On the Performance of Games using Solid State Drives

Mark Claypool, Jared Hays, Alex Kuang and Thomas Lextrait
Computer Science and Interactive Media & Game Development
Worcester Polytechnic Institute, Worcester, MA 01609, USA
email: {claypool}@cs.wpi.edu

***Abstract*—Since games typically demand considerable computer resources, game players will often purchase new technologies to improve their game performance. One such technology is the solid state drive (SSD) with the potential to provide significantly better performance than the traditional hard disk drive (HDD). However, while the benefits of SSDs to drive access speeds can be demonstrated, the benefits to computer game performance is largely unknown. This paper presents a detailed study comparing the performance of SSDs to HDDs for several popular computer games. Initial experiments provide read access speeds on both a desktop PC and a laptop to provide a baseline for SSD and HDD comparison. Then, detailed experiments are run for three computer games, Civilization IV, Portal 2, and Torchlight, covering a range of disk activity types. Analysis of the results shows SSDs compared with HDDs provide a 25% improvement to game boot times and game start times, but no significant improvement to game save times.**

I. Introduction

Games often demand significant resources of their computers, requiring fast processors, graphics cards and disk drives in order to provide an immersive gaming experience. Before playing, however, a game needs to be booted and started, which can take a significant amount of time to get into the game. Any reduction in this time is coveted, especially for players that frequently switch between games or for the casual player that may have has less interest in playing games, and hence less tolerance for delays in getting into the game.

Solid state drives (SSDs) provide block-based I/O with the same interface as do traditional hard disk drives (HDDs), thus easily replacing them in for most computer game uses. However, whereas HDDs contain spinning disks and moveable read/write heads, SSDs use non-volatile microchips to retain data and have no moving parts [1]. Compared to HDDs, SSDs have lower access times and latencies, providing potentially improved read/write performance [2]. However, SSDs have a shorter life expectancy than HDDs and can cost significantly more per MByte (about 5x to 10x more). In addition, any reported performance gains are highly dependent upon the application workload [3]. Thus, a computer game player interested in an improved gaming experience may be willing to invest in SSDs, but only if the performance gains to games are tangible.

Computer games use a range of resources, including at least the processor, memory, network card, graphics card and storage drive. Games have several phases that differ in the player's interactions with the game and in the computer resources used [4]. Although the duration and frequency of each phase varies depending upon the specific game, fundamental phases common to most computer games include *boot* when the game is first launched, *start* when the map data and other object information is loaded, *play* when the game is actually played, and *save* when player progress is saved. As one would expect, the storage drive is not used uniformly throughout these phases, but can be heavily used during the boot, load and save phases. While whitepapers from SSD manufacturers or paid technology consultants have briefly examined SSD benefits to computer games [5], [6], [7], to the best of our knowledge, the impact of SSDs compared to HDDs on computer game performance has not been objectively provided in a peer-reviewed forum.

This paper presents results on experiments that measure the benefits of SSDs on the performance of computer games. Two platforms were selected, a desktop PC and a laptop, both suitable and actively used for playing a wide range of computer games. Each computer was equipped with a traditional HDD which could be exchanged with an SSD to allow for direct performance comparison. Initial experiments were run to first gather baseline read and write performance, providing an approximate upper bound on the possible performance improvements for a game. Next, three games were selected based on their storage profiles, considering number and sizes of files as well as in-game drive activity. Careful experiments were run on these games, concentrating on the boot time when the game is first started, the start time when the player starts the game, and the save time when game progress is recorded to the drive.

Analysis of the results finds SSDs about twice as fast as HDDs for reading, and 15% faster for writing. SSDs provide 25% faster game boot times than HDDs, 20% faster game start times, but no significant speedup to game save times. Relative base access speeds (reading and writing) on a laptop compared to a desktop are not always reflected in game boot, start and save performance with or without an SSD.

The rest of this paper is organized as follows: Section II describes the experiment setup, including computer and drive configurations, game selection, and baseline and game experimental design; Section III analyzes the results from the baseline and game experiments; and Section IV summarizes our conclusions and presents possible future work.

II. Experiments

This section provides details on the experiments run to assess the performance of SSDs for computer games.

A. Computer Setup

Two different gaming environments were selected, a desktop PC and a laptop. Both systems were actively used at the time of the study for playing computer games. Table I lists the specification for each test machine.

Component	Desktop	Laptop
OS	Windows 7 Ultimate 32-bit	Windows Vista Ultimate 32-bit
Processor	2.4 GHz Intel Core 2 Quad Q6600	2.8 GHz Intel Core 2 Extreme X9000
RAM	4 GB DDR2 1066 MHz	4 GB DDR2 664 MHz
HDD	1.5 TB Seagate Barracuda SATA 3 Gb/s, 7200 rpm	320 GB Seagate Momentus SATA 3 Gb/s, 7200 rpm
GPU	1 GB Sapphire Radeon HD4870	512 MB NVIDIA Geforce 8800M GTX
Display	19", 1440x900 pixels	15.4", 1920x1200 pixels

TABLE I
Component Specification for the Test Machines (Desktop PC and Laptop)

For experiments with the SSDs, the HDDs were swapped out and 160 GB Intel X25-M SSDs were put in their place. The specifications from the manufacturer[1] are provided in Table II.

Component	Specification
NAND Flash Components	Multi-Level Cell (MLC), 34 nm 10 Parallel Channel Architecture
Interface	SATA 1.5 Gb/s and 3.0 Gb/s
Latency	Read: 65 microseconds Write: 65 microseconds
Bandwidth	Sustained sequential read: up to 250 MB/s Sustained sequential write: up to 100 MB/s
Random I/O Ops/s	4 KB read: up to 35k 4 KB write: up to 8.6k

TABLE II
Component Specification for Intel X25-Ms 160 GB SSD drives

B. Baseline Experiments

Baseline experiments were run to assess read and write performance for each type of drive on both the laptop and desktop. The tests measured the ability of both the SSDs and the HDDs to sequentially read and sequentially write data. For games, sequential read is typically the most significant drive operation, done when the game is first started up and used when the game level/map is loaded. Writing is typically only done when saving game state data, typically modest in size, upon exiting the game or completing a level.

A C++ program was created to read a short text string sequentially from a file with a separate C++ program to write a short text string sequentially to a file up to a fixed file size. For reading and writing, file sizes of 0.5 GB, 1 GB, 2 GB, 4 GB, and 8GB were tested, in order, for five iterations each. By the time any given file was tested again, enough data had been read to ensure that none of the file contents remained in memory (e.g. the 8 GB file was larger than any disk cache).

[1] http://www.intel.com/design/flash/nand/mainstream/technicaldocuments.htm

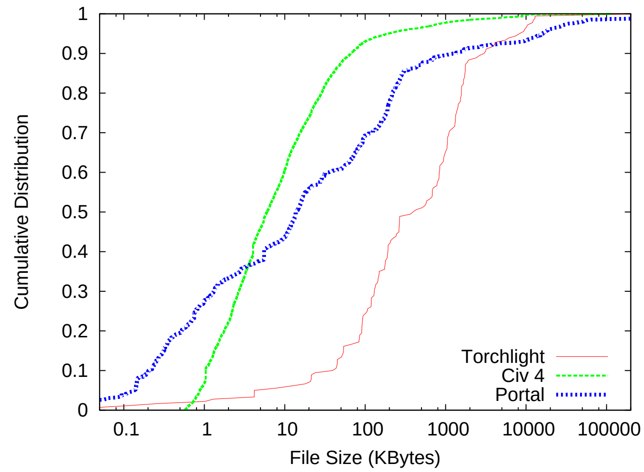

Fig. 2. Distribution of File Sizes for Games Tested

C. Game Selection

Computer games vary in the frequency and size of their disk accesses. To choose which games to test, a number of games were profiled by file size distribution, assuming that different file size installations have different file access patterns. The sizes of every file within the game directory were obtained, and the games were classified based on the nature of their files. Two main criteria were examined: the number of files in the game install and the average file size. This allowed for the classification of games by install profile, such as games with a few large files versus games with a lot of small files.

The file profiles were generated by retrieving the sizes for every file in each games install directory, which was accomplished either using a Python script or the Windows `dir` command. Around ten games were initially profiled, with the goal of choosing three games with distinct profiles for final testing. Based on the profiles, the three games chosen were Runic Games' *Torchlight*[2] - a 3rd person role-playing game, Sid Meier's *Civilization IV*[3] - a top-down strategy game, and Valve's *Portal 2*[4] - a 1st person shooter/puzzle game. Figure 1 shows screen shots of each game. The install profiles can be seen in Figure 2, with summary statistics provided in Table III. In Figure 2, the x-axis is the file size (in KBytes) and the y-axis is the cumulative distribution. Note that because of the skew towards fewer large files, the x-axis is in log scale.

From the figure and the table, all three games have a skewed distribution of sizes with many more small files than large files. Torchlight has relatively few files, but they tend to be relatively large. Civilization IV has a lot of files, but most are

[2] http://www.torchlightgame.com/
[3] http://www.2kgames.com/civ4/
[4] http://www.thinkwithportals.com/

Fig. 1. Screen Shots of Games Tested: Torchlight (left), Civilization IV (middle), Portal 2 (right)

	Torchlight	Civ IV	Portal 2
Total files	180	8076	2374
Minimum (KB)	0.04	0	0
Maximum (KB)	311000	117000	221000
Mean (KB)	3034	194	4365
Median (KB)	409	6	14
Total size (MB)	546	1570	10360

TABLE III
SUMMARY STATISTICS OF INSTALL FILE PROFILE FOR GAMES TESTED

small. Portal 2 is in-between Civilization IV and Torchlight in terms of number of files and median file size, but has some files that are very large, giving a large total size as well as large mean file size.

D. Game Experiments

Three different game phases were identified based on their heavy dependence on drive performance: *boot* - when the player first launches the game from the operating system; *start* - when the player starts the game from the main menu, often loading a map and other game object information; and *save* - when game progress is saved, typically when a level is cleared or a player quits. The game boot time was measured from when player launches the game until the game menu displays. The game start time was measured when the player choose to start a new game from the menu until the first image of the game appears. Any parts of the booting and starting phases that contained short producer and developer splash videos or small trailers were skipped. The game save time was measured from when the player selected save from the menu until a confirmation screen was shown. The exception was Torchlight, which does not have an explicit save feature and instead saves player progress automatically at periodic intervals. Measurements were taken using Windows performance logging to measure the time required by the game process to complete each operation, when possible, or with a stopwatch, if not. All tests were run three times on each platform and with each drive. In order to prevent memory caching and obtain consistent measurements, the computers were rebooted before each measurement.

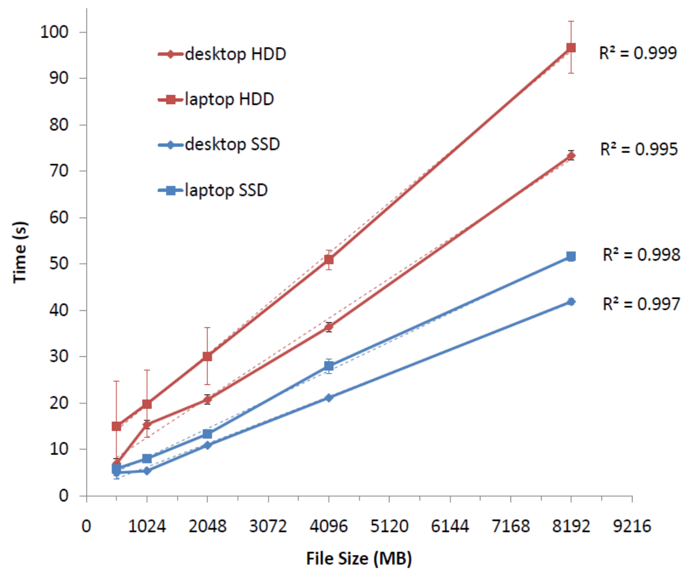

Fig. 3. Sequential Read Times [laptop and desktop, SSD and HDD]

III. RESULTS

Analysis of the results is provided for both the baseline experiments and the game experiments.

A. Baseline Results

Figure 3 depicts the results of the read experiments on both the laptop and desktop. The x-axis is the file size read, in KBytes, and the y-axis is the time taken to read the entire file. There are four trendlines shown, two for the laptop and two for the desktop, with one configuration for each with an SSD and with an HDD. The points shown are an average of 5 runs with the error bars depicting the standard deviation. The data points are fitted with a best-fit line with the coefficient of determination[5] shown to the right of each line.

From the figure, the SSD read times are consistently lower than the HDD read times, taking about 1/2 as long. The laptop generally has higher read times than the desktop. Read times vary linearly with file size, with the coefficients of

[5]The coefficient of determination (R^2) represents the fraction of variability in y that can be explained by the variability in x.

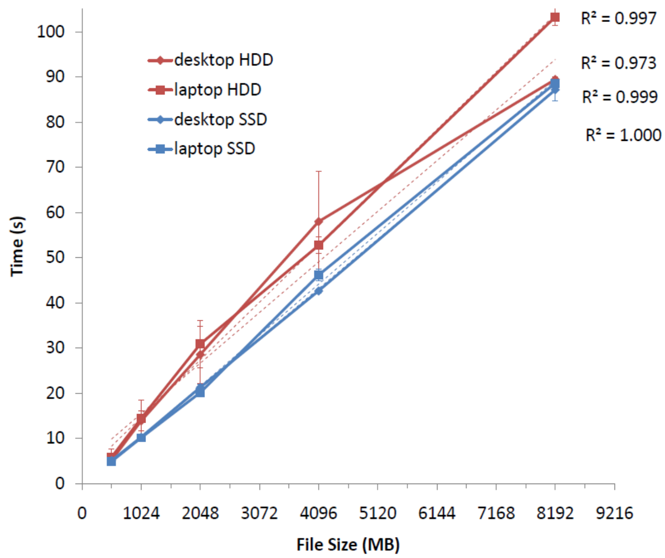

Fig. 4. Sequential Write Times [laptop and desktop, SSD and HDD]

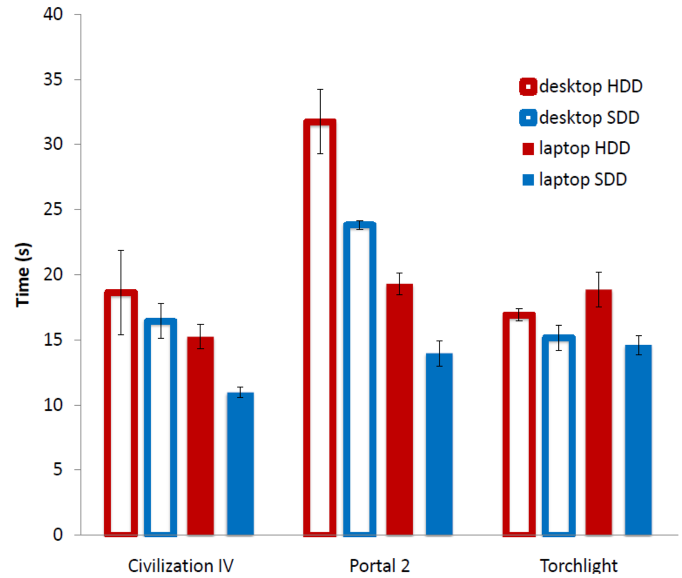

Fig. 5. Game Boot Times

determination all being close to 1. Summary messages are: 1) SSDs are about twice as fast as HDDs for reading, and 2) it takes about 5 seconds to read a 1 GByte file on the desktop SSD, and about 8 seconds on the laptop SSD.

Figure 4 depicts the results of the sequential write experiments on both the laptop and desktop. The x-axis is the file size written, in MBytes, and the y-axis is the time taken to write the entire file. The trendlines, data points and line fits are the same as for Figure 3.

From the figure, the SSD write times are consistently lower than the HDD write times, but the difference is less noticeable than it was for the read times. Similarly, the laptop generally has higher write times than the desktop, but this difference is reduced compared to the read times. Write times also vary linearly with file size. Summary messages are: 1) SSDs are about 15% faster than HDDs for writing, and 2) it takes about 10 seconds to write a 1 GByte file on either the desktop or the laptop SSD.

B. Game Results

Figure 5 depicts the time needed to boot the three selected games. The y-axis is the time to boot, in seconds. The x-axis has three clusters of data, one for each of Civilization IV, Portal 2 and Torchlight. The hollow bars represent the desktop and the solid bars the laptop, with the reds being the HDDs and the blues the SSDs. The bar heights are the average of the three experimental runs, with the error bars showing the standard deviation.

From the figure, the SSDs have lower game boot times than the corresponding HDDs, ranging from the smallest of 10% faster for the desktop booting Torchlight, to the largest of nearly 30% faster for the laptop booting Civilization IV. Unlike in the baseline experiments, the laptop consistently has lower game boot times than does the desktop, possibly due to the laptop's slightly faster processor (2.4 GHz versus 2.8 GHz). While the installed file profiles of the games vary considerably (as shown in Figure 2 and Table III), the game boot times do not vary as much, with average game boot times of about 12.5 seconds for Civilization IV, 15 seconds for Torchlight and 20 seconds for Portal 2. Summary messages are: 1) SSDs provide game boot times about 25% faster than HDDs, 2) game boot times can vary by at least 60% across games, and 3) pure read speed differences in systems are not always reflected in the same relative game boot time differences.

Figure 6 depicts the time needed to start the three selected games. The y-axis is the time to start, in seconds. The x-axis has clusters for each of Civilization IV, Portal 2 and Torchlight. The hollow bars represent the desktop and the solid bars the laptop, with the reds being the HDDs and the blues the SSDs. The bar heights are the average of the three experimental runs, with the error bars showing the standard deviation.

From the figure, the SSDs have lower start times than their corresponding HDDs, ranging from the smallest of about 5% faster for Torchlight on the laptop, to the largest of nearly 40% faster for Portal 2 on the laptop. The start times vary across games, from about 9 seconds for Civilization IV, 23 seconds for Portal 2 and 8 seconds for Torchlight. Summary messages are: 1) SSDs provide game start times about 20% faster than HDDs, 2) game start times can vary by almost 300% across games, and 3) pure read speed differences in systems are not always reflected in the same relative game start time differences.

Figure 7 depicts the time needed to save two of the three selected games (Torchlight not having a save game option). As above, the y-axis is in seconds, the x-axis has the two games, the hollow bars are the desktop, the solid bars the laptop, the reds are HDDs and the blues are SSDs. The bar heights are the average times, with standard deviation error bars.

From the figure, SSDs do not significantly impact game save

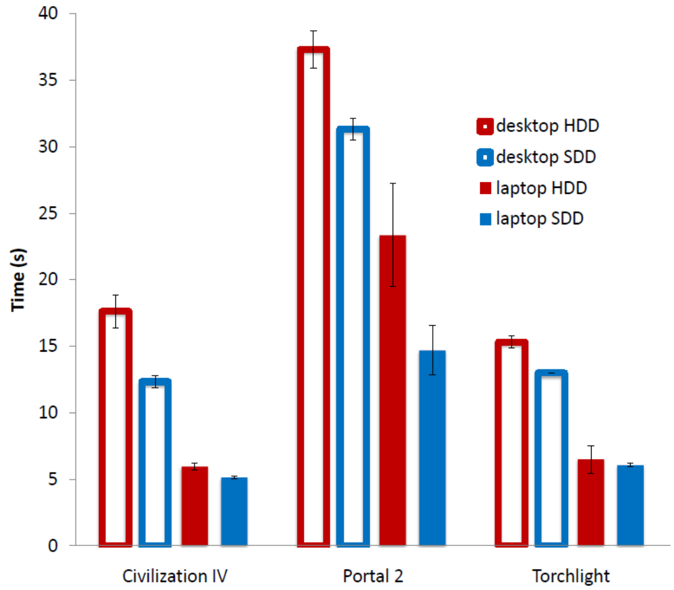

Fig. 6. Game Start Times

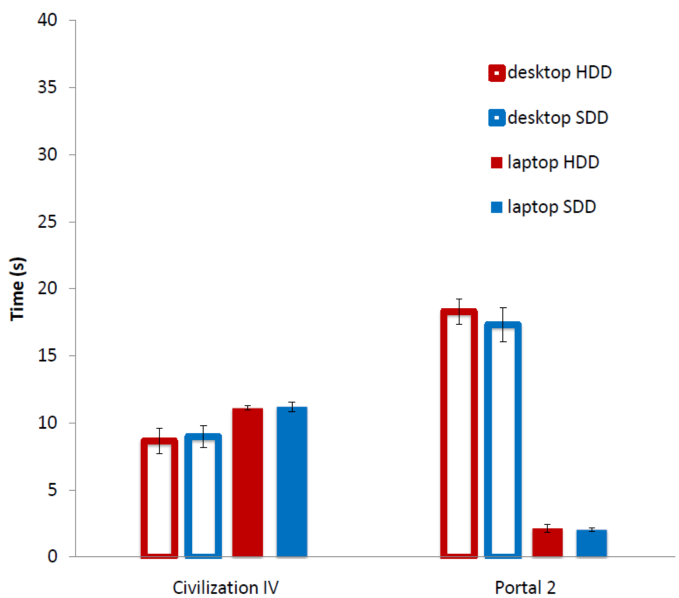

Fig. 7. Game Save Times

times compared with HDDs, with averages overlapping the standard deviation error bars for each HDD/SSD configuration pair. Save times are slightly higher on the laptop compared to the desktop for Civilization IV, but much lower on the laptop compared to the desktop for Portal 2. The average save time is about 10 seconds for both games. The main take away is: SSDs provide no significant improvement to save times compared with HDDs.

IV. Conclusions

Computer game players typically want the highest performance computer system possible. Gamers will spend extra money on liquid cooling systems, specialized network devices and the most powerful graphics cards, and even manipulate CPU clock speeds to get an extra boost in performance. Not having the mechanical parts of traditional hard disk drives (HDDs), solid state drives (SSDs) use less power and run cooler and quieter. However, SSDs are considerably more expensive than HDDs, so other than their quiet operation, gamers need performance justification to account for the cost difference. To the best of our knowledge, there have been no objective studies in a peer-reviewed forum that have measured the effects of SSDs versus HDDs on game performance.

This paper compares game performance with SSDs versus HDDs through carefully designed experiments. Two gaming platforms were setup, one a desktop PC and the other a laptop where the computer drive could be swapped between an SSD and an HDD. Three games were selected for study: Torchlight, Civilization IV and Portal 2. Baseline experiments compared the difference in SSD versus HDD performance for sequential read and write operations. Game experiments measured the time to boot the game, start the game and save the game state.

Overall, for our experimental setup, SSDs are twice as fast as HDDs at reading and 15% faster at writing. For computer games, SSDs improve game boot times by about 25% and game start times by about 20%, but provide no significant improvement to save times compared with HDDs.

Future work could compare the performance of HDDs and SSDs for some of the numerous other games not yet studied. Such experiments should first profile the drive install and activity in an attempt to differentiate from the games studied in this paper. In particular, some games stream terrain from storage so may have an in-game performance benefit from SSDs. Additional experiments might look at why saved games do not benefit from SSDs as well as explore other game operations, such as installation or patching. The benefit of SSDs for games that make heavy use of virtual memory may warrant future study, too, as well as the impact of SSDs on the server-side of multiplayer games, such as their benefit to massively multiplayer games.

References

[1] "SSD Power Savings Render Significant Reduction to TCO," STEC, Tech. Rep., Accessed 2011, [Online at: http://www.stec-inc.com/downloads/whitepapers/Performance_Power_Advantages.pdf].

[2] C. Park, P. Talawar, D. Won, M. Jung, J. B. Im, S. Kim, and Y. Choi, "A High Performance Controller for NAND Flash-based Solid State Disk (NSSD)," in *Proceedings of the IEEE Non-Volatile Semiconductor Memory Workshop*, Feb. 2006, pp. 17–20.

[3] N. Agrawal, V. Prabhakaran, T. Wobber, J. Davis, M. Manasse, and R. Panigrahy, "Design Tradeoffs for SSD Performance," in *Proceedings of the USENIX Annual Technical Conference*, 2008, pp. 57–70.

[4] M. Claypool and K. Claypool, "Latency Can Kill: Precision and Deadline in Online Games," in *Proceedings of the First ACM Multimedia Systems Conference (MMSys)*, Scottsdale, Arizona, USA, Feb. 2010.

[5] J. Peddie, R. Dow, and A. Garovi, "Performance Benefits in Gaming Through the Use of a Solid-State Drive," Jon Peddie Research, Tech. Rep., 2007, [Online at: http://tinyurl.com/4yfd286].

[6] "Delivering Immersive Gaming," Intel, Tech. Rep., [Online at: http://www.intel.com/references/pdfs/ubisoft.pdf].

[7] "Delivering Hitch-free Immersive Gameplay and Increased Developer Productivity," Intel, Tech. Rep., [Online at: http://www.intel.com/references/pdfs/Intel_Gaming_Supplement.pdf].