Lecture: Introduction to Unix

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introduction

- this lecture introduces the course "Unix Systems Programming" and its study focus
  - course prerequisites
  - materials
  - grading expectations
  - Unix history
  - Unix today
- this lecture does *not* provide a thorough history of Unix or a complete filiation, although it does touch on the basics

course details

- this course concentrates upon
  - defining Unix-class operating systems
  - programming for and in Unix systems

- this course does *not* cover
  - operating Unix systems
  - administering Unix systems

prerequisites

- thorough knowledge of the C language
- basic knowledge of assembly language
  - IA-32, PA-RISC, MIPS32
- thorough knowledge of data structures
  - B-trees, hash tables, priority queues, ...
- thorough knowledge of algorithm analysis
  - big-O notation, sigma notation
- a general understanding of system theory
  - the memory hierarchy, scheduling and related topics

prerequisites

- a general knowledge of navigating Unix systems
- a general knowledge of programming in Unix environments

- you'll absolutely need access to a computer running one of the relevant operating systems (NetBSD, OpenBSD or GNU/Linux)

materials

- most cited materials are available on the Internet, free of charge
- these lectures will cite in full from any text materials

lecture notes

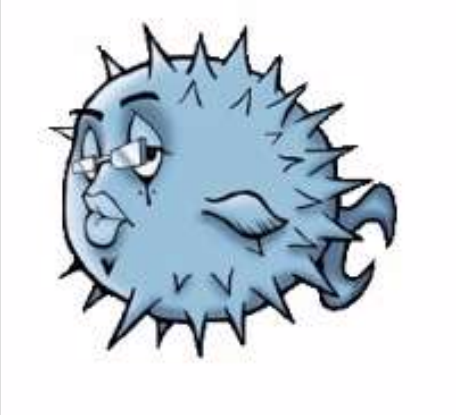
- lectures notes written with OpenOffice's Impress tool
- are available in both Open Document and PDF formats

relevant systems

- we'll use several systems as both examples and development bases during this course
  - OpenBSD
  - NetBSD
  - GNU/Linux (Debian stable)

relevant systems

- OpenBSD
  - OpenBSD is a 4.4BSD-based Unix
  - focusses on stable and secure releases
  - strict philosophy of open content (fully BSD licensed)
  - www.openbsd.org



relevant systems

- NetBSD
  - NetBSD is a 4.4BSD-based Unix
  - focusses on multi-platform architecture & portability
  - strict philosophy of open content (fully BSD licensed)
  - www.netbsd.org

relevant systems

- Debian GNU/Linux
  - Debian Linux "stable" is a GNU/Linux distribution
  - focuses on multi-platform, stable releases
  - strict philosophy of open content (GPL)
  - packages in the "stable" branch have undergone years of testing
  - www.debian.org

what is unix?

- "Unix" is a class of operating system
- "UNIX" is a trademark held by The Open Group, and describes Unix systems certified by The Open Group

what is unix?

- these days, the „Unix” classification is based largely on standards compliance
- specifically, the SUS (Single Unix Specification) standard, maintained by The Open Group
- „Unix-like” systems, or just „Unix” (lowercase or title-case letters), fulfill part of the standard
- „UNIX” (uppercase letters) systems fully conform to the standard

what is unix?

- these lectures will mostly deal with "Unix-like" systems, so references to "UNIX" systems will be specifically noted by being in all capital letters

what *was* unix?

- historically, "UNIX" was an operating system developed at AT&T's Bell Labs in the 1960s and 1970s
- we'll discuss AT&T's UNIX later in this lecture

Image: Ken Thompson (left), Dennis Ritchie (right)

unix: the word

- Unix is pronounced yü-niks
- Unix and eunuchs are homophones
  - Unix: covered in this course
  - Eunuchs: castrated men
  - ...
- historically, Unix was a pun on MULTICS (also developed at AT&T Bell Labs)

unix and standards

- the modern-day term "Unix" refers to systems adhering to part of SUS, the Single Unix Specification
- "UNIX" refers to fully-compliant systems
- SUS is maintained by The Open Group

"The Open Group is a vendor-neutral and technology-neutral consortium, whose vision of Boundaryless Information Flow™ will enable access to integrated information, within and among enterprises, based on open standards and global interoperability."

unix and standards

- SUS is currently at version 3, sometimes referred to as UNIX03
- previous versions include UNIX98, UNIX95 and UNIX93

unix-certified systems

- some UNIX-certified (SUS) systems include
  - Sun Microsystems: Solaris 10 (UNIX 03)
  - Sun Microsystems: Solaris 9 (UNIX 98)
  - HP Company: HP Tru64 V5.1A (UNIX 98)
  - IBM Corporation: AIX 5L (UNIX 98, 03)
  - Caldera Intl.: UnixWare 7.1.3 (UNIX 95)

Source: www.opengroup.org/openbrand/register/

unix-like systems

- some Unix-like systems include
  - NetBSD, OpenBSD and FreeBSD
  - GNU/Linux (all distributions)



non-unix systems

- for comparison, some non-Unix (and non-UNIX) systems
  - OpenVMS
  - MS-DOS,
  - LISP Machines
  - BeOS
  - AmigaOS

another perspective

- Eric S. Raymond ("ESR") suggests another break-down of the Unix name
  - genetic Unix
  - trademark Unix
  - functional Unix

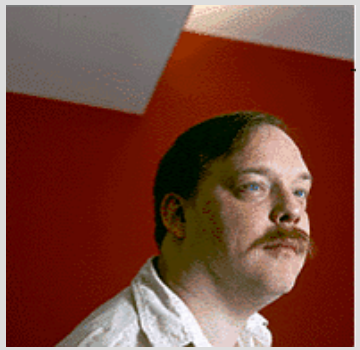


Image: ESR

another perspective

- genetic Unix
  - historical connection to AT&T sources
  - thus, mostly BSD systems
  - thus, mostly commercial systems
  - matches either "Unix-like" or "UNIX"
- trademark Unix
- functional Unix

another perspective

- genetic Unix
- trademark Unix
  - validated by The Open Group with SUS
  - thus, several commercial systems
  - matches our definition of "UNIX"
- functional Unix

another perspective

- genetic Unix
- trademark Unix
- functional Unix
  - any manner of roughly-compliant systems
  - thus, most free/open systems
  - matches our definition of "Unix-like"

what is unix?

- we'll stick with **UNIX** to discuss either the historical UNIX operating system or SUS-certified systems
- **Unix-like** to identify partially-compliant systems

unix: the beginning

- what follows is a short history of the Unix class of operating system
- there are many areas omitted due to restraints (this is a programming course, not a history course)
- there is especial focus on systems used in this course and the path of standards

unix: the beginning

- in the beginning, there were Ken Thompson and Dennis Ritchie, creators of the UNIX operating system and its descendents

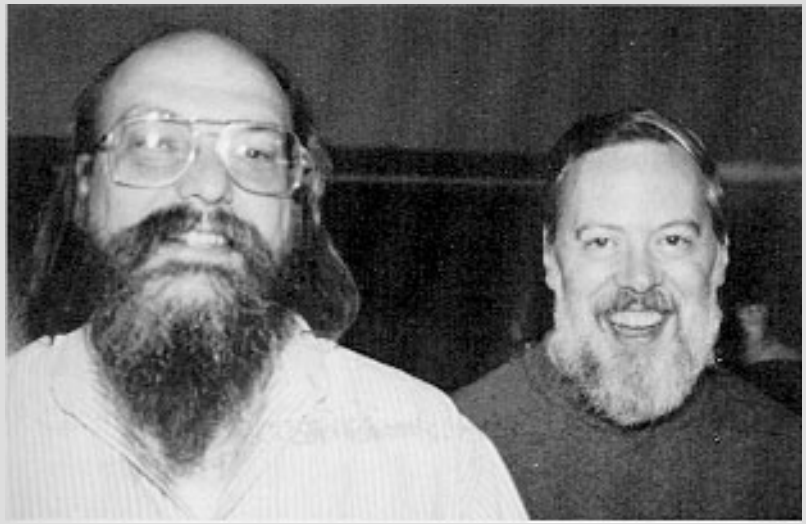


Image: Ken Thompson (left), Dennis Ritchie (right)

unix: the beginning

- in the beginning, there was a DEC PDP-7, which inspired development of UNIX

unix: the beginning

- the year is 1969...
  - Ken Thompson writes a game on MULTICS, but access to the system was limited
  - Thompson translates the game into FORTRAN on a GE-635 computer: display movement is jerky and expensive
  - Thompson finds a PDP-7 computer with a good display processor at AT&T Bell Labs
  - Thompson and Ritchie port the game to the PDP-7's assembly language

unix: the beginning

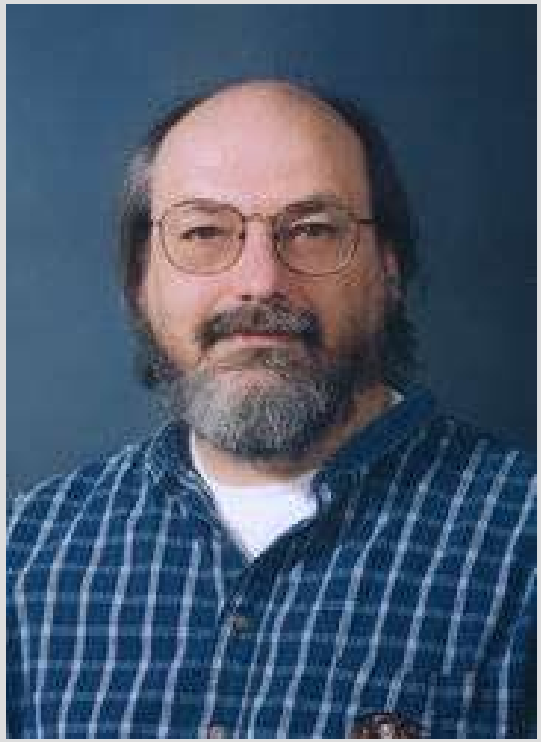
Image: GE-625

unix: the beginning

- after learning how to program the PDP-7, Thompson, Ritchie, Ossanna and Canaday begin to program a new operating system based on concepts from MULTICS
- by 1970, the basic elements of the operating system are in place for the PDP-7
- the system is ported to the PDP-11
- Dennis Ritchie ports the kernel code to the C programming language

ken thompson

- "One of my most productive days was throwing away 1000 lines of code."



ken thompson

- 1943: Born in New Orleans, Louisiana
- 1943 - 1960: Navy brat moving every few years
- 1965 - 66: Graduates with B.S and M.S. degrees in electrical engineering from the University of California at Berkeley
- 1966: Joins Bell Labs Computing Research Department, working on the MULTICS project
- 1969: Develops UNIX operating system
- 1970: Writes B language, precursor to C

ken thompson

- 1971: Moves UNIX from the PDP-7 to the -11
- 1973: Rewrites UNIX the C language
- 1973: Rewrites portions of UNIX to include Doug McIlroy's concept of pipes
- 1975 - 76: Visiting professor at UCB
- 1980: "Belle," a chess-playing computer he developed with Joe H. Condon, wins the U.S. and World Computing Chess Championships
- 1980: Elected to the U.S. National Academy of Engineering
- 1983: Named Bell Labs Fellow

ken thompson

- 1983: Receives with Dennis Ritchie the ACM Turing Award
- 1980: Elected to the U.S. National Academy of Science
- 1988: Visiting professor at the University of Sydney, Australia
- 1998: Awarded with Dennis Ritchie the National Medal of Technology for the development of the UNIX system
- 2000: Retires from Bell Labs

dennis ritchie

- "UNIX is basically a simple operating system, but you have to be a genius to understand the simplicity."

dennis ritchie

- 1941: Born in Bronxville, N.Y.
- 1963: Graduates from Harvard University with a B.S. in Physics
- 1968: Receives from Harvard University a Ph.D. in mathematics
- 1967: Joins Bell Labs, following his father, Alistair E. Ritchie, who had a long career there
- 1968: Joins the Bell Labs team working on Multics, a joint effort of Bell Labs, MIT and GE to develop a general computer operating system
- 1972: Creates C language

dennis ritchie

- 1989: Receives with Ken Thompson the NEC C&C Prize for significant contributions to computer technology
- 1983: Named Bell Labs Fellow
- 1988: Elected to the U.S. National Academy of Engineering
- 1990: Appointed head, System Software Research Department in the Computer Sciences Research Center at Bell Labs, Murray Hill, N.J.
- 1995: Heads the effort to create the Plan 9 Operating system

dennis ritchie

- 1996: Heads the effort to create the Inferno operating system
- 1998: Awarded with Kenneth Thompson the U.S. National Medal of Technology for the development of the UNIX system

unix timeline (1969 - 83)

1969	**The Beginning**	The history of UNIX starts back in 1969, when Ken Thompson, Dennis Ritchie and others started working on the "little-used PDP-7 in a corner" at Bell Labs and what was to become UNIX.
1971	**First Edition**	It had an assembler for a PDP-11/20, file system, fork(), roff and ed. It was used for text processing of patent documents.
1972	**First UNIX Installations**	The first installations had 3 users, no memory protection, and a 500 KB disk.
1973	**Fourth Edition**	It was rewritten in C. This made it portable and changed the history of OS's.
1975	**Sixth Edition**	UNIX leaves home. Also widely known as Version 6, this is the first to be widely available outside of Bell Labs. The first BSD version (1.x) was derived from V6.
1979	**Seventh Edition**	It was an "improvement over all preceding and following Unices" [Bourne]. It had C, UUCP and the Bourne shell. It was ported to the VAX and the kernel was more than 40 Kilobytes (K).
1980	**Xenix**	Microsoft introduces Xenix. 32V and 4BSD introduced.
1982	**System III**	AT&T's UNIX System Group (USG) release System III, the first public release outside Bell Laboratories. SunOS 1.0 ships. HP-UX introduced. Ultrix-11 introduced.
1983	**System V**	Computer Research Group, UNIX System Group (USG) and a third group merge to become UNIX System Development Lab. AT&T announces UNIX System V, the first supported release. Installed base 45,000.

unix timeline (1984 - 90)

1984	**4.2BSD**	University of California at Berkeley releases 4.2BSD, includes TCP/IP, new signals and much more. X/Open formed.
1984	**SVR2**	System V Release 2 introduced. At this time there are 100,000 UNIX installations around the world.
1986	**4.3BSD**	4.3BSD released, including internet name server. SVID introduced. NFS shipped. AIX announced. Installed base 250,000.
1987	**SVR3**	System V Release 3 including STREAMS, TLI, RFS. At this time there are 750,000 UNIX installations around the world. IRIX introduced.
1988		POSIX.1 published. Open Software Foundation (OSF) and UNIX International (UI) formed. Ultrix 4.2 ships.
1989		AT&T UNIX Software Operation formed in preparation for spinoff of UNIX development group. Motif 1.0 ships.
1989	**SVR4**	UNIX System V Release 4 ships, unifying System V, BSD and Xenix. Installed base 1.2 million.
1990	**XPG3**	X/Open launches XPG3 Brand. OSF/1 debuts. Plan 9 from Bell Labs ships.

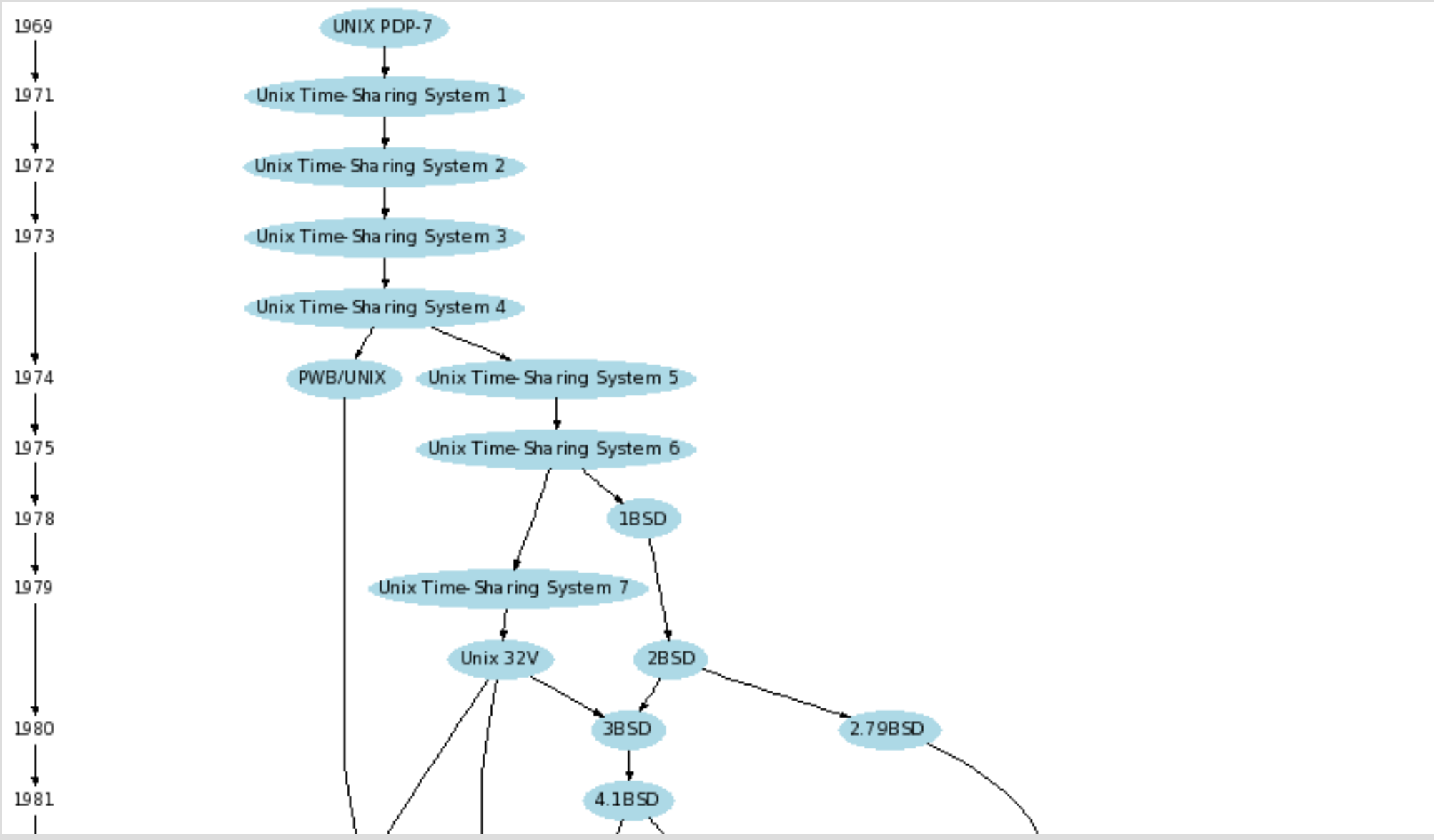
unix timeline (1991 - 95)

1991		UNIX System Laboratories (USL) becomes a company - majority-owned by AT&T. Linus Torvalds commences Linux development. Solaris 1.0 debuts.
1992	**SVR4.2**	USL releases UNIX System V Release 4.2 (Destiny). October - XPG4 Brand launched by X/Open. December 22nd - Novell announces intent to acquire USL. Solaris 2.0 and HP-UX 9.0 ship.
1993	**4.4BSD**	4.4BSD the final release from Berkeley. June 16 - Novell acquires USL
Late 1993	**SVR4.2MP**	Novell decides to get out of the UNIX business. Rather than sell the business as a single entity, Novell transfers the rights to the UNIX trademark and the specification to X/Open Company. COSE Initiative delivers "Spec 1170" to X/Open for fasttrack. In December Novell ships SVR4.2MP , the final USL OEM release of System V
1994	**Single UNIX Specification**	BSD 4.4-Lite eliminated all code claimed to infringe on USL/Novell. As the owner of the UNIX trademark, X/Open introduces the Single UNIX Specification (formerly Spec 1170) which separates the UNIX trademark from any actual code stream itself, thus allowing multiple implementations.
1995	**UNIX 95**	X/Open introduces the UNIX 95 branding program for implementations of the Single UNIX Specification. Novell sells UnixWare business to SCO. Digital UNIX introduced. UnixWare 2.0 ships. OpenServer 5.0 debuts.

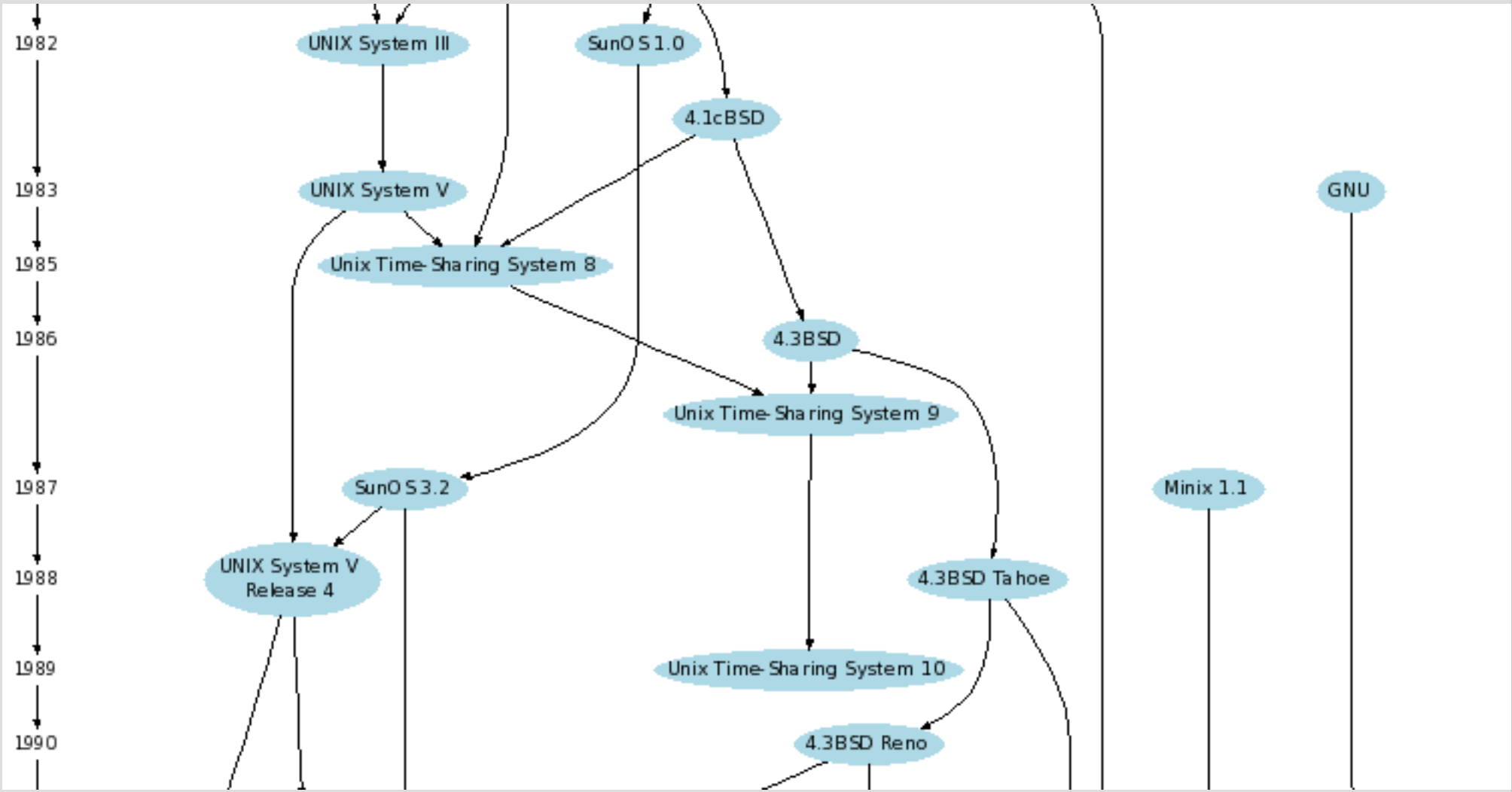
unix timeline (1996 - 2003)

1996		The Open Group forms as a merger of the Open Software Foundation (OSF) and X/Open. UnixWare 2.1, HP-UX 10.20 and IRIX 6.2 ship.
1997	**Single UNIX Specification, Version 2**	The Open Group introduces Version 2 of the Single UNIX Specification, including support for realtime, threads and 64-bit and larger processors. The specification is made freely available on the web. IRIX 6.4, AIX 4.3 and HP-UX 11 ship.
1998	**UNIX 98**	The Open Group introduces the UNIX 98 family of brands, including Base, Workstation and Server. First UNIX 98 registered products shipped by Sun, IBM and NCR. The Open Source movement starts to take off with announcements from Netscape and IBM. UnixWare 7 and IRIX 6.5 ship.
1999	**UNIX at 30**	The UNIX system reaches thirty. Solaris 7 ships. Linux 2.2 kernel released. The Open Group and the IEEE commence joint development of a revision to POSIX and the Single UNIX Specification. First LinuxWorld conferences. Dot com fever on the stock markets. Tru64 UNIX ships.
2001	**Single UNIX Specification, Version 3**	Version 3 of the Single UNIX Specification unites IEEE POSIX, The Open Group and the industry efforts. Linux 2.4 kernel released. The value of procurements of open systems referencing the UNIX brand exceeds $55 billion. AIX 5L ships.
2003	**ISO/IEC 9945**	The core volumes of Version 3 of the Single UNIX Specification are approved as an international standard. "Westwood" test suites shipped for UNIX 03 brand. Solaris 9.0 E ships. Linux 2.6 kernel released.

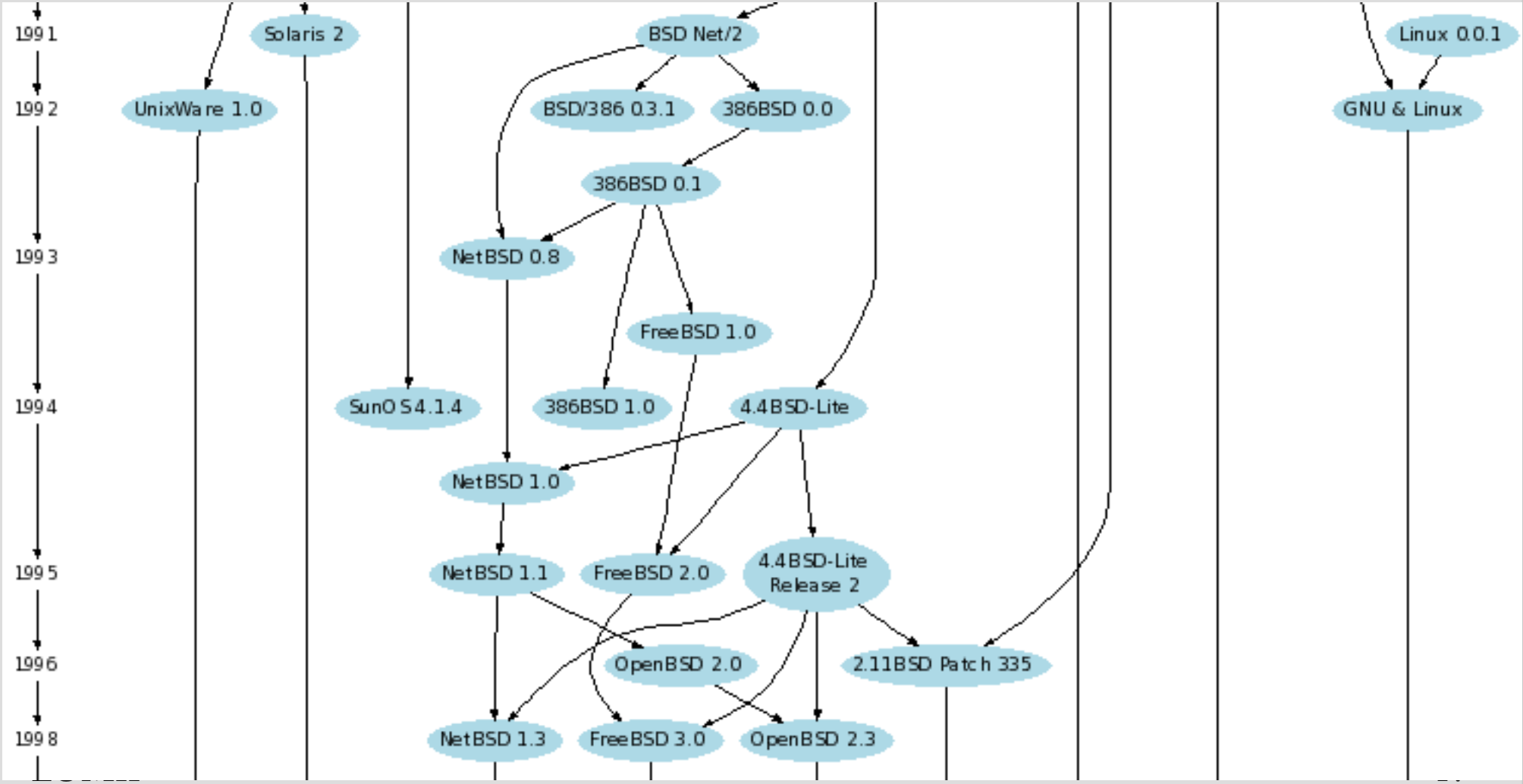
unix filiation (1969 - 81)



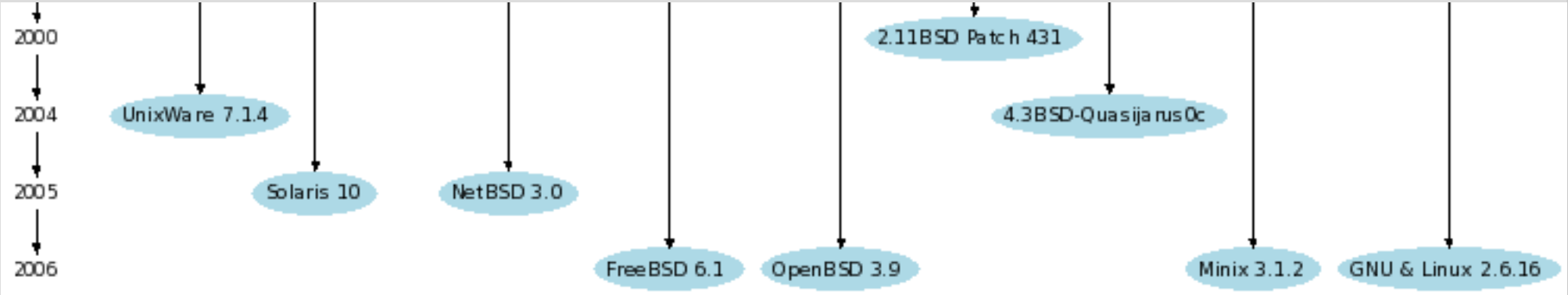
unix filiation (1982 - 90)



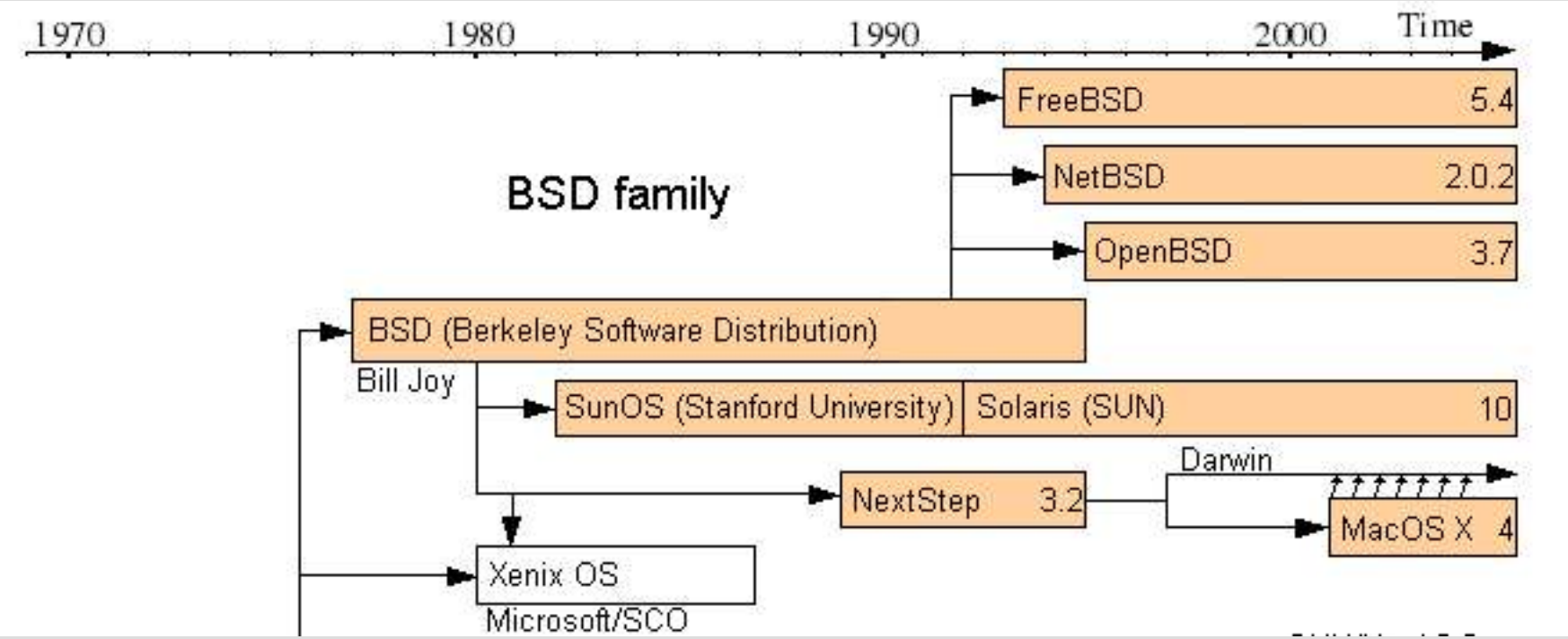
unix filiation (1991 - 98)



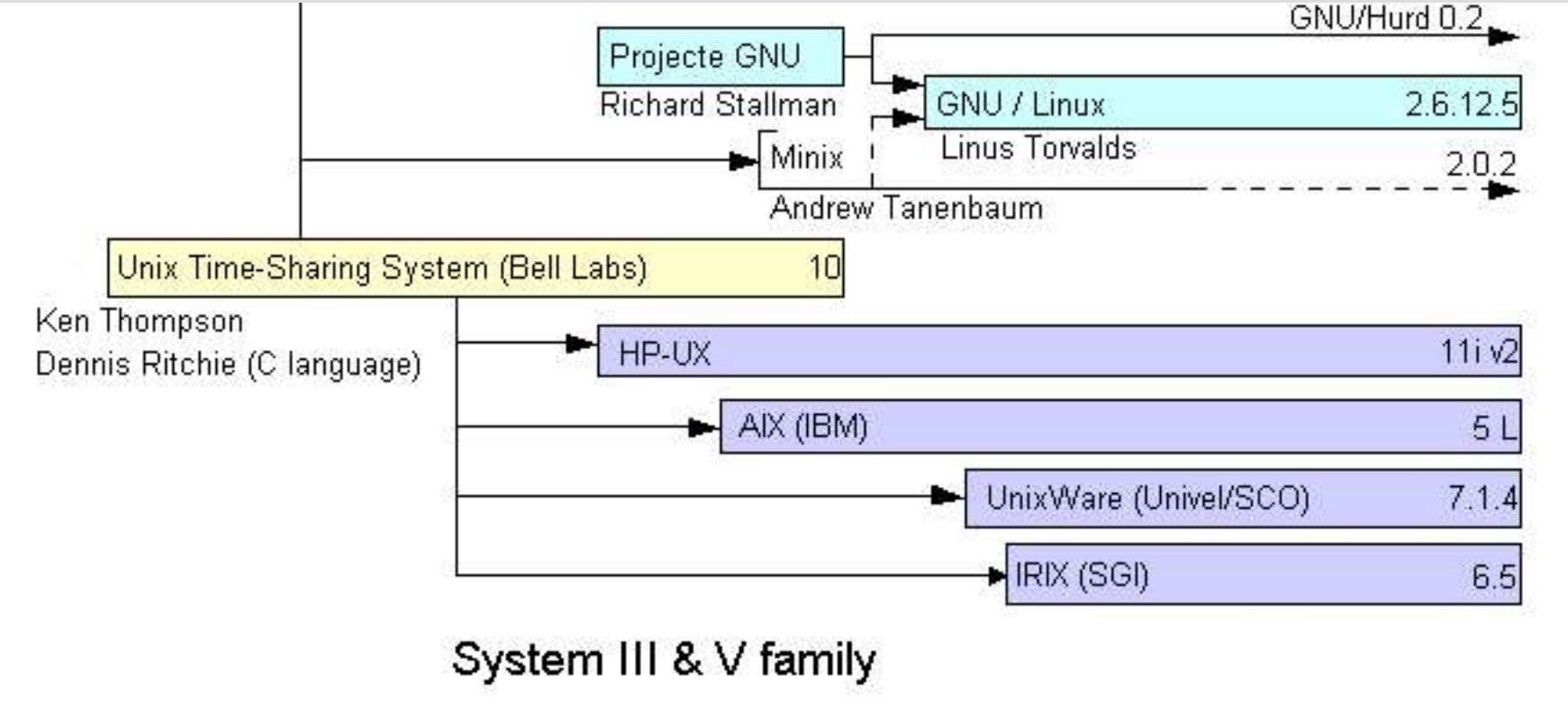
unix filiation (2000 - 06)



unix filiation (short-1)

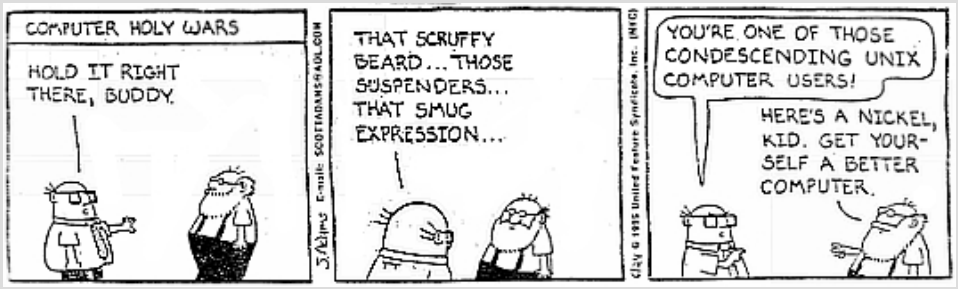


unix filiation (short-2)



why is unix still around?

- history
- standardisation
- quality
- availability



why is unix still around?

- history
  - early porting requirements (GE-625 to PDP-7, then PDP-11) quickly made the system develop abstraction layers in its code
  - existing systems (MULTICS, CTSS) made clear which features were (and weren't) required
  - AT&T's considerable corporate presence (budget) behind the project
- standardisation
- quality
- availability

why is unix still around?

- history
- standardisation
  - standards quickly developed to handle the glut of UNIX clones on the market
  - modern standards are freely available to the public, allowing new systems to come pre-compliant
- quality
- availability

why is unix still around?

- history
- standardisation
- quality
  - Unix systems have a reputation for being reliable and robust in any environment
  - Unix systems have a long history of attention to its conceptual and practical parts
- availability

why is unix still around?

- history
- standardisation
- quality
- availability
  - there are a large number of high-quality free and open Unix implementations available for download
  - many of these are licensed to allow for proprietary systems to be built atop the codebase

why *isn't* unix around?

- the „Unix wars”
- lack of strong standards early-on
- emerging PC market not targeted

Image: a leading Unix competitor showcases their operating system in its most familar running mode

why *isn't* unix around?

- the "Unix wars"
  - competition between the "open" versions of Unix in the late 1980s and early 1990s
  - gave rise to a group of competing standards – really companies pushing their own systems' basis specification
  - AT&T vs. BSD: UNIX International vs. OSF/1
- lack of strong standards early-on
- emerging PC market not targeted

why *isn't* unix around?

- the "Unix wars"
- lack of strong standards early-on
  - as mentioned in the Unix wars, there were too many conflicting standards at too early a stage
  - the POSIX standard, IEEE 1003, is not available to the public at no cost, thus hindering development toward the standard
- emerging PC market not targeted

why *isn't* unix around?

- the "Unix wars"
- lack of strong standards early-on
- emerging PC market not targeted
  - in the 1980s, a glut of cheaper, smaller processors became available
  - Microsoft Corporation released MS-DOS on the Intel 8086 processor and negotiated a license with IBM Corporation for PC-DOS
  - competition for was Digital Research's CP/M-86; low cost of the Intel chip made it popular
  - Unix concentrated on higher-powered, more expensive chips

unix today

Image: screenshot of OpenSolaris system

unix today

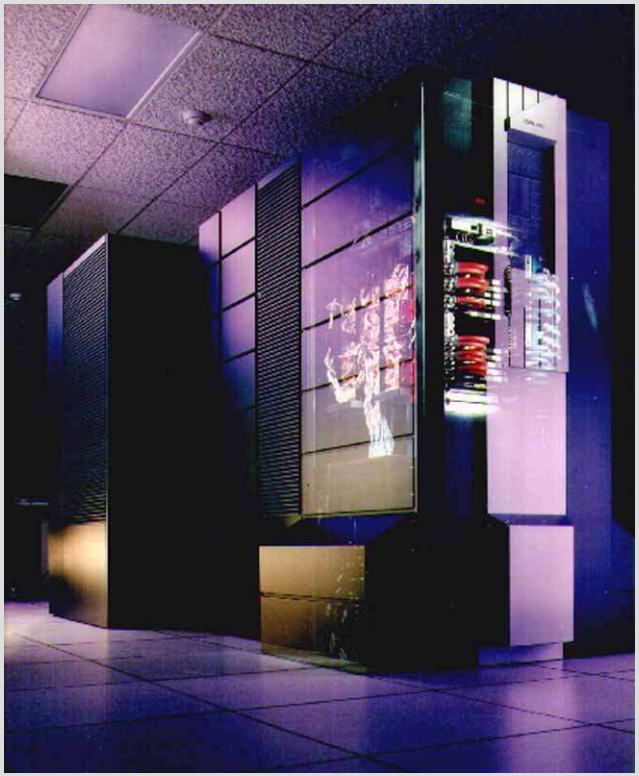


Image: Cray T3D runnnig UNICOS (Unix)

Image: iPod running Linux

unix today

- Unix systems today derive from two roots
  - 4.4BSD
    (Bill Joy, University of California, Berkeley)
  - UNIX System V
    (AT&T Bell Labs)
- A third meta-root is GNU, whose presence has had significant impact on the popular Linux kernel and related distributions

unix today

- 4.4BSD: University of California Berkeley

1977: Bill Joy puts together first BSD distribution on a PDP-11
1980: DARPA funds Berkeley's CSRG to release 4BSD
1986: 4.3BSD first released under a permissive license
1992: USL vs. BSDi lawsuit filed (settled in 1994) as regards proprietary AT&T code illegally distributed
1995: 4.4BSD released (the ancestor of NetBSD and FreeBSD)

Image: Bill Joy

Image: DEC PDP-11

unix today

- 4.4BSD: University of California Berkeley
  - initially popular in academia
  - genetically inherited by Sun's SunOS, DEC's Ultrix, the free BSDs and their derivatives (OpenBSD, NetBSD, FreeBSD, DragonflyBSD etc.), NeXT's NEXTSTEP etc.
  - began the BSD license, a permissive license used by many popular utilities and systems (among them, the free BSDs)

unix today

- The first versions of BSD were little more than patches and tools atop AT&T's Sixth Edition Unix (specifically, 32V, a port of UNIX V6 for the VAX architecture). When DARPA chose Berkeley/CSUG to develop a reference Unix platform (in conjunction with the ARPANET, the Internet's ancestor), BSD became the first Unix to support the network stack.

- A lawsuit (over copyright violation) filed in 1992 stalled development for two years until the suit was settled in favour of Berkeley. It was during this time that Linux, based on Minix, gained popularity (arguably) due to its legally-unencumbered state.

unix today

- System V: AT&T (SVR)

1983: initial release (SVR1) on DEC's VAX
1984: SVR2 with initial SVID reference on DEC's VAX 11/780
1989: SVR4 released, support for sockets, VFS, NFS, x86, etc.

Image: AT&T logo

Image: similarity?

unix today

- System V: AT&T (SVR)
  - genetically influenced many commercial Unix systems (AT&T SVR4, Apple A/UX, IBM AIX, SCO UnixWare, SCO OpenServer)

unix today

- GNU: GNU's Not Unix (FSF)

1983: plan for GNU announced by Richard Stallman
1985: Stallman founds the FSF, the Free Software Foundation

Image: Richard Stallman

Image: FSF mascot?

unix today

- GNU: GNU's Not Unix (FSF)
  - main sponsor is the Free Software Foundation
  - along with the Linux kernel, makes GNU/Linux
  - started the GPL family of licenses:
    - GPL: General Public License
    - LGPL: Lesser/Library General Public License
    - GFDL: GNU Free Documentation License

unix today

- GNU is a complete operating system: it contains a kernel, libraries, system utilities, compilers and end-user applications. The system's most popular components are gcc (the GNU Compiler Collection), binutils (GNU Binary Utilities), glibc (the GNU C Library) and bash (the Bourne-Again Shell).

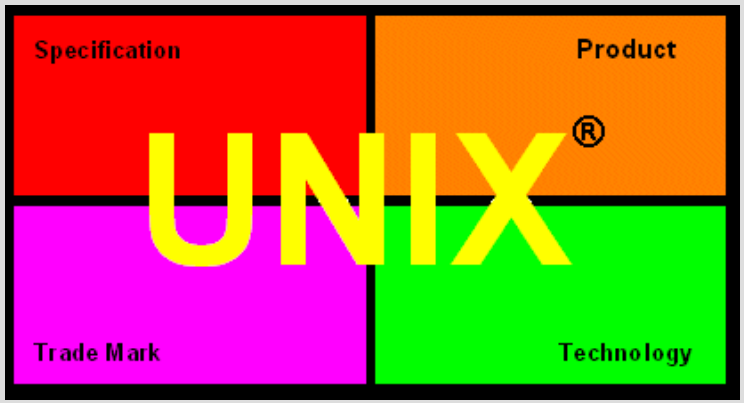
- Although the kernel for GNU is Hurd, the Hurd itself is not production-ready. Most GNU systems use the Linux kernel, which makes them GNU/Linux. Most people mistakenly refer to GNU/Linux as just Linux (which in fact designates the Linux kernel).

standards

- there are a number of standards that govern interoperability between Unix systems
  - SUS: Single Unix Specification
    (system interface, shells & utilities, etc.)
  - C99: ISO/IEC 9989:1999
    (C language)
  - FHS: File-system Hierarchy Standard
    (file-system layout, paths)

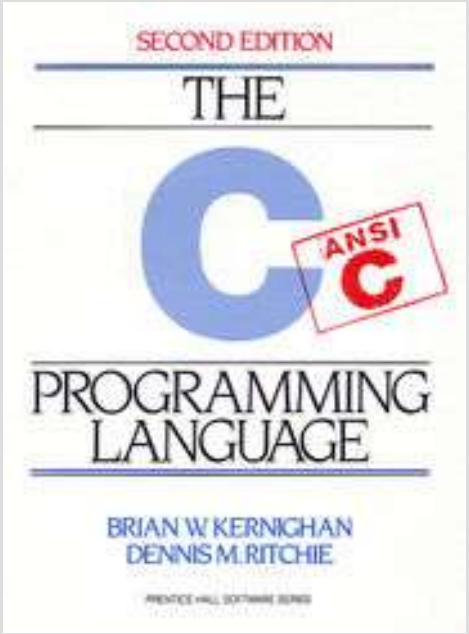
standards

- SUS: Single Unix Specification
  - mentioned earlier as "Unix-certified"
  - systems complying to SUS may be certified as UNIX
  - SUS is a general superset of other significant standard texts: POSIX, XPG/4, SVID and others
  - has gained more popularity than POSIX largely due to its free distribution
  - **no systems referenced in this course are fully SUS-compliant, although the parts referenced will be**



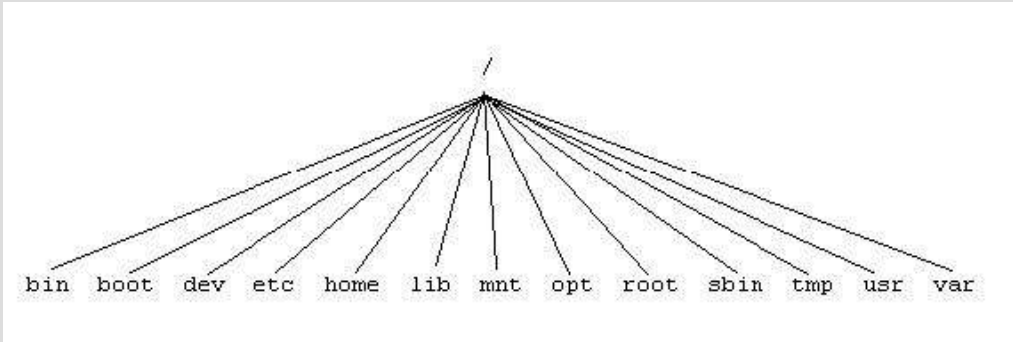
standards

- C99: ISO/IEC 9899:1999
  - the C language standard
  - latest in a long set of C standards (first in 1989, ANSI X3.159-1989, a.k.a. C89)
  - C99 concluded as ISO 9899:1999, ANSI adoption in March of 2000
  - most popular compiler gcc, whose support (ironically) for the standard is incomplete



standards

- FHS: File-system Hierarchy Standard
  - defines how a Unix file-system should be structured
  - maintained by the Free Standards Group (FSG)



licenses

- Unix systems may be grouped by their licenses, a separation initially stemming from the Unix wars
  - BSD license: BSD 3-part
    (started with the BSD4.4 class of system)
  - GPL license: GPL v2
    (started with the GNU system)

licenses

- BSD license
  - currently "BSD 3-part license"
  - is the successor to the four-part "advertising-clause" BSD license (since deprecated)
  - MIT and X11 licenses derive from the BSD license
  - most BSD sources (OpenBSD, NetBSD and FreeBSD) are kept under this license

licenses

- GPL license
  - currently "GPL v2" (GPL v3 in the making)
  - GPL is part of license family (with the LGPL and GDFL)
  - most popular systems using this license are the Linux kernel and all GNU utilities
  - the LGPL is more permissive than the GPL, allowing libraries so licensed to link with proprietary-licensed components
  - the GDFL is used for documentation

licenses

- GPL license
  - focuses on software rights
  - derivative works must inherit license
  - may not be linked against proprietary components (exception: LGPL)
- BSD license
  - focuses on user rights
  - derivative works need not inherit license
  - may be linked against proprietary components

end