Utilizing DVD Players as Low-Cost Offline Internet Browsers

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ABSTRACT
In the developing world, computers and Internet access remain rare. However, there are other devices that can be used to deliver information, including TVs and DVD players. In this paper, we work to bridge this gap by delivering offline Internet content on DVD, for interactive playback on ordinary DVD players. Using the remote control, users can accomplish all of the major functions available in a Web browser, including navigation, hyperlinks, and search.

As our driving application, we map the entirety of schools-wikipedia.org – encompassing 5,500 articles and 259,000 screens – to a double-layer DVD. We evaluate our system via a study of 20 low-income users in Bangalore, India. Using our DVD as reference, participants are able to answer factual questions with over 90% success. While most participants prefer to use a computer if one is available, for resource-poor environments the DVD platform could represent a viable and low-cost alternative.

ACM Classification Keywords
H.5.2 User Interfaces; K.3.1 Computers and Education

General Terms
Human Factors, Design

INTRODUCTION
While many of us in the industrialized world have come to rely on having continuous access to the Internet, we represent a small minority: as of 2009, nearly three quarters of the world's population are classified as Internet non-users [2]. In countries such as India, Internet penetration stands at 5.7% [4] while the penetration of broadband is less than 1% [5].

At the same time, developing regions have witnessed significant penetration of other information and communication technologies, including television and DVD players. In India, 58% of households have television and 9% have DVD players; DVD penetration is expected to rise to 21% by 2013 (exceeding the projected penetration of Internet-enabled PCs, which stands at 8.9%) [4]. Even in rural villages and urban slums, households often manage to acquire and sustain TVs and DVD players – as well as DVDs themselves, which are widely copied and distributed through informal markets.

In this paper, we aim to enable new and interesting interactions with an old piece of technology: the DVD player. While DVD players are typically used for watching movies, they also include a rich set of interactive features that are rarely utilized to their full potential. Just as one can use a DVD menu to select the chapter of a movie, it is possible to map hundreds of thousands of menus to a single disc and navigate between them using the remote control [1]. This opens the door to new applications, including the delivery of offline Internet content for browsing on TV and DVD.

As an initial exploration of this idea, we have mapped the entirety of Schools-Wikipedia [6] to a DVD. The DVD contains about 5,500 articles from Wikipedia, which translate to over 259,000 interactive screens on TV. Unlike prior efforts to map Wikipedia or other Internet content to DVD, our disc is playable in off-the-shelf DVD players without any dependence on a computer. Our DVD offers navigation functions that are comparable to a Web browser, including search, hyperlinks, scrolling, and a back button (see Figure 1).

This paper makes two contributions. First, we present an innovative and generalizable design for navigating and searching offline Internet content using the DVD platform. Second, we demonstrate that our design is usable via a study of 20 low-income users in Bangalore, India. Our conclusion is that while TV-DVD is not superior to a computer for delivering offline Internet content, it can nonetheless provide similar functionality at much lower cost.

RELATED WORK
We are unaware of any other tools or techniques for viewing offline Internet content on DVD players. While there are many efforts to build an offline version of Wikipedia on CD or DVD (e.g., [7]), none of the discs produced to date work on an ordinary DVD player. They utilize HTML or compressed formats that require a computer for playback.

The WikiReader [8] is a $99 portable device designed specifically for reading Wikipedia. It can hold 3 million articles, compared to the 5,500 articles that we fit on a double-layer DVD. However, WikiReader omits all images, limits the display to black and white, and has a 240 x 200 resolution (less than that of a TV). The primary advantage of our solution is to leverage existing household technologies to enable anyone to copy and distribute the disc at very low cost.

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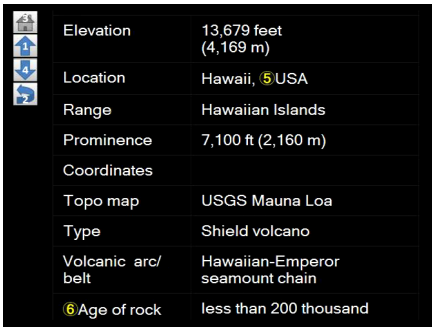
Step 1: Home Page. Numbered links can be followed by pressing the corresponding key on the remote control. The user advances to the search page by pressing "1".

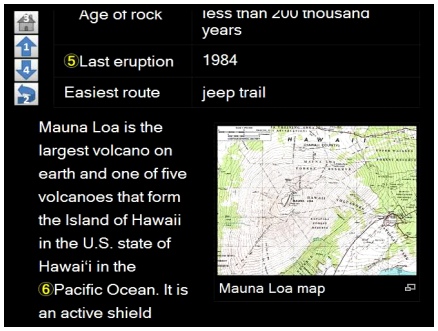
Steps 2-5: Search Pages. Using the arrow keys and select button, the user spells out the search term one letter at a time. In this case, after 4 letters the system jumps to the appropriate index page.

Step 6: Index Page. The user selects the desired article from the index using the number keys on the remote control. In this case she enters "12", for Mauna Loa.

Step 7: Content Page. The user arrives at the desired article. She can scroll up and down by using the "1" and "4" keys, respectively. In this cases she presses "4" in order to scroll down.



Step 8: Content Page. In addition to scrolling, the user can press "2" to go back, or "3" to return to the home screen. In this case the user presses "4" to scroll down further.



Step 9: Content Page. The user finds the information she was seeking: Mauna Loa last erupted in 1984. To learn more about eruptions, she can follow the hyperlink by pressing "5".

Figure 1. Example interaction with Schools-Wikipedia on TV-DVD. This example traces the steps needed for a user to answer one of our test questions: when was the last eruption of Mauna Loa?

In India, there are varied educational materials available on DVD, for example, from BookBox or Pebbles Infotainment; however, interactivity is almost completely absent. Conversely, in the United States, companies such as Screenlife have exploited many of the interactive capabilities of DVDs, but have focused on games rather than educational content.

Prior research has investigated the use of interactive DVDs in low-income schools in India [1], but focused on the domain of children's books and PowerPoint teaching aids. Researchers have also established guidelines for usable DVD menu design [3], though their focus is on movie DVDs and there is little overlap with our inquiries in this paper.

SCHOOLS-WIKIPEDIA ON DVD

We highlight the most interesting challenges and design decisions in mapping Schools-Wikipedia (a subset of Wikipedia intended for offline use) to DVD. Our discussion spans navigation, search, formatting, and our implementation.

Navigation

Navigating offline Internet content on DVD represents an interesting challenge. Instead of using a mouse and keyboard, the only input device available is the DVD remote control. (While it could also be possible to utilize the buttons on the DVD player itself, these generally represent a subset of what is available on the remote.) On DVDs, all navigation is done by selecting one of the options (or *links*) on an interactive menu. There are two ways to follow a link. The first is to highlight the link using the arrow keys and then to activate it using the select key on the remote control. The second is to press a number key directly; typing the number n on the remote will activate the nth link on the menu.

Our DVD uses a combination of these mechanisms for navigation. On the search pages (Figure 1, Steps 2-5), the user spells out the search term, one character at a time, using the arrow and select keys. We judged this to be simpler than typing a number, since there are 26 letters of the alphabet and most selections would require a tedious two-digit entry. However, for the home page, index page, and content pages (Steps 1, 6, and 7-9), we utilize the number keys for navigation. On all pages, links that are labeled with a yellow number can be followed by typing that number. In addition, on content and index pages, the numbers 1 through 4 are tied to specific functions: 1 scrolls up, 2 goes back, 3 goes to the home screen, and 4 scrolls down. The scrolling functions are assigned to keys 1 and 4 because of their intuitive vertical alignment on most DVD remote controls. The back key is limited in that it only stores a history of one page; pressing back twice will return to where the user started.

Search

Indexing and search is a critical component of Wikipedia and other Internet resources. However, search is especially challenging to provide on DVD players, as they have very primitive computational abilities. In particular, it is not possible to programmatically render text on the screen; one can only display frames of MPEG2 video that are stored on disc.

Our solution to this problem is to *simulate* the experience of search by pre-rendering all possible search screens and linking them together in a fixed configuration. For example, in Figure 1 (Steps 2-5), the user has the experience of selecting letters and appending them to the search term at the top of the screen (M, MA, MAU, etc.). However, in actuality, the DVD player is transitioning between separate menus, each of which has been pre-rendered to display a fixed string at the top. While it would require a large number of menus to represent all possible combinations of characters, we decrease the storage requirements drastically by prohibiting the user from spelling any word which does not correspond to an article on the disc. For example, in Figure 1, after the user has entered "M", the letter "Z" is removed from the options for the second character because no entries starting with "MZ" are available. Using this strategy, we require only 675 screens to cover all 4-letter prefixes that the user could search for; in comparison, an exhaustive enumeration of all 4-letter strings would require $26^4 = 456,976$ screens, which would likely exceed the capacity of the DVD.

Once the user has entered a requisite number of characters, the DVD automatically jumps to an index page, where all topics on the disc are sorted alphabetically. Our disc performs this jump when either: 1) the prefix entered by the user identifies a unique page of the index, or 2) the user has entered five characters. In the latter case (which is rare), the user may have to scroll through one or two pages of the index to find what she is looking for. Note that a given title is indexed multiple ways; for example, "St Matthew Passion (Bach)" is also indexed as "Matthew Passion (Bach), St" so that the user can find it when searching for "Matthew".

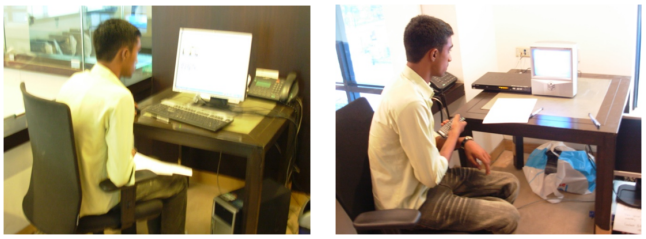
Formatting

Our design underwent many iterations to improve the readability of text on TV-DVD. We performed our testing on a second-hand analog TV (obtained for $50) that is representative of those found in the rural developing world. We found that using a white sans-serif font on a black background led to the best readability; serif fonts were particularly hard to read, as the thin lines caused an appearance of flickering on the screen. We also chose a relatively large font size, to enable viewing from a distance even on low-resolution screens.

Finally, to maximize the number of screens that could fit on the DVD, we simplified some of the Wikipedia content. We eliminated the bibliography from each page, as well as external links and the capability to zoom in on pictures.

Implementation

To generate the images for use on DVD, we render the HTML pages in a Web browser and take screenshots via .NET controls. We utilize a separate tool (details forthcoming) to author the DVD. One limitation of our tool is that the DVDs produced are compatible with many but not all DVD players, as different vendors appear to implement slightly different functionality. We are working to improve the compatibility of our disc in preparation for a broader deployment.



(a) Using computer (b) Using TV-DVD

Figure 2. User completes exercise on (a) computer and (b) TV-DVD.

We note that there is nothing fundamental in our implementation that restricts it to Wikipedia. The same infrastructure could be used to map general HTML content – complete with hyperlinks, indexing, and search – to interactive DVD.

USER STUDY

The goal of our user study is to assess whether low-income users in a developing-country context can utilize offline Internet content on DVD to accurately and efficiently retrieve needed information.

Participants

We conducted our user study with 20 participants (9 female) across two locations in Bangalore, India. 17 participants were enrolled in a non-profit IT training center that offers subsidized courses for people from low-income backgrounds, while 3 were support staff in an office facility. The average age of participants was 21 years (min 16, max 40). Participants had completed 12.6 years of schooling on average (min 11, max 15); also, 9 participants were currently enrolled as students. All participants were equipped with basic digital literacy skills and were comfortable reading English.

Only 25% of participants owned a computer at home, though 50% used a computer daily and 90% used a computer weekly (or more frequently). None of the participants had Internet access at home, though 10% used the Internet daily and 45% used the Internet weekly (or more frequently). In contrast, 100% of participants had a TV at home and 75% had a DVD player at home. Only one person had seen Wikipedia before.

Methodology

Our study represents a within-subjects design in which participants answer questions using both Wikipedia on computer and Wikipedia on TV-DVD. Both configurations utilized Schools-Wikipedia [6], a validated subset of 5,500 Wikipedia articles intended for offline use in schools. As Schools-Wikipedia does not include a search engine, the computer setup (Figure 2a) featured a custom Google search that indexed only pages hosted on schools-wikipedia.org; this search was set to the home page and default search engine of the Web browser. The TV-DVD setup (Figure 2b) utilized a 10-inch black-and-white TV (obtained new for $20 in India) and a generic DVD player, which was used to play our DVD.

	TV-DVD	Computer
Correctness	**91.0%** ($\pm$ 5.3%)	**92.8%** ($\pm$ 4.5%)
Time per Question	**1:41** ($\pm$ 0:15)	**1:47** ($\pm$ 0:27)

Figure 3. Main results of our user study. Time is given in minutes and seconds. Figures in parentheses represent 95% confidence intervals.

To evaluate the technologies, we asked participants to answer a set of 10 factual questions, including (for example) "what is the capital of Ukraine?" and "what year will Halley's Comet appear next?". We designed these questions to be 1) previously unknown to the participants, 2) answerable by viewing a (clearly-associated) Wikipedia article, and 3) answerable near the "beginning" of that article – within the first page of the computer screen, or the first 1-4 screens on TV-DVD. We divided the 10 questions into two equal groups; half of the participants completed Group A on computer and Group B on TV-DVD, while the other half did the opposite. All participants used the computer prior to TV-DVD, as we anticipate that many of our target users would explore Wikipedia on computer prior to utilizing our disc.

The specific experience of each participant was as follows. We started with informed consent and a demographic survey. Then, on the computer, we conducted a brief 1-on-1 training session in which the researcher demonstrated how to answer a practice question. The participant then answered two practice questions on their own, receiving help from the researcher and also asking the researcher as many questions as they liked. Subsequently, the participant completed five test questions on computer, with minimal assistance supplied by the researcher[1]. Following completion on computer, the training and testing process was repeated on TV-DVD. The session closed with an exit interview. We compensated participants Rs. 100 (about $2.20) for their time, which was usually between 60 and 90 minutes. We also gave all participants a complimentary copy of Schools-Wikipedia on DVD.

Results and Discussion

Our main results appear in Figure 3. In terms of success rate, participants correctly answered 91.0% of questions using TV-DVD and 92.8% of questions using computer. Both of these rates are very high, and while the average for computer is higher, the difference is not statistically significant.

Also evident in Figure 3 is the time required on each platform: participants spent an average of 1:41 per question on TV-DVD but 1:47 per question on computer. While the difference is not significant, it is interesting that TV-DVD was competitive with computer (and faster on average). We attribute this to two factors. First, as the computer screen has a higher resolution than the TV screen, it displays more content at a given time. This distracted participants in some cases, especially when the answer appears in Wikipedia's summary table (which appears in the corner on computer, but is shown first on TV-DVD). Second, some participants were slow typing on QWERTY keyboards, and benefited from the alphabetical layout of letters on TV-DVD.

[1]Across 210 questions, the researcher supplied a hint in 5 cases – 3 for DVD and 2 for computer – only when it became apparent that a participant was stuck.

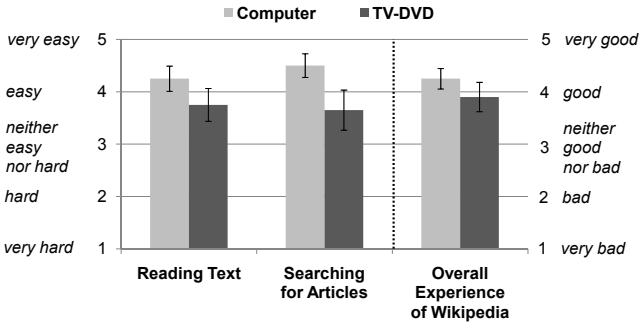


Figure 4. Users' opinions regarding the difficulty of reading text and searching for articles as well as their overall experience of Wikipedia. Error bars represent 95% confidence intervals.

Qualitative feedback was also gathered, and results appear in Figure 4. On computer, all but one participant judged it to be "easy" or "very easy" to read text and search for articles, while on TV-DVD participants indicated that it was significantly harder to read text ($p < 0.02$) or search for articles ($p < 0.01$). Regarding participants' overall experience, everyone indicated that the experience on computer was either "good" or "very good", while for TV-DVD three participants assigned neutral or negative labels. The overall experience on computer was rated significantly higher than that of TV-DVD ($p = 0.05$). Nonetheless, 25% of participants reported that they preferred TV-DVD to computer, and 90% said that they would use Wikipedia on TV-DVD if the computer was not available – as is the case in 75% of their homes.

CONCLUSIONS

Offline Internet content on interactive DVD has the potential to reach a large part of the developing world, due to the relatively high penetration of TVs and DVD players. In this paper, we show that the DVD platform is capable of supporting the core functionality of Web browsers – including navigation, hyperlinks, and search – by mapping the entirety of schools-wikipedia.org to a double-layer DVD. Our user study suggests that while the DVD platform is not superior to a computer, it nonetheless represents a usable and viable alternative for finding needed information at very low cost.

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