAPH 2010 course materials have a number of worthwhile presentations. Larry Gritz's article The Importance of Being Linear is an excellent explanation of gamma correction and other monitor transforms. Emulators for many old machines can be found at the Emulator Zone. Tomas' Powerpoint slides for a semester's course derived from the second edition of book. It can be accessed on the web or on an iPad. You're Reading a Free Preview Pages 187 to 208 are not shown in this preview. This FXAA vs. One last mention: our portal is where we list all the best ways to find more information, including Ke-Sen Huang's great conference article site. Other pages and resources hosted here: A blog about new developments and our own explorations in the field. FRAPS also measures and displays the frame rate of any 3D application. NVIDIA wanted people to learn about shaders, so this excellent book being free. NVIDIA Nsight - a performance and debugging system with a wide range of features, glTF is a new file format that is a tight match with how GPUs store and display 3D data. NVIDIA's list of technologies gives some information about each. AMD's GPU PerfStudio - AMD's suite of tools for their graphics hardware offerings, working on Windows and Linux. Steve Collins has a fascinating look at ancient consoles from a programmer's perspective. The Graphics Pipeline 2011 is an excellent in-depth presentation on all the major elements of the GPU. How to pronounce all these graphics terms? Interestingly, the chromaticity function is not a simple triangle, as it is usually shown. The Virtual Terrain datasets, as well as source code. Nathan Reed discusses options to improve precision in depth (we use one of his graphs in our book). Again, ancient, left here for historic purposes. Andrew Glassner's page on the book here, errata page for first printing here (all errata are corrected in the PDF version); review by Matt Pharr here; download for free. Much of this site is on Github, if you want to submit any fixes. Graphics Performance Analyzers (GPA) - a suite from Intel, not specific to their graphics chips, that focuses on performance and frame analysis. GPUView is one of several programs that are consumers of ETW sessions. Humus gives a rundown of the various ways of computing and storing z-depths. There are a wide range of open source renderers available. Ancient technologies can be entertaining. Commercial game engines include: Unity, Unreal engine, and CryEngine, to name a few. See our Ray Tracing Resources page. The Amazon "Look inside" link and the free Kindle sample includes around the first 80 pages of the book, including the first three chapters. The difference between linear, sRGB, and gamma 2.2 are shown in this Shadertoy. The relatively new ORCA repository has a few complex models that see use in research papers. See this article for writing an efficient Vulkan renderer. Matt Pharr's The story of ispc discusses the failure of Larrabee, and his subsequent project of making a better compiler for SIMD. Dan Sunday's Geometry Algorithms.com (defunct, but archived) has some good summaries of algorithms for making bounding containers for various geometric primitives. Irrlicht, bgfx, OGRE, Godot, and sauerbraten are open source 3D games engines with some popularity. Computer Vision Metrics: Survey, Taxonomy, and Analysis, by Scott Krig, Apress, July 2014 (table of contents and free download; see our blog for options). See this demo, which runs in your browser, for a straightforward visualization of occlusion culling's effect. Ancient, but impressive that there's an 82-page article on shadow volumes. Learn OpenGL - Graphics Programming: Learn modern OpenGL Welling, June 2020 (Book's website, with free downloadable version; also, the beginnings of a new book, Learn Vulkan). You're Reading a Free Preview Pages 12 to 58 are not shown in this preview. J.M.P. van Waveren discusses matrix to quaternion transforms and how to use SIMD for them. There are many shader tutorials out there. The first book on ray tracing. Maxima is a symbolic computation program, like Mathematica and Maple: you define equations and can easily combine them, integrate, take the derivative, etc. Principles of Digital Image Synthesis, by Andrew S. If that article doesn't click for you, maybe this one will. The Portable Game Library includes code for a Simple Geometry library. We drew upon Tarek Sherif's WebGL 2 Examples for our shader examples. Here is part 1, part 2, and the third part to appear. Ray Tracing Gems, edited by Eric Haines and Tomas Akenine-Möller, Apress, March 2019 (Book's website, publisher's page, Amazon), download for free. DevIL is an open-source image conversion library that reads and writes DDS and many other formats. For a glimpse at what goes into a AAA title game, this short (and old, 2013, but worthwhile) video shows some of the many elements involved. MeshLab is an open source system for manipulating meshes. Note that the free version is the second edition; other than these errata fixes, the 3rd edition's major changes are that Chapter 7 includes information on Voronoi diagrams of line-segments and for farthest point, and Chapter 12 includes BSP trees for low-density scenes. Already mentioned in "Pipeline Optimization" but worth a repeat: This tool allows you to see how the waves (warps) are executed; the documentation explains various stalls and other problems that can happen. GPUView - from Microsoft; uses Event Tracing for Windows (ETW), an efficient event logging system. The Patent Arcade site tracks patent infringement, copyright infringement, and other videogame related legal issues. There are any number of presentations about using particles and other effects in games, such as in Unity. GPU-accelerated 2D engines include Will Dobbie's (try the War and Peace demo, YMMV). Some excellent examples of LOD popping in games are available; move your mouse in and out of each image to see the effect. Flipcode has a 3D geometry primer online. The Book of Shaders is an introduction to fragment shaders, under development. These are books that are FREE ONLINE, ordered by publication date. Matt Pettineo's Baking Lab demo lets you explore depth of field, tone mapping, and other effects. Ancient, but worth a peek. See our portal page for more model sources. Steve Baker gives a good summary of the basics of the problem and traditional solutions. We list a number of tools for debugging in the book, here are the links: RenderDoc - a high-quality Windows, Linux, and Android debugger for DirectX, OpenGL, and Vulkan, originally developed by Crytek and now open source. For a general history of computer graphics, see Wayne Carlson's site. One notable tool provided is a static shader analyzer that gives performance estimates without needing to run the application. If you need to start from scratch, Wolfire's blog has a basic two-part tutorial on linear algebra, here and here. Christer Ericson has a nice presentation on the scalar triple product, a way to compare the orientation of one line compared to another. The Humus 3D site has some excellent sample programs that show advanced techniques. Tarek Sherif's depth of field demo runs in the browser, so is just a click away. Figure 3.14, about user-defined clipping planes, was generated with this and this live interactive three is demo. The USC-HairSalon is a set of 343 hair models. The Cg Tutorial, by Randy Fernando and Mark J. Physically Based Rendering, Third Edition: from Theory to Implementation, by Matt Pharr, Wenzel Jakob, and Greg Humphreys, Morgan Kaufmann, November 2016 (more information), Patreon page, read for free. You can access the bibliography of the book, with many of the articles having hyperlinks. This is the seminal paper, and there's now even an app, Prisma. A dated but worthwhile NPR resources page has been put together by Craig Reynolds. It is an extensible format that allows arbitrary buffers of data. You're Reading a Free Preview Page 137 is not shown in this preview. The USC-SIPI Image Database has many classic images (Lena, Mandrill) and other texture samples for research. The Windows demo used to generate Figure 19.33 still works and can be found here. Figure 14.40, water ripples, is from Evan Wallace's live WebGL demo, explained here. CGAL has a computational geometry bias, but supports many operations on polygonal models. Andreas Mischok gives great visual comparisons and explanations of the various types of bump and displacement techniques. For translating various file formats, we recommend Assimp. Figure 10.32 was derived from this Shadertoy by Nimitz. G3D is a research-oriented renderer that offers a wide range of modern effects and works on all major PC operating systems. The dangers of improperly accounting for alpha in cutouts is lavishly illustrated in this blog post. Developing Graphics Frameworks with Python and OpenGL, by Lee Stemkoski and Michael Pascale, CRC Press, July 7, 2021 (Publisher's website). Figure 17.32 was generated using Tamy Boubekeur's Phong tessellation Windows demo. You're Reading a Free Preview Pages 219 to 240 are not shown in this preview. Figure 7.12 was generated with this demo by Christoph Peters using the Sintel model. Paul Baker has an old demonstration program with source that tessellates and renders metaballs. Code for rotating from one vector to another rapidly using quaternions (as described in our book) is available online from Tomas

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