Digital Vellum

Vint Cerf
Google

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Archiving Static Content
Archiving Static Text/Image Content
22nd Century
Doris Kearns Goodwin

- A Team of Rivals (Lincoln)
  - How did she reconstruct the dialog??
  - 100 Libraries and repositories w/physical correspondence

- What will the 22nd C. Doris Kearns Goodwin find?
- What will the National Archives be able to offer?
- What will our descendants know of our 21st Century?
  - Correspondence, entertainment, advertising, education, jobs, family life,…
What About Executable Content?

Games
What About Executable Content?

**WordPerfect 1.0 doc**
Can you read it today?
100 years from now?

**Games**

**Simulation model**
Can you re-run old model with new data?

**Application-specific content**

**Original Wang doc**
Can you read it today?
100 years from now?
Challenges

• Interpretation of bits
• Metadata capture
• Source or executable code
• “Digital X-ray”
• Capacity for BIG DATA

• Bankruptcies, sunsetting of apps, OS, hardware
• Intellectual Property Rights
• Legal frameworks, exceptions for preservation
The OLIVE Project

- Carnegie-Mellon University
- Mahadev Satyanarayanan ("Satya")
- NSF funded project on digital preservation
Execution Fidelity

*Ability to precisely reproduce execution*

Many moving parts

- hardware
- operating system
- dynamically linked libraries
- configuration parameters
- language settings
- time zone settings
- ...

*Inspiration: “Digital X-Ray” of the hardware and operating software*

*Very difficult to achieve and then maintain*
Transform into a Scaling Problem

Pack up and carry the entire environment with you
  including the OS
  transitive closure of everything you need

Central idea of a (hardware) virtual machine (VM)

But VMs are huge
  many GB to tens of GB
  waiting to download → long launch delay

Inspiration from YouTube: stream instead of downloading
VM Streaming Not So Easy

Access to VM image is not linear

Reference pattern depends on many runtime factors
  • data dependencies
  • human interaction
  • spatial and temporal locality (program behavior)

Our approach
  • demand paging
    intercept missing VM pieces and fetch over Internet
  • prefetching
    mask stalls due to demand misses
    (if hints are good)
## Client Structure

<table>
<thead>
<tr>
<th>Host Environment</th>
<th>Guest Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Today’s Hardware (x86)</td>
<td></td>
</tr>
<tr>
<td>2. Operating System (Linux) (host OS)</td>
<td>7. Old Application (e.g., Great American History Machine)</td>
</tr>
<tr>
<td>3. VMNetX (demand paging and prefetching of VM state)</td>
<td>6. Old Operating System (guest OS) (e.g., Windows 3.1)</td>
</tr>
<tr>
<td>4. Virtual Machine Monitor (KVM/QEMU)</td>
<td>5. Hardware emulator (e.g. Basilisk II) (not needed if old hardware was x86)</td>
</tr>
</tbody>
</table>

**Virtual Machine**
(streamed over the Internet from Olive archive)
VM Image Representation

Domain XML

Disk Image

Memory Image

Machine details

Single file representation

<domain type="kvm">
  <name>example</name>
  <uuid>a7434757-631b-496d-a1ba-638014c74c84</uuid>
  <memory>65536</memory>
  <currentMemory>65536</currentMemory>
  <cpus>1</cpus>
  <os>
    <type arch="i686" machine="pc">hvm</type>
    <boot dev="hd"/>
  </os>
  <features>
    <pae/>
  </features>
  <clock offset="utc"/>
  <devices>
    <emulator/usr/libexec/qemu-kvm/emulator>
      <disk type="file" device="disk">
        <driver name="qemu" type="raw"/>
        <source file="/disk.img"/>
        <target dev="hda" bus="ide"/>
        <address type="drive" controller="0" bus="0" unit="0"/>
      </disk>
      <controller type="ide" index="0">
        <address type="pci" domain="0x0000" bus="0x00" slot="0x01" function="0x1"/>
      </controller>
      <interface type="user">
        <mac address="52:54:00:03:a0:11"/>
      </interface>
    </emulator>
    <input type="mouse" bus="ps2"/>
    <graphics type="vnc" autoclose="yes"/>
    <video>
      <model type="vga" vRAM="9216" heads="1"/>
      <address type="pci" domain="0x0000" bus="0x00" slot="0x02" function="0x0"/>
    </video>
  </devices>
</domain>
Olive Implementation

Guest OS

Guest App

KVM / QEMU

VM Image file

Linux

VMNetX client

pristine cache

modified cache

FUSE

to Olive server via standard HTTP range requests

Unmodified Web Server
Cloud Execution of Olive

Olive Execution Server in Cloud or Cloudlet
Many Future Technical Challenges

We are a long way from being “done”!

Scaling and performance issues
• VMs keep getting bigger, networks are never fast enough
• clever prefetching techniques

Precise emulation of hardware
• even x86 extended memory modes not quite right in QEMU
  (can’t boot Windows 95 in KVM/QEMU)
• exotic hardware platforms
• host compatibility (e.g. CPU flags in x86) vs performance
• hardware performance accelerators (e.g. GPUs)

Multi-VM ensembles (e.g. HPC environments)
Tools for easy building of VMs (physical to virtual?)
Archiving entire cloud services

… many others …
Scope of Digital Preservation

• Digital object structures, representations, vocabulary and standard terminology (schema, OWL, …)

• Identifier spaces, registries, resolution mechanisms
  • The irony of WWW, URLs, DNS (TBL was at CERN)
  • Robert Kahn: Digital Object Architecture, CNRI

• Standard, rigorous ingestion processes

• Metadata (about the data, provenance, authenticity, calibration, ....)

• Legal frameworks for preservation (copyright, patents, licensing, special treatment for perserving bodies)

• Business Models for extended, long term operation
Milestones

- Technical means to capture and update digital storage media
- Capture and representation of relevant metadata
- Clearance of rights to share/execute digital objects
  - Possible legislation granting archives/libraries special “preservation” rights?
  - Might include both copyright and patent privileges
- Provision for assuring integrity of digital objects
- Monitoring and management of changes to rights (e.g. expiration of copyright, patent)
- Development of business model(s) to sustain long-term preservation and access
  - Libraries, Archives, Universities, Museums
  - Long-lived institutions as vehicles or models?
    - E.g. Breweries, vineyards, Catholic (and other) Churches, Banks… (!)
- Personalization of preservation options accessible to the general public
Other Projects

• The Internet Archive – Brewster Kahle et al
  • Library of Alexandria backup among others
  • Digital content, books, software

• The Computer History Museum
  • Software and computing artifacts

• Google Book Scans and Cultural Institute

• Digital Object Architecture and Identifiers (CNRI)
More Projects

• RHIZOME, University of Freiburg
• Interplanetary File System (IPFS)
• International Internet Preservation Consortium
• UK Depositary Libraries Program