

## **Virtual Computers**

EEL 6892 Section CAMP

**Class Periods:** MWF Period 7 (1:55 PM - 2:45 PM)

**Location:** CSE E107

**Academic Term:** Spring 2023

### **Instructor:**

Renato Figueiredo

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Office Hours: Available on Canvas; tentatively T W F 4-5pm, via Zoom, subject to change

### **Course Description**

Techniques for virtualization of networked computer systems. Virtual machines (classic VMs, application binary interface VMs, para-virtualization), virtual distributed file systems (file system proxies, call-forwarding), and virtual networks (tunneling, virtual private networks). 3 credits.

### **Course Pre-Requisites / Co-Requisites**

Principles of Computer Systems Design (EEL 5737), Computer architecture (EEL5764 or equivalent) and operating systems principles (COP5615 or equivalent) or instructor approval. Knowledge of TCP/IP networking and C/C++ programming

### **Course Objectives**

Virtualization technologies allow the decoupling of the user-perceived behavior of hardware/software systems from their physical implementation. Techniques to virtualize the basic functionality of today's typical computing systems – processing, networking, and data storage – are becoming pervasive in industry and form a foundation for the Infrastructure-as-a-Service (IaaS) cloud computing model. The combination of virtualization technologies and ubiquitous network connectivity allows for the creation of virtual computers where processing, data and communication are distributed and decoupled from physical resources. This class will cover the basic mechanisms and techniques involved in resource virtualization, from individual machines to virtualized networked infrastructures.

### **Materials and Supply Fees**

N/A

### **Required Textbooks and Software**

- “Virtual Machines”
- James E. Smith and Ravi Nair
- First Edition, April 2005
- ISBN 1558609105

### **Recommended Materials**

Additional technical papers will be covered in class, from the following reading list:

Virtual Machine introduction/theory:

- IEEE Computer special issue on virtualization technologies, Renato J. Figueiredo, Jose A. B. Fortes, Peter A. Dinda, Editors (May 2005). (Articles available online to UF students from IEEE Express).
- “Survey of Virtual Machine Research”, Robert P. Goldberg, IEEE Computer, June 1974, pp 34-45.
- “Architecture of Virtual Machines”, Robert P. Goldberg, Proc. Workshop on Virtual Computer Systems, Cambridge, MA, 1973, pp 74-112.
- “Formal Requirements for Virtualizable Third Generation Architectures”, Gerald J. Popek, Robert P. Goldberg, Communications of the ACM, 17(7), July 1974, pp 413-421.

- “Intel Virtualization Technology: Hardware Support for Efficient Processor Virtualization”, G. Neiger, A. Santoni, F. Leung, D. Rodgers, R. Uhlig, Intel Technology Journal, 10:03, August 2006

#### Virtual machine techniques and case studies:

- “Virtualizing I/O Devices on VMware Workstation’s Hosted Virtual Machine Monitor”, Jeremy Sugerman, Ganesh Venkitachalam and Beng-Hong Lim, Proc. 2001 USENIX Annual Technical Conference, Boston, MA June 2001.
- “A user-mode port of the linux kernel”, Jeff Dike, Proceedings of the USENIX Annual Linux Showcase and Conference, Atlanta, GA, Oct 2000
- “Xen and the Art of Virtualization”, Paul Barham, Boris Dragovic, Keir Fraser, Steven Hand, Tim Harris, Alex Ho, Rolf Neugebauer, Ian Pratt and Andrew Warfield, Proceedings of the ACM Symposium on Operating Systems Principles (SOSP), October 2003
- “Scale and Performance in the Denali Isolation Kernel”, A. Whitaker, M. Shaw, S. Gribble, Proceedings of the 5th USENIX Operating Systems Design and Implementation (OSDI), 2001.
- “A Comparison of Software and Hardware Techniques for x86 Virtualization”, K. Adams and O. Agesen, Proceedings of ASPLOS, 2006.
- B. Lin, and P. Dinda, “VSched: Mixing Batch and Interactive Virtual Machines Using Periodic Real-time Scheduling”, Proceedings of ACM/IEEE SC 2005 (Supercomputing), November, 2005
- Christopher Clark et al, “Live Migration of Virtual Machines”, Proceedings of the 2nd ACM/USENIX Symposium on Networked Systems Design and Implementation (NSDI), 2005.
- “Memory Resource Management in VMware ESX Server”, Carl A. Waldspurger, Proceedings of the 5th Symposium on Operating Systems Design and Implementation, 2002
- “Remus: High Availability via Asynchronous Virtual Machine Replication”, Brendan Cully, Geoffrey Lefebvre, Dutch Meyer, Mike Feeley, Norm Hutchinson, and Andrew Warfield, 5th USENIX Symposium on Networked Systems Design and Implementation, 2008

#### Virtual Machine security/isolation:

- “A Virtual Machine Introspection Based Architecture for Intrusion Detection”, T. Garfinkel, M. Rosenblum, Proceedings of NDSS, 2003
- “Application and Analysis of the Virtual Machine Approach to Information System Security and Isolation”, Stuart E. Madnick and John J. Donovan, Proc. Workshop on Virtual Computer Systems, Cambridge, MA, 1973, pp 210-224.
- “Terra: a virtual machine-based platform for trusted computing”, T. Garfinkel, B. Pfaff, J. Chow, M. Rosenblum, D. Boneh, Proceedings of the nineteenth ACM symposium on Operating systems principles, 2003
- “Analysis of the Intel’s Pentium Ability to Support a Secure Virtual Machine Monitor”, John S. Robin, Cynthia E. Irvine, Proc. 9th USENIX Security Symposium, Denver, CO, August 2000.
- G. Dunlap, S. King, S. Cinar, M. Basrai, and P. Chen. ReVirt: Enabling Intrusion Analysis through Virtual-Machine Logging and Replay. Proceedings of OSDI 2002

#### Virtual networks and applications in distributed systems:

- Sundararaj, P. Dinda, “Towards Virtual Networks for Virtual Machine Grid Computing”, Proceedings of the third USENIX Virtual Machine Research and Technology Symposium (VM 04), May, 2004.
- Xuxian Jiang, Dongyan Xu, “VIOLIN: Virtual Internetworking on OverLay INfrastructure”, Department of Computer Sciences Technical Report CSD TR 03-027, Purdue University, July 2003
- Tsugawa, Maurício; and Fortes, José A.B. “A Virtual Network (ViNe) Architecture for Grid Computing”. In Proceedings of 20th International Parallel and Distributed Processing Symposium (IPDPS-2006), Rhodes Island, Greece, April, 2006
- Ganguly, Arijit, Abhishek Agrawal, P. Oscar Boykin, Renato Figueiredo ‘WOW: Self-Organizing Wide Area Overlay Networks of Virtual Workstations’. In Proc. High Performance Distributed Computing (HPDC)
- “Network Virtualization and Software Defined Networking for Cloud Computing: A Survey”, Raj Jain and Subharthi Paul, IEEE Communications Magazine, Nov. 2013

### Virtual storage/file systems:

- “Virtual Machine File System”, Satyam Vaghani, ACM SIGOPS Operating Systems Review, Dec. 2010
- “Versatility and Unix Semantics in Namespace Unification”, C. Wright, J. Dave, P. Gupta, H. Krishnan, D. Quigley, E. Zadok, and M. Zubair, ACM Transactions on Storage ACM, Vol. 1, No. 4, November 2005
- “The PUNCH Virtual File System: Seamless Access to Decentralized Storage Services in a Computational Grid”, R. J. Figueiredo, N. H. Kapadia, and J. A. B. Fortes. Proceedings of the Tenth IEEE International Symposium on High Performance Distributed Computing. IEEE Computer Society Press, August 2001.

### Miscellaneous:

- “Resource Containers: A New Facility for Resource Management in Server Systems”, Gaurav Banga, Peter Druschel, Proceedings of the 3rd Symposium on Operating Systems Design and Implementation, 1999
- “Virtual Appliances for Deploying and Maintaining Software”, C. Sapuntzakis, D. Brumley, R. Chandra, N. Zeldovich, J. Chow, M. S. Lam, and M. Rosenblum, In Proceedings of the 17th Large Installation Systems Administration Conference (LISA 2003), pages 181-194, October 2003
- “The Collective: A Cache-Based System Management Architecture”, R. Chandra, N. Zeldovich, C. Sapuntzakis, and M. S. Lam In Proceedings of the Second Symposium on Networked Systems Design and Implementation (NSDI 2005)
- “Are Virtual-Machine Monitors Microkernels Done Right?”, Gernot Heiser, Volkmar Uhlig, and Joshua LeVasseur, ACM Sigops Operating System Review (OSR), January 2006
- “Are Virtual Machine Monitors Microkernels Done Right?”, Steven Hand, Andrew Warfield, Keir Fraser, Evangelos Kotsovinos, Dan Magenheimer, HotOS 2005.

### **Course Schedule**

Week 1:	Review of Operating Systems and Hardware Support for OSs/VMs
Week 2:	Introduction to Virtual Machines
Week 3:	Formal Requirements for Virtualization, Memory and I/O Virtualization
Week 4:	Para-virtualization and Xen
Week 5:	Binary Translation and Hardware Extensions
Week 6:	VM memory management / Midterm 1
Week 7:	VM migration
Week 8:	Containers and User-mode VMs
Week 9:	High Availability and Security in VMs
Week 10:	Multiprocessor virtualization / Midterm 2
Week 11:	Network virtualization
Week 12:	Network and Storage virtualization
Week 13:	Storage virtualization
Week 14:	Advanced topics on virtualization
Week 15:	Advanced topics on virtualization / Final exam

### **Attendance Policy, Class Expectations, and Make-Up Policy**

Excused absences must be consistent with university policies in the Graduate Catalog (<https://catalog.ufl.edu/graduate/regulations>) and require appropriate documentation. Additional information can be found here: <https://gradcatalog.ufl.edu/graduate/regulations/>

### **Evaluation of Grades**

Assignment	Total Points	Percentage of Final Grade
Homework Sets (3)	100 each	20%
Exams (3)	100	60%
Class project	100	20%
		100%

### **Grading Policy**

Letter grades will be assigned based on the distribution curve of final numeric grades of the class.

More information on UF grading policy may be found at:

[UF Graduate Catalog](#)

[Grades and Grading Policies](#)

### **Students Requiring Accommodations**

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

### **Course Evaluation**

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

### **In-Class Recording**

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

### ***University Honesty Policy***

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

### ***Commitment to a Safe and Inclusive Learning Environment***

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, [jpennacc@ufl.edu](mailto:jpennacc@ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

### ***Software Use***

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

### ***Student Privacy***

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

### ***Campus Resources:***

#### ***Health and Wellness***

#### **U Matter, We Care:**

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

**Counseling and Wellness Center:** <https://counseling.ufl.edu>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

#### **Sexual Discrimination, Harassment, Assault, or Violence**

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

**Sexual Assault Recovery Services (SARS)**  
Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

### Academic Resources

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.  
<https://lss.at.ufl.edu/help.shtml>.

**Career Connections Center**, Reitz Union, 392-1601. Career assistance and counseling; <https://career.ufl.edu>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.  
<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.  
<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus**: <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>; <https://care.dso.ufl.edu>.

**On-Line Students Complaints**: <https://distance.ufl.edu/state-authorization-status/#student-complaint>.