

Advanced File Statistics and Understanding

Agenda

- Big File Data
- How does studying files help?
- Files by Size and Job Type
- Compositional Granularity
- Directories
- File Age and File Lifetime
- File Type
- Filesystems

Context Paper – Studying Files

- A Large-Scale Study of File-System Contexts
 - Douceur and Bolosky (1999, ACM Computing Surveys)
 - Basic Contributions
 - Looked at 10.5 TB – TWO orders magnitude larger study than any other study of files at the time
 - Looked at the relationship between job function and file
 - Looked at the relationship between file extension and size
 - Looked at the lifetime of file age and how it has increased
 - Looked at the compositional granularity of file size
 - Only looked at Windows systems – sign of the times
75% of all client computers ran Windows then

Some statistics over the years

- 1981 – Satyanarayanan
 - Captured data from eight 200 MB disk drives, 36k files
 - Recorded file sizes, timestamps, and types/extensions
 - Introduced file functional lifetime shows file counts decrease monotonically as increase in file lifetime
- 1984 – Mullender & Tanenbaum
 - UNIX version of Satyanarayanan's study - Matches file size distribution closely
- 1991 – Bennett, Bauer and Kinchla
 - Mean text-file size increased by 5%
 - Mean executable file size decreased by 38%
 - Mean number of files per user increased by order of magnitude
- 1994 - Siemknecht et al.
 - Captured 54GB of 2.3 million files from 1845 active users
 - File size ranged from 10kB to 40kB – more than Bennett et al.

File System Job Types / Categories

- Admin jobs least amount of files, and mostly FAT fs
- Technical development
 - Most files 96M, 7TB
 - Mostly FAT and NTFS
- Business and Mgmt
 - ~17M files, 1.6TB
 - Mostly FAT and NTFS
- FAT32 mostly used in tech development

Job Category	Systems	Files	Megabytes
administration	385	2,408,453	222,415
business	902	6,994,811	715,720
management	934	1,000,000	92,120
non-tech development	548	5,287,621	386,095
technical development	6353	96,935,138	7,406,619
technical support	862	11,449,217	925,513
(other job or no record)	579	7,212,925	477,909

Table 2: Job Categories for Partitioning File Systems

Job Category	FAT	FAT32	NTFS	WCEFS
administration	213	0	1	0
business	636	158	108	0
management	580	135	224	0
non-tech development	445	30	73	0
technical development	3432	418	2502	1
technical support	514	72	276	0
(other job or no record)	381	60	138	0

Table 3: File System Types vs. Job Category

Big File Data

- It's all about the files!
- Statistics, what can we learn from the way people are storing their data
- Data and files are a lot larger today than they were 20 years ago – we will see evidence of this
- What are the implications for Big Data
 - On File Systems
 - On the access patterns for files
 - On the creation of files

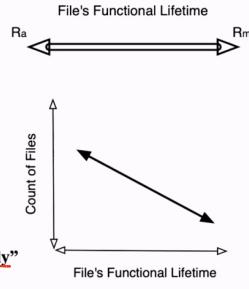
What does studying files help us do?

- Filesystem
 - Designers need usage data to test hypotheses
 - Drive workload simulations
 - Stimulate insights to make new features
- Same was true of GFS and eventually HDFS
 - R/W access pattern for search indexing was big driver in developing network filesystem on highly redundant and distributed hardware
- File diversity and relationship to statistical properties about their storage

Some Basic Tenets

• File's functional lifetime

- Time between most recent access (R_a) and its most recent modification (R_m)
- Found that files that have large functional lifetime typically are indicative of
 - Less files e.g., in a directory
 - Files created, then never went back to – these are “append only” and immutable typically



Abundance of Small Files

- 50% of all filesystems studied in Douceur and Bolosky 65% of the files are smaller than 16 kB
- 95% of all file systems studied, 35% of the files are smaller than 16 kB
- Fits a normal log distribution

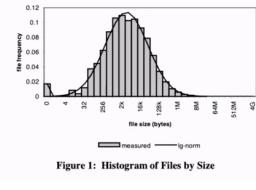


Figure 1: Histogram of Files by Size

Most Bytes are in Larger Files

- Median size of files = 2MB
 - 512 greater than the median for file frequency distrib.
- Most files are small but most bytes are present in larger files
- On 50% of all filesystems studied
 - Median Byte-weighted file size ranges by a factor of 8 from 256kB to 2 MB
- On 90% of all filesystems range by a factor of 4096 from 32kB to 128MB

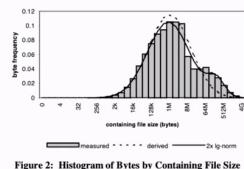
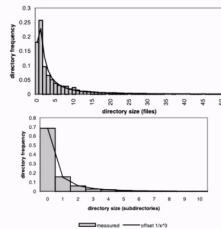


Figure 2: Histogram of Bytes by Containing File Size

Directory Sizes

- 18% of all directories contained no files
 - Increase compared to Sienknecht et al. from 14%
- Median directory size is 2 files
 - 50% systems, median 1-4 files
 - 90% of systems median 0-7 files
- 69% of all directories contain no sub-directories
- 16% of all directories contain one or fewer sub-directories and 0.5% contain more than 20
 - Similar to Sienknecht et al.



File Age and Lifetimes (1/3)

- Had to use NTFS only**
 - FAT and FAT32 record only modification timestamps
- Median file age is 48 days**
 - 3x the expected file value reported by Smith et al. 1975
 - Files were lasting for longer => data storage and archival
 - Many files deleted within minutes and thus not part of study
- Though F-lifetimes should always be positive 2% of those files studied had negative F-lifetimes
 - Suggests applications that modify file mod time

File Age and Lifetimes (3/3)

- 67% of files on tech support systems have zero F-lifetimes
 - Maybe only apps for testing?
- Administration files have very long lifetimes
- Non-tech developers
 - 22% spike in 3 to 6 day files
 - Potentially for the work week?

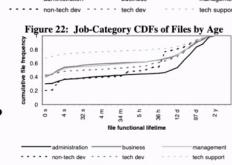
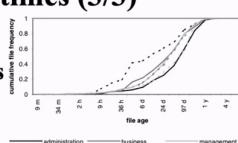


Figure 23: Job-Category CDFs of Files by Func. Lifetime

Filesystems

- On average, filesystems only half full
 - Fullness independent of job category
- 62% of filesystems have 1 to 2 GB total space
 - Clearly, in today's terms this is ~1000 less
 - < 2 GB space
- Mean number of files per user is 31,835
 - 20-26x larger than studies in 1991 and 1994
 - Each user's machine has separate OS install
- 31% of all filesystems contain 8k to 16k files

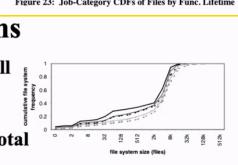


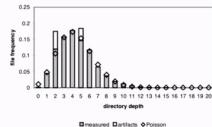
Figure 27: Job-Category CDFs of File Systems by File Count

Compositional Granularity

- CG = the size of the records that compose the file
- File Size = some number N * CG**
 - Not necessarily largest power of 2 that divides into the file size
- Record size is important e.g., in GFS and Hadoop**
 - Later referred to as "block size"
 - Minimal splittable "block" defines e.g., replication factor and other areas

Directories by job type

- Very little difference in directory size distribution amongst job categories
 - Relative fraction of leaf directories is correlated with technical work
 - Means that technical work involves creating more leaf directories
- Interesting spikes in frequency of files / sub-dirs
 - Frequency spikes at 2 and 5, both artifacts of the Windows architecture, System or System32
 - Also artifacts of Web Cache Directories
- 15% of all directories are depth 8 or more, in contrast to Sienknecht et al
 - 90% are depth of 5 or more
 - Less dense directory structures



File Ages and Lifetimes (2/3)

- 44% of files have an F-lifetime of 0
- Median F-lifetime is 8 seconds
 - Median F-lifetime for Satyanarayanan's dataset was 30 days, closer to file age
- On 50% of the file systems, F-lifetime range is 0 to 6 days
- On 90% of file systems, 0 to 97 days
- Non-technical developers tend to have younger files on average

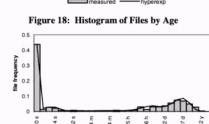
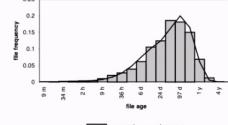


Figure 19: Histogram of Files by Functional Lifetime

File Extensions

- Most popular files are GIF, .H files, HTM(L), DLL, .C files, .EXE – 70% of files have these ext
- Extensions fit Zipf distribution ("power law")
- Only looked at extensions with 5 chars or less
- Found approximately 19,140 file types
- 31% of all extensions have 1 file per extension
 - Not real MIME type?
- File-size prediction – select disk allocation based on MIME type as it defines access pattern and age

Most filesystems weren't full

- Mean space usage is 53%
- Usage of 0% to 1% seen on admin systems
- Usage of ~7% on technical developers systems

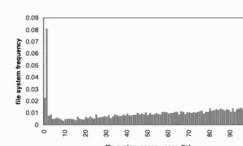


Figure 30: Histogram of File Systems by Space Usage

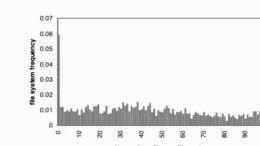


Figure 32: Histogram of File Systems by Unwritten Files

Main lessons of the study

- File sizes continue to grow
- File ages are increasing
- Most files are small and most bytes are in large files
- Can't judge anything based on file ages and types when correlated to job function – need to be adaptive
- File extension can predict file size and compositional granularity

Summary

- Big File Data
- How does studying files help?
- Files by Size and Job Type
- Compositional Granularity
- Directories
- File Age and File Lifetime
- File Type
- Filesystems

Do these lessons hold true today?

- File sizes are growing ,
 - Multimedia content
 - Abundance of log records and increased resolution of instrumentation (phones, etc.)
- File ages are growing
 - Forensics
 - Storage is increasing, so keep data for longer
 - Many files are written once, and not appended to as often
- Many files are still small
- Hard to judge based on age and types what function the file will play – not necessarily
- File types can help to predict size – YES, multimedia files generally bigger for example