

Page turning solutions for musicians: A survey

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Abstract. Musicians have long been hampered by the challenge in turning sheet music while their hands are occupied playing an instrument. The sight of a human page turner assisting a pianist during a performance, for instance, is not uncommon. This need for a page turning solution is no less acute during practice sessions, which account for the vast majority of playing time. Despite widespread appreciation of the problem, there have been virtually no robust and affordable products to assist the musician. Recent progress in assistive technology and electronic reading devices offers promising solutions to this long-standing problem. The objective of this paper is to survey the technology landscape and assess the benefits and drawbacks of page turning solutions for musicians. A full range of mechanical and digital page turning products are reviewed.

Keywords: Automatic page turner, assistive technology, hands-free reading

1. Introduction

Page turning is an important ancillary process of reading. It is a pervasive task that many people take for granted. The goal of this paper is to review the state-of-the-art in automatic page turners, the assistive technology for automating this mechanical process. An *automatic page turner* is a device that automates the mechanical elements of reading so that book pages can be turned hands-free in either direction. A suitable hand/foot pedal or breath-controlled switch can be used to activate the page turning mechanism without hindrance. Additional activation options include an eye switch, chin switch, or voice activation unit.

Hands-free operation is particularly important to musicians and disabled individuals. Musicians, for example, are often hampered by the need to turn pages in a music score while their hands are occupied playing their instrument. Disabled people, facing the challenges of the physical process of page turning, require assistive technology to aid them in the basic daily function of reading books, magazines, and newspapers. In this manner, the page turner is directed toward the sub-

stitution of normal reading functions for people with disabilities.

A page turner is particularly beneficial to people with limited bilateral upper extremity function caused by neurological impairment, musculoskeletal problems, and generalized weakness. Included in this population, for example, are patients who have suffered cerebrovascular accidents, spinal cord injuries, amyotrophic lateral sclerosis (ALS), multiple sclerosis, cerebral palsy, and arthritic joint changes. An automatic page turner serves to enhance their quality of life by improving their independence in reading, an important activity of daily living.

The vast majority of commercialization efforts in this field has targeted people with disabilities. As a result, offerings have often proven to be bulky, noisy, and expensive mechanical devices operating on conventional books and magazines. This has generally limited the use of automatic page turners to disabled individuals who place a high premium on this technology. Successful penetration in the consumer market is needed to offer economies of scale that would significantly lower cost. Only then can page turners grow beyond the

disabled market to musicians and avid readers, providing them with convenient book support and hands-free page turning features. This would enable the product to find pervasive use among the disabled and elderly populations, and become convenient attachments to pianos, music stands, book stands, and exercise equipment. Its role as assistive technology in hospitals, nursing homes, and libraries is clear. Sections 2 and 3 respectively survey the mechanical and digital product offerings that address page turning for musicians.

2. Mechanical page turners

In order to best understand and evaluate automatic page turners that operate on conventional books, it is necessary to observe that all mechanical page turning devices must address the following actions relating to a page: engagement, transport, and restraint. The engagement process refers to the act of fetching, or lifting, a single page. This can be achieved by means of suction tubes, friction wheels, adhesives, clips, magnetic tabs, or torpedo tabs. Once the page is engaged, it may be transported (turned) by many possible means, including a rotating arm, rotating page disks, spring mechanism, or linear movable arm. Throughout these processes, some page restraint mechanism must ensure that underlying pages are held in place.

Hands-free operation cannot be successfully achieved without an effective page restraint design. Most books do not lay open without some effort in holding the pages down. New books, in particular, have a tendency to close upon themselves. This complicates the page turning process since the need to hold open the book and prevent pages from turning unintentionally are in conflict with the associated task of turning one page at a time. This is perhaps the most critical component to a successful page turning device.

While there are over fifty patents on the subject of automatic page turners dating back to 1874, virtually none of these patents have led to widely commercialized working products. This is due to the fact that almost all of the patents lack one or two of the three major functions of a successful page turner: engagement, transport, and restraint. A review of the patent literature identified several design flaws, including unreliable and noisy mechanisms for engaging one page at a time, and cumbersome preprocessing whereby clips or tabs must be attached to each page. The patents differ in the manner in which they handle the page engage, transport, and restraint processes [2–9,11,13–19]. In-

deed, the products surveyed in this section highlight the difficulties in balancing these three processes across a wide array of book sizes and paper weights.

It is important to note that the marketing videos accompanying many devices restrict their demos to well-behaved books that *do not* challenge the delicate balance between page restraint and page transport. This is depicted in YouTube videos demonstrating class design projects as well as corporate product demonstrations. The goal in any high-performing page turner is to offer an effective and unobtrusive page restraint mechanism coupled with the page turning process.

To date, commercialization of mechanical page turners has focused on the disabled community. The limited product offerings in this market can be grouped into two tiers: fully-automatic and semi-automatic robotic systems. These tiers are distinguished by their requirement to treat the pages with magnetic clips or some other method to assist the device in accurately turning pages. In a fully automatic system, the user simply needs to attach the book to the unit before beginning to turn any number of pages with the tap of a switch. It is important to note that the term “fully automatic” *does not* refer to the turning of pages at preset time intervals. Rather, the term refers to the fact that no preprocessing is necessary in loading the book to assist the system in turning exactly one page at a time when activated. Semi-automatic systems are limited to turning only those pages that have been treated with attachments. In both cases, the user must trigger a page-turn cycle by tapping a pedal, pressing a pushbutton, or using a breath-controlled, chin, or eye switch. These external switches can be mounted to most page turners that are equipped with outlets for stereo or mono plugs.

2.1. Fully-automatic page turners

There are several leading products that qualify as fully automatic page turners. These products, shown in Fig. 1, include GEWA Page Turner BLV-6, QED Page Turner, Ablenet’s Flip Automatic Page Turner, Qidenus Technologies’ QiCare and QiVinci page turners, and the Touch Turner. Perhaps owing to the targeted user base, these units are large, rugged, slow, noisy, and expensive.

The GEWA Page Turner from Zygo Industries (www.zygo-usa.com) is a large industrial robot offering several switches for manual operation of a rubber roller to flip through pages. The user is in total step-by-step control of the turning process. A rubber roller manipulates pages forward and backward, singly

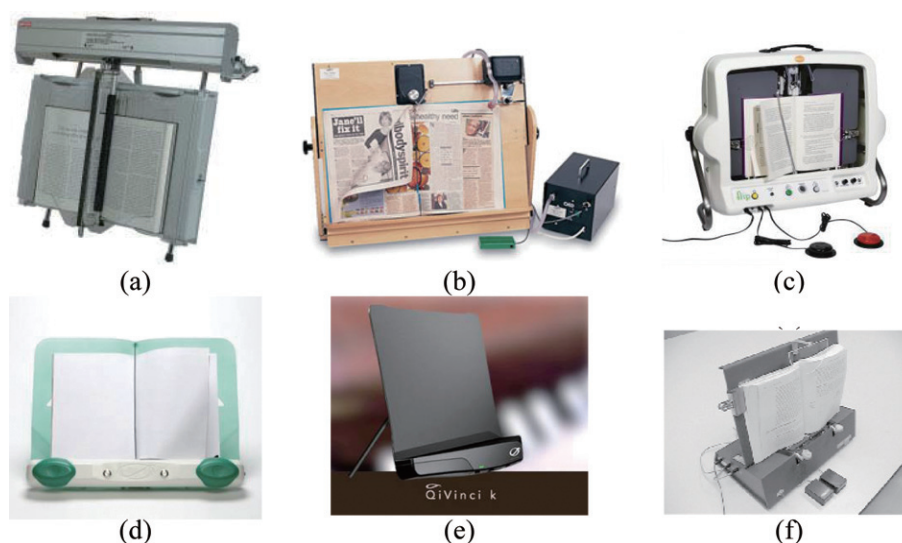


Fig. 1. (a) GEWA; (b) QED; (c) Ablenet Flip; (d) QiCare; (e) QiVinci and (f) Touch Turner fully automatic page turners.

or continuously, for readers who are sitting up or lying down. No adhesive or tapes are used. Inner and outer plastic panels secure and flatten the reading material. Errors in turning, such as sticking pages or crumpled and misangled pages, can be manipulated by meticulously controlling the rubber roller wheel via switches. The GEWA page turner accommodates most textbooks, paperbacks, and magazines having a maximum page size of $12'' \times 9''$, and a maximum thickness of $2''$. At a cost of \$5000, GEWA is the most expensive page turner. Its cost and 15 lbs weight make it best suited for institutional use for disabled people.

Another related device in the same price range is the QED page turner from Quality Enabling Devices in the UK (www.qedltd.com). QED page turners can turn the pages of tabloid newspapers, magazines, paperbacks, and hardcoverd books up to 50 mm (2 inches) thick. This design uses a vacuum pump connected to a patented nozzle system to separate the pages. The system separates pages by using the specially shaped nozzle to suck up and slightly bend the corner of the top page, thus forcing the other pages away. A central wand (wiper) then rotates and turns the page, flattening it ready for reading. The QED page turner, priced at \$5000, accommodates the same-sized reading material as GEWA.

Ablenet's Flip page turner (www.ablenetinc.com) is the most recent entry in this field of products. At a cost of \$3900, it is priced competitively with the other expensive options in this tier. The setup time for attaching a book to the unit is approximately two minutes. Whether it is a book or a magazine, this device

can turn pages one at a time or 5 continuous pages by pressing down the button once or holding it down to move through several pages. The Flip page turner has an adjustable stand and a handle as well as a mouthstick built into the front of the device. The unit accommodates book and magazines with pages sizes ranging between $4.13'' \times 5.83''$ and $8.67'' \times 11.69''$, and spine widths up to $1.18''$. The turning speed is rated at eight seconds per page, although the scanning rate (for fast browsing) can vary between 0.6 to 3.0 seconds. The unit is large, having dimensions $23.62'' \times 18.90'' \times 11.02''$ and weighing 18.74 lbs. Like the GEWA and QED page turners, these specifications make this unit more likely to be used in institutional settings rather than directly in the home.

Another recent entry into this price range of fully automatic page turners is the QiCare automatic page turner from Qidenus Technologies in Austria (www.qidenus.com). This page turner works exclusively with thin magazines or periodicals. To use, the magazine or periodical is placed on the unit's reading surface and fixed in place with the built-in fastener. When activated by a signal, this page-turning system uses a gentle movement to leaf through the pages, either forwards or backwards. The unit can be operated using a variety of controls, including voice control, Piko dual switch, finger switch, or proximity sensor. The device is intended for use by individuals with mobility or severe physical disabilities. The unit is compact and elegant but its design restricts usage to thin reading material. The \$3000 cost of the QiCare page turner may seem particularly excessive given this restriction.



Fig. 2. (a) Volta Bene and (b) the PageFlip Lite semi-automatic page turners.

The QiVinci page turner by Qidenus Technologies offers a lower cost unit that turns pages in only the forward direction. Its mechanism is closely related to that of the QiCare product. The QiVinci page turner is intended for musicians with thin well-behaved music books that readily stay open. Most bound music books, however, do not often cooperate and so this solution is rather brittle for this application. The cost of QiVinci is about \$1500, rendering it out of reach for most musicians.

The Touch Turner (www.touchturner.com) is one of the older product offerings on the market in this tier. This device uses a pickup wheel coated with an adhesive putty to pick up a page while a swinging arm (wiper) moves the lifted page across the book. Like the page turners from Qidenus Technologies, The Touch Turner fails to work for books that are not “conditioned” to stay flat when opened. Priced at \$1500, it is still a prohibitively expensive solution that is slow, bulky, and restricted for use to thin books. A transparent flap hanging above the top edge of the book helps flatten the page for reading.

2.2. Semi-automatic page turners

Semi-automatic page turners offer a cost-effective alternative to fully automatic devices. This class of devices requires the user to affix a clip, adhesive, or other attachment to each page that is to be turned. It is expected that a limited set of pages will be read in one session and that those pages can be treated in a preprocessing paper-handling step. The act of placing attachments to the pages is fast, often requiring no more than three seconds per page. This class of devices is the lowest-cost solution for musicians using traditional music books.

A recent low-cost page turner introduced by Volta Bene (www.voltabene.com) targets the musician market (Fig. 2(a)). The \$400 Volta Bene page turner requires the user to attach metallic clips to the bottom of each page. The system makes use of a rotating magnetic arm to turn the page. The arm first attaches itself to the page by rotating to make contact with the metallic clip. The arm then sweeps from one side of the book to the other to turn the page. The trajectories of the arm and the page diverge to permit the arm to eventually pull itself away from the clip and detach itself from the page. This process is depicted in the sequence shown in Fig. 3.

There are several drawbacks with this product. First, only *thin* (< 30 pages) well-conditioned music books whose pages freely stay open can be handled. There is no page restraint element to the Volta Bene page turner to prevent pages from inadvertently turning. This problem applies when the arm attempts to turn a page and while the unit remains at rest. Second, pages can only be turned in the forward direction. There are no provisions for turning pages in the reverse direction. Our experience with this device is that it is brittle, working well in only a small operating range for thin books whose pages freely stay open. Unfortunately, the vast majority of books do not fall into this category.

The PageFlip Lite page turner from PageFlip (www.pageflip.com) is a response to many of these deficiencies. The PageFlip Lite page turner, shown in Fig. 2(b), requires sheets to be individually installed into dedicated arms that will turn one page at a time at the press of a wireless pedal or sip-and-puff switch. Although this guarantees 100% reliability in turning exactly one page at a time, there exists the inconvenience of spending up to three seconds loading each page into an arm, and the limited number of arms (10) that can perform



Fig. 3. Animation sequence of Volta Bene page turner.

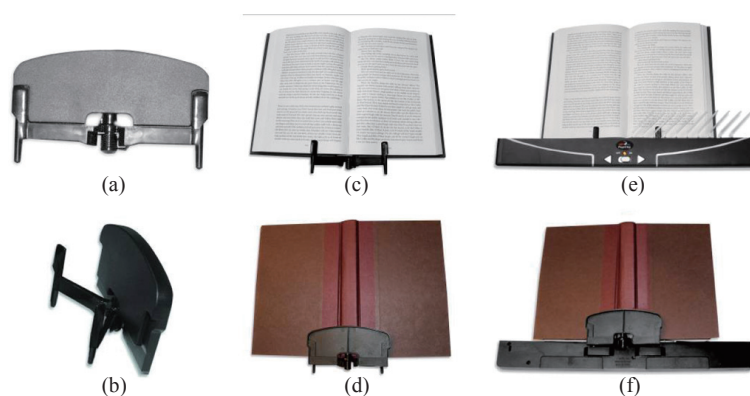


Fig. 4. (a) Book clamp; (b) Pull spring-loaded arms outward to slide book between flexed arms and supporting plate. (c) Front and (d) rear view of book clamp with mounted book; (e) Front and (f) rear view of book/clamp assembly mounted on PageFlip Lite. Notice that clamp snaps into rear slots of PageFlip Lite.

this function before the next batch of pages must be installed.

This unit advances a novel design that is superior in several respects: reliability, portability, ease of use, and cost. The device works in either the forward or reverse directions with a wide range of paper sizes and weights. It requires minimal setup for operation, allowing for fast placement and removal of printed material. In addition, the device is small, unobtrusive, discreet, light, and portable. However, due to the fact that it attempts to swing pages from the bottom, it is not well-suited for thin pages as found in some magazines. In those cases, the paper lacks stiffness and so it folds instead of turning when the bottom portion of the page is swung across the center of the book.

PageFlip Lite is designed to operate with books having a wide range of sizes and thicknesses. This is made possible with the use of a specially-designed clamp that can mount a book to the unit while firmly restraining pages from inadvertently turning. The clamp consists

of a back support and two spring-loaded arms, as shown in Fig. 4(a). Each arm has a tip that includes a page restraint to block loose pages from turning freely. Each tip also includes a peg that slides into a rear slot on the PageFlip Lite to secure the book clamp into place. Before setting up the book clamp, it must first be detached from PageFlip Lite by pulling it out of the two rear slots.

A book is attached to PageFlip Lite by securing the book clamp to the bottom edge of an open book. This is done by pulling the page restraints away from the supporting plate (Fig. 4(b)). An open book is slid into the space between the flexed arms and the supporting plate. Releasing the arms allows the compressive force of the springs to secure the book between the page restraints and the supporting plate (Fig. 4(c)). The user can then pick up the clamped book and slide the clamp pegs into the rear slots on PageFlip Lite, as shown in the bottom row of Fig. 4.

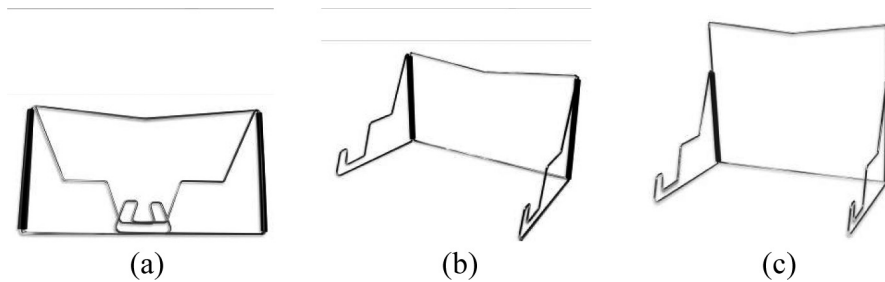


Fig. 5. Collapsible support stand shown in the (a) closed and (b) opened positions. (c) Lift the horizontal crossbar to alter the tilt angle of the book.

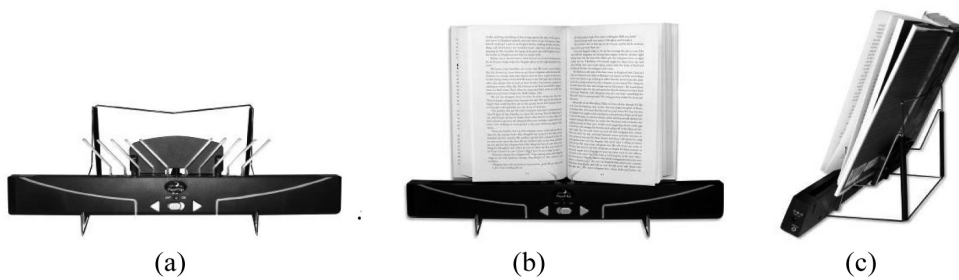


Fig. 6. (a) PageFlip Lite and the attached book clamp mounted on the support stand; (b) Front and (c) side view of PageFlip Lite mounted on support stand.

The PageFlip Lite page turner can be securely held on virtually any workspace, including a table or desk, the ledge of a music stand, or the book rest of a keyboard instrument. If the workspace is a table or desk, a support stand must be used to prop up the PageFlip Lite and the attached book. Simply unfold the collapsible support stand (Fig. 5) and rest the PageFlip Lite in the bottom groove (Fig. 6). It is recommended that the horizontal crossbar be raised, as shown in Fig. 5(c), to alter the tilt angle of the book for maximal stability and comfort.

No support stand is needed when PageFlip Lite rests on a music stand or piano. Instead, two configurations are possible: (1) PageFlip Lite sits on ledge and supports book (Fig. 7(a)) or (2) book sits on ledge and supports PageFlip Lite (Fig. 7(b)). The first case is best suited for lightweight books, while the second case is appropriate for heavy books that can support a light page turner clipped along its top edge, as shown in Fig. 7(b). One benefit to this approach is that the book does not have to be lifted to apply the clamp. Simply clamp from above while the book rests on the ledge, and then hang PageFlip Lite upside down on the clamp pegs (that are now pointing up). The only drawback is that there is less support for the pages from below and so the front page may sag, as seen in Fig. 7(b).

Before the semi-automatic PageFlip Lite turner can begin to turn pages, a page-loading preprocessing step must be completed. This requirement, however, makes it possible to guarantee 100% accuracy in turning one page at a time. This is a claim that no fully-automatic page turner can match. One caveat, though, is that the page must be stiff enough so that swinging it from the bottom will permit the top edge of the page to follow and not simply fold over. This is generally true for most reading material except for very thin pages found on some magazines or newspapers. Fig. 8 depicts the effort involved in loading pages into the dedicated arms, as outlined below.

1. Move all forked arms to the right side for loading
2. Attach clamped book onto PageFlip Lite (Fig. 4(e))
3. Release up to ten sheets from under page restraint
4. Lay them between forked arms and page restraints (Fig. 8(a))
5. Lift topmost page to be turned from under forked arms
6. Slide it through slot of centermost forked arm (Fig. 8(b))
7. Press left panel button to turn page and expose next sheet
8. Repeat steps (5) to (7) for all pages

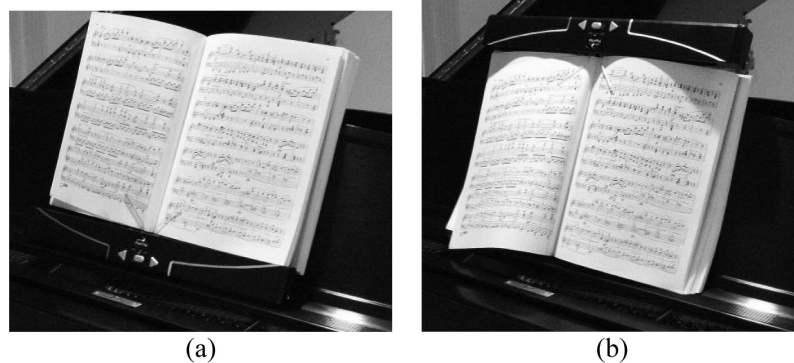


Fig. 7. PageFlip Lite clipped to (a) bottom and (b) top of book. No support stand is needed on piano.

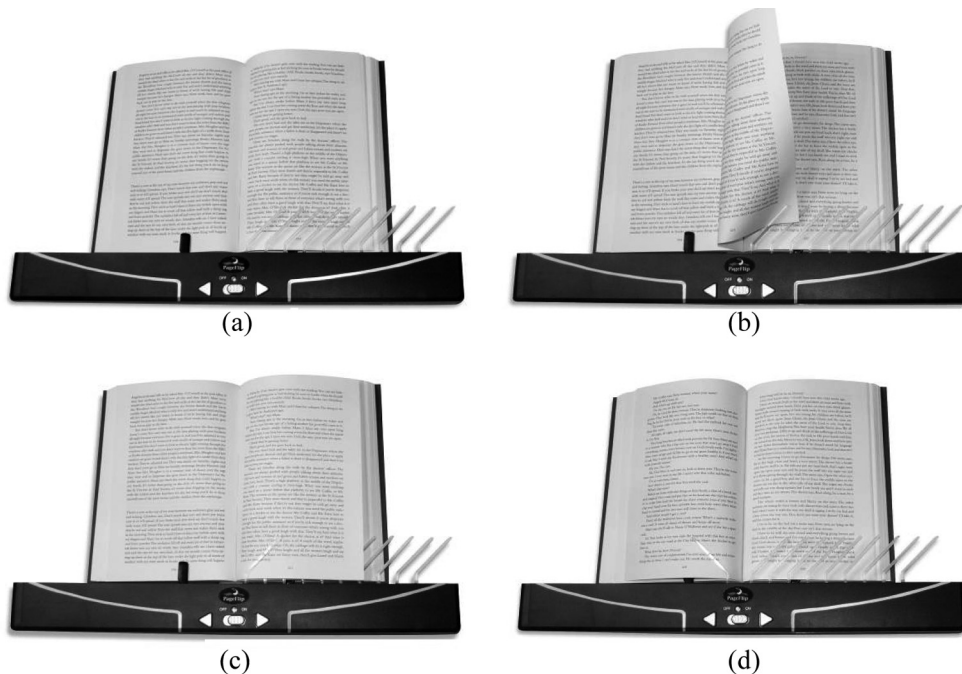


Fig. 8. (a) Release sheets from under page restraint; (b) lift corner of topmost page and feed it into forked-arm slot; (c) slide page into slot and flatten; (d) turn page and repeat process.

9. Reset by repeatedly pressing the right button to rewind pages

It is important to note that some of the ten arms may not be usable if the book width is too narrow. The example above, for instance, only used seven forked arms. This problem may be solved by attaching Post-It[®] notes to the edge of the page to extend its effective width. These Post-It[®] notes can be slid into the slots of the outermost arms to maximize the number of pages that can be turned prior to reloading the sheets. Common music books with page widths of 9" or more will be able to fully utilize all ten forked arms.

2.3. Summary

A survey of the mechanical page turners reviewed in this section are listed in Table 1 and sorted by price. The two lowest-cost units listed in the table represent the limited commercial offerings for semi-automatic page turners.

Due to the inevitable problems that may arise from pages sticking together, no fully-automatic page turner can guarantee 100% accuracy in turning one page at a time. Only the PageFlip Lite semi-automatic page turner can meet this goal because the risk is taken out

Table 1
Survey of automatic page turners

Product	Page engagement	Page transport	Page restraint	Reversible	Cost
GEWA	Rubber roller	Rubber roller	Transparent flap	Yes	\$5000
QED	Vacuum	Wiper	None	Yes	\$5000
Ablenet Flip	Rubber pad	Wiper	Retractable fingers	Yes	\$3900
Touch Turner	Putty wheel	Wiper	Transparent flap	Yes	\$1500
Volta Bene	Metallic clips	Wiper	None	No	\$400
PageFlip Lite	Preloaded forked arms	Sliding/rotating arm	Forked arms	Yes	\$199

of the system by the user who loads the pages into the dedicated arms. Since this loading happens as a preprocess, any problems that may have arisen due to stuck pages are now resolved in advance by the user.

The QiVinci semi-automatic page turner attempts to approach 100% accuracy by using metallic clips that allow the magnetic tip of the wiper to easily grab one sheet. However, there is insufficient page restraint mechanism in that unit to guarantee that additional pages do not follow the wiper as it turns a page. This error is simply impossible with the PageFlip Lite page turner because the other pages are locked down by the forked arms.

3. Digital solutions

All of the products described in Section 2 pertain to the mechanical problem of turning the pages of actual books. There are several disadvantages with this approach. Complete accuracy in turning one page at a time is impossible for fully automatic page turners. As a result, manual preprocessing will always be necessary to achieve this level of reliability. This approach is embodied by the semi-automatic PageFlip Lite page turner. In addition to the inconvenience during setup, manual preprocessing inherently limits the number of pages that can be read continuously in one session before the next batch of pages must be set up. Although the user may quickly attach clips to pages or preload pages into dedicated arms, it is nevertheless a disruptive act that interrupts long reading sessions.

A tradeoff clearly exists between preprocessing effort and accuracy. In general, more disruptive preprocessing efforts lead to higher accuracy in turning one page at a time. Musicians, for instance, who demand 100% accuracy will likely opt for a system such as the PageFlip Lite that is low-cost and requires page loading to achieve completely reliable operation. However, while this may meet the needs of a musician during a practice session, it would be too burdensome to install several different music scores during a live per-

formance. Another consideration is the noise that mechanical solutions make. Musicians may find this unacceptable during performance or recording sessions.

The ideal solution for musicians lies in the use of digital sheet music. Once the music is available in digital form on a computer, it may be presented to the musician on a standard LCD screen. A simple tap of a foot pedal can then advance the sheet music to the next page. This approach offers the musician the ability to carry their entire musical library with them on the computer, and avoid the risk of mechanical failure and noise that are present with turning conventional books.

3.1. Book scanning

Digital sheet music may be acquired by scanning printed books or by downloading scanned or rendered versions of the sheet music over the Internet. If the musician already has a large library of printed books, it may be most cost-effective to simply scan that music. This also permits the musician to retain their preferred edition/version of the score, which may not be available in the downloaded format.

Scanning a book is akin to “ripping” a CD, a popular method for importing music into iPods and other music storage devices. In both cases, the process involves sampling the input to reproduce the content into digital files. Ripping a CD simply requires freely available hardware and software, such as a CD drive and software to copy from that drive at a desired sampling rate. The barrier to implementing this solution is very low.

Scanning books, however, is a far more tedious and costlier operation. Although virtually any scanner can process book pages, most scanners don’t scan books well because you have to lay the book face down on the scanner. The edges near the spine lift away from the glass platen, leaving the text to appear warped and in shadow. There is a special class of consumer-grade devices, such as the \$250 Plustek OpticBook book scanner (www.plustek.com), which improves matters by making the glass platen extend to the edge of the scanner (Fig. 9). The user simply places a book so that one

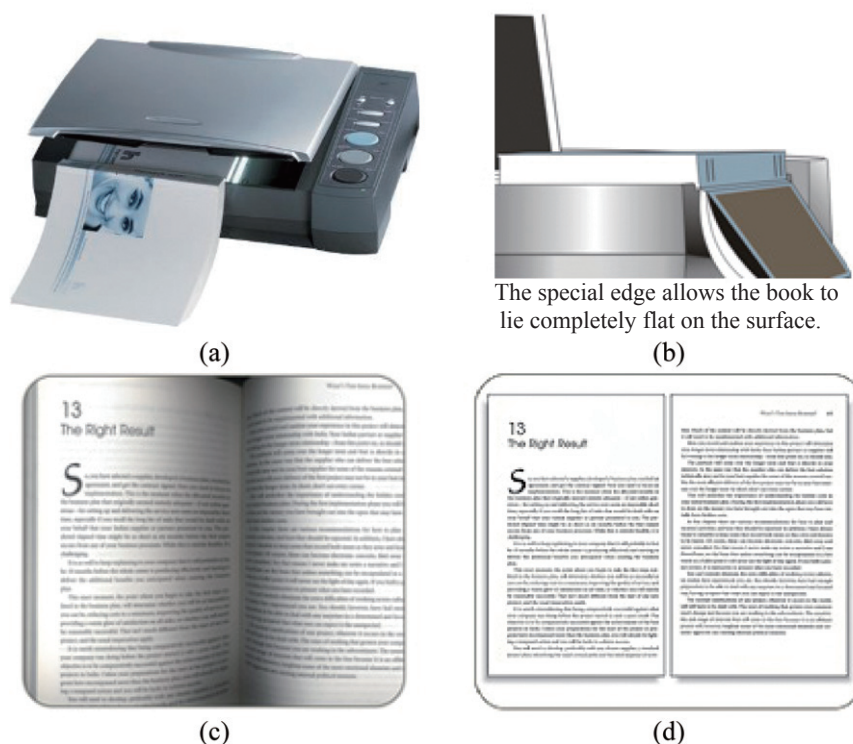


Fig. 9. (a) Plustek Opticbook 3600 book scanner; (b) the special edge helps protect books from excessive pressure at the spine and yields a perfectly scanned image; (c) images produced by regular scanners; and (d) image produced by OpticBook 3600 book scanner.

page lies almost flat, with the facing page and that side of the book hanging off the side of the scanner. Plustek uses a special lamp design that lets the scan element see the entire page, right up to the edge near the spine, so the perfectly flat text doesn't fall in a shadow.

In addition to the cost of the book scanner, there is also the additional physical effort involved in the process. The user must position the page properly on the glass platen of the scanner, press a button, wait for the scanner to complete the scan, and then turn the page. Each page takes about 9 seconds to scan, so this solution is far slower than the equivalent sampling process for ripping CDs.

It is important to note that unlike the case of books, in which there may be multiple arrangements or editions of the same songs, the music stored on iPods is the same whether it is purchased or ripped from the CD. Only the selected sampling bit-rate may differ. Therefore, ripping CDs presents iPod users with low-cost and easily implemented alternatives to buying the music from iTunes. Scanning books, on the other hand, is necessary to guarantee retention of preferred versions but there is a higher barrier to implementing this solution in terms of cost, time, and effort. Once this barrier is

passed, however, the digital sheet music is available in a mainstream format, such as PDF or JPG, for use on a wide variety of computers and display devices. This remains the ideal method for preserving an existing sheet music library.

It is worth pointing out that Google and major libraries around the world involved in the Herculean efforts to preserve and import fragile, out-of-print manuscripts as well as conventional books and periodicals, all employ book scanning solutions. Some systems utilize low-cost scanning that require a person to manually turn each page, while others utilize very high-end and costly book scanners that automatically turn each page. Automatic book scanning systems are prohibitively expensive, with some models costing over \$100,000 and scanning as many as 2500 pages per hour. Vendors of such systems include Kirtas Technologies (www.kirtas.com), Qidenus (www.qidenus.com), and Treventus (www.treventus.com).

3.2. Download digital content

The alternative to book scanning is to access the many Internet websites that have emerged to service

the needs of musicians to obtain free or low-cost digital sheet music. The International Music Score Library Project website (imslp.org) is an extensive community-built library of public domain sheet music scanned to PDF. It offers tens of thousands of free scanned copies of classical works by thousands of composers. Since the files are available in PDF format, it is platform-neutral. Additional PDF music content can be found on bandmusicpdf.org.

Another simple option for acquiring the complete classical works of composers in PDF format is to purchase CD sheet music from www.cdsheetmusic.com or sheetmusicplus.com. They offer a comprehensive selection of published scores and sheet music by the world's great classical composers from the Baroque, Classical, Romantic and Modern eras, including works for orchestra, chamber ensemble, piano, strings, winds, voice, and chorus. The entire works of composers such as Bach, Beethoven, Chopin, Mozart, and others can each be contained on one CD. At \$20 per CD, this is a truly affordable option for collecting the entire works of masters from well-known and highly regarded editions in a convenient format for personal use. Original sources are out-of-copyright standard editions from publishers such as Breitkopf and Hartel, C.F. Peters, G. Schirmer, Carl Fischer, G. Ricordi, Durand and many others. The CDs also include biographical and analytical information from Grove's Dictionary of Music and Musicians, 1911 Edition.

Retaining files in PDF format remains the most platform-independent option for storing and viewing digital sheet music. Aside from the PDF offerings available on imslp.org and bandmusicpdf.org, many digital download sites are tied to a specific platform and a proprietary format. For instance, the freehandmusic.com website offers music in the Solero format to allow you to transpose, print, and play a MIDI version of the song. The songs, however, are often arranged versions of the original. Another popular format for digital sheet music is Sibelius Scorch, which is used by sheetmusicdirect.com. The Scorch software must be installed prior to viewing and interacting with the music. In many cases, however, these editions may not compare favorably to the editions that are available in printed form. For instance, fingering, pedal notation, and other elements common in preferred music book editions may be lacking in the content available for digital downloading.

Finally, digital downloads of sheet music tend to be sparsely available and very expensive compared to their printed versions. For instance, large music distributors

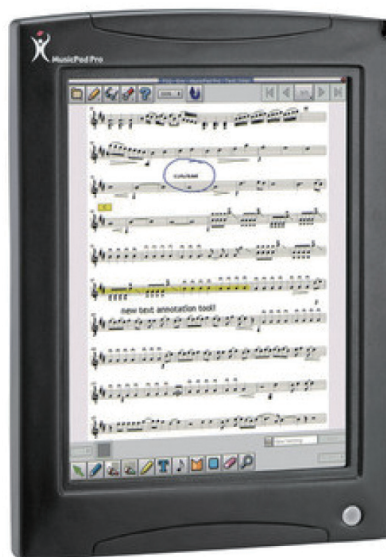


Fig. 10. MusicPad Pro from FreeHand Music Inc.

such as Hal Leonard (www.halleonard.com) offer digital downloads of their printed sheet music. These offerings, however, are incomplete and relatively expensive. Whereas printed volumes offer many songs for a low-price, digital sheet music is typically sold on a per-song basis at an average price of \$5 per song. This is far costlier than the printed book option.

3.3. MusicPad Pro

Despite the many advantages to digital page turning, a hands-free dedicated hardware device for handling digital sheet music has only recently been advanced for musicians. The MusicPad Pro digital sheet music display system is an easy-to-use digital music notebook in a handy 12.1" tablet size (Fig. 10). Pioneered by FreeHand Music Inc, the MusicPad system permits a musician's entire sheet music, drill charts, lyrics, guitar tablature, bowing and fingering marks, class schedules, set lists and other study and performance aids to all be kept in one convenient place. Its touch screen permits the user to make marks and notations right on the page of music. At \$900, though, it is an expensive stand-alone device leveraged upon a proprietary sheet music standard. The competitive advantage of such a system is now diminished by the widespread proliferation of low-cost general-purpose laptops and tablet computers. As a result, the company has focused their efforts on becoming a prime digital sheet music supplier, selling over 130,000 titles over a variety of genres.

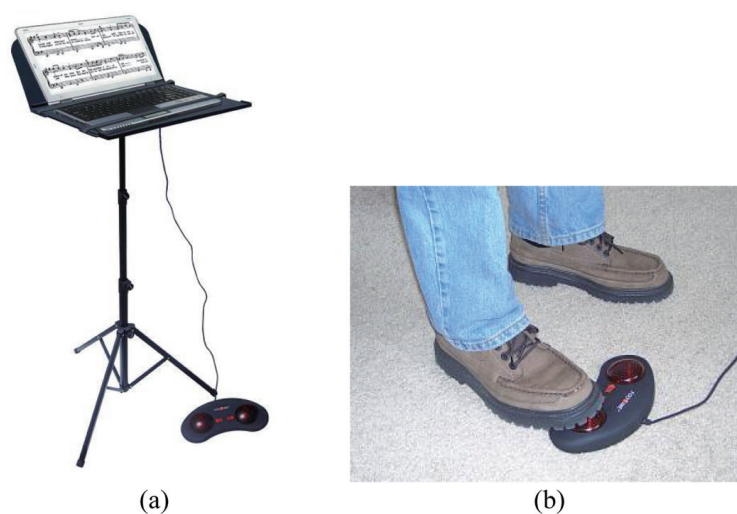


Fig. 11. (a) Footime USB pedal connected to a laptop computer; (b) press pedal to turn page.

Users can now simply download sheet music directly from www.freehandmusic.com and print it or add it to the MusicPad Pro. Most of their digital sheet music selections include the ability to transpose, MIDI recordings with tempo adjustment, and the ability to change the sounds of the MIDI files. The user can also remove a track and play along with the MIDI file. Playing is as simple as pulling up a song, transposing it to the desired key, and downloading it to the computer or MusicPad Pro.

3.4. Footime page/score turner

Bili Inc www.bilila.com produces a \$50 USB plug-and-play foot pedal to advance through a digital document stored on a computer (Fig. 11(a)). Ordinarily, navigating from one page to the next in a document viewer requires the user to press PageUp or PageDown on the keyboard. The Footime page turner sends these keypress events to the attached computer by tapping the left or right foot pedal (Fig. 11(b)). This product is a wired device that requires a cable to run from the pedal to the computer. It may be attached to an iPad with the use of an additional \$30 iPad Camera Connection Kit adapter.

3.5. Airturn

The AirTurn automatic page turner (www.airturn.com) is a \$50 wireless USB page turning transmitter that works with any Mac or Windows PC program that can accept a PageUp or PageDown keystroke. The Air-

Turn includes a receiver that plugs into a computer's USB port and is ready to use without any additional software to install. The AirTurn transmitter and receiver are shown in Fig. 12.

The transmitter is not integrated into a pedal, so users must plug their own pedals to the unit. Pages are turned by pressing the footswitch connected to the AirTurn transmitter, allowing for a true hands-free reading experience (Fig. 13). Developed originally for musicians who need to be able to read music while using their hands to play their instruments, the AirTurn can be used as a teleprompter for speakers who need to keep their hands free for gestures and demonstrations. PowerPoint and Keynote presentation program slides can be advanced forwards or backwards with a simple foot tap.

The AirTurn works with almost any electronic document, such as sheet music downloads, guitar tabs, song lyrics, PDFs, and PowerPoint presentations. The company offers MusicReader, an optional sheet music reading software, to assist in the process of converting music sheet downloads, scanning paper music scores, drawing notes in the digital music with colored ink, and the creation of playlists from the user's sheet music library. In this manner, thousands of pages of scores can be carried in a single laptop. In general, though, any software that can accept the PageUp and PageDown keys to advance through a digital document can work with AirTurn.

Together, the AirTurn automatic page turner and MusicReader software provide a complete digital sheet music solution. The system is useful for students who

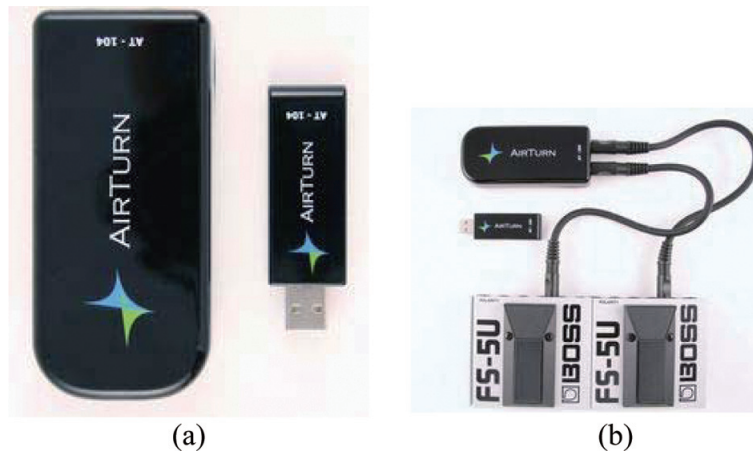


Fig. 12. (a) Airturn transmitter and receiver; (b) Two pedals connect to the Airturn transmitter.

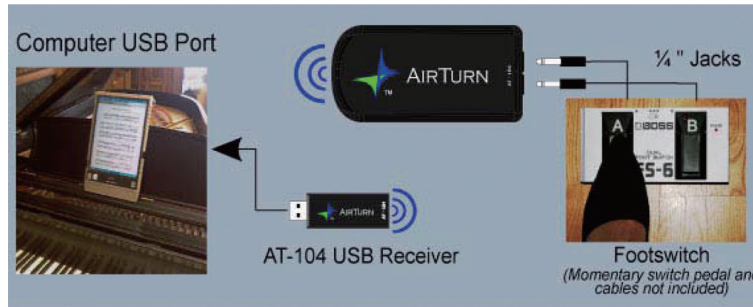


Fig. 13. Airturn system. A dual footswitch (not included) connects to the Airturn transmitter via two 1/4" jacks. The USB dongle (included) is attached to the computer's USB port to receive the transmitted keypress signals. These signals trigger the document viewer to turn the pages of the digital sheet music in the forward or reverse directions.

can appreciate having all their sheet music available for study. The system is also useful for teachers who can appreciate the benefits of marking up the music in bright colors for clearer instruction. Digital page turning with Airturn is suitable for amateurs and professionals who will find the convenient storage and display of digital sheet music coupled with a wireless dual-pedal indispensable for hands-free reading.

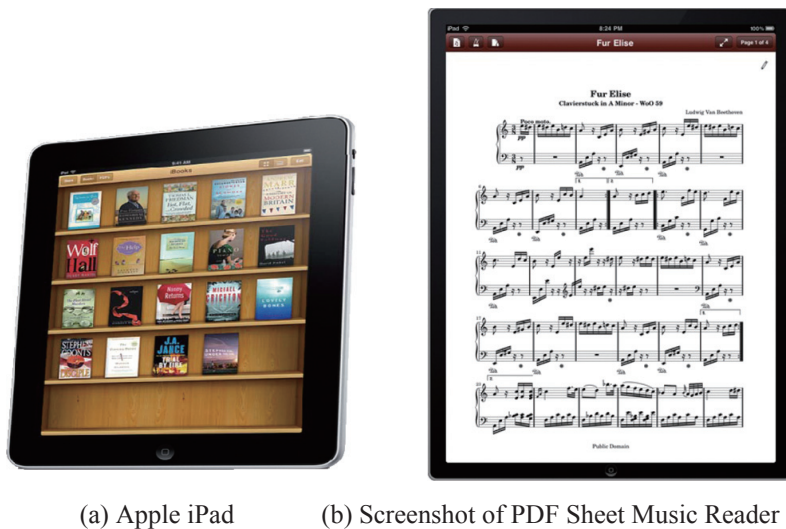
3.6. iPad

Apple's recent iPad product is an elegant and compact tablet computer that has enjoyed explosive growth (Fig. 14(a)). It has been marketed as a revolutionary device to navigate information, web browsing, watching videos, and reading books and documents. Although the 9.7 inch screen might be considered diminutive for displaying sheet music, the sharpness and brightness of the backlit screen make it easy on the eyes, particularly in moderately lit indoor environments.

Several apps available on the Apple App Store offer sheet music support for the iPad. These apps fall into four main categories: (1) apps that read (and recognize) your music, (2) apps that read all files, (3) apps that allow paid downloading from a single source, and (4) apps that display music included with the app. Here is a breakdown of some of the apps that fall in each category.

3.6.1. Apps that read your music

MusicReader for the iPad is free, but the user must have the MusicReader Solo Basic (\$59) or MusicReader Solo Pro (\$99) installed on their computer. Although a tablet PC is the preferred platform, the software cannot be installed directly on an iPad. Instead, the MusicReader app for the iPad lets you transfer and view the music from the computer onto the iPad. It is a comprehensive music reading app that recognizes measures and displays on the iPad in either full or half page (landscape) modes. All kinds of image files are supported



(a) Apple iPad (b) Screenshot of PDF Sheet Music Reader app.

Fig. 14. (a) Apple iPad; (b) Screenshot of PDF Sheet Music Reader app.

by the program, not just PDFs. Annotation and playlist support is included as well.

3.6.2. Apps that read all files

Digital sheet music available as PDF files can be stored and displayed using any number of PDF readers available on the iPad, including iBooks, the iPad's native ebook reader.

The PDF Sheet Music Reader and ForScore iPad apps, both priced at \$4.99, are music-centered apps that read PDF files. They enable the musician to create PDFs of their music and transfer the pieces via iTunes to the iPad. While they don't attempt to recognize the music, they do offer a metronome, the ability to create playlists and annotate music. A sample screenshot of the PDF Sheet Music Reader app is shown in Fig. 14(b).

GoodReader, available for \$4.99, is a highly popular general-purpose reader that handles PDF, TXT, and all Microsoft Office and iWorks formats. The app supports annotation and offers the user a robust viewer and cataloger of PDF files.

UnrealBook (\$4.99) is an app that features many of the reading capabilities of apps like GoodReader, but adds the in-app capability to bookmark with the same ease as iTunes library playback controls.

3.6.3. Apps that allow paid downloading from a single source

MusicNotes Sheet Music Reader is a free app that only syncs proprietary files downloaded from Musicnotes.com. It offers annotation, a metronome, and

bookmarking. The app is limited to only reading music purchased from Musicnotes.

Muzibook Publishing provides one musical piece per download at \$3.99 each. There are currently only a few dozen classical pieces available now, although the library is likely to grow substantially.

3.6.4. Apps that display music included with the app

eScore (\$2.99) is an iPad app that includes original edition sheet music titles in the public domain. It features live updates with new sheet music titles and Wikipedia pages for composers and their works. It currently includes over 500 masterpieces and favorite music pieces. The content is accessible even when the iPad is not connected to the WiFi or 3G network. Thousands of recently accessed music score pages are locally stored (cached) for faster access and offline operation. Updates with new music titles are automatically delivered when the iPad is connected online. The sheet music pages are downloaded only upon first access to them to save network usage and memory space. Through live updates, new music score updates are seamlessly delivered to the iPad without the need for an app update or upgrade.

iReal Book (\$7.99) includes 900 standard charts with the app. While the app does not include lyrics, it does show changes, with the ability to alter the chords shown, and to change the key of the piece. The app promises one-page charts for all songs, so the player can keep his hands on the keyboard.

In order to accommodate hands-free reading, an app must accept keyboard commands such as Page-



Fig. 15. (a) PageFlip Cicada Bluetooth Pedal (\$79); (b) Airturn BT-105 Bluetooth transmitter and two ATFS-1 foot pedals (\$125).

Up/PageDown or arrow keys to navigate through the musical score. Most apps currently do not operate in this manner. Instead, they rely on the user to swipe the screen to turn pages. This requires the user to take their hands off their instruments, which interrupts their playing. The only apps that currently accept keyboard commands are ForScore, UnrealBook, Deepdish Gigbook, MusicReader, MusicPodium, OnSong, NextPage, and Planning Center Online. The selection of such keyboard-compatible apps is likely to surge with the widespread proliferation of USB or Bluetooth Pedals for hands-free reading.

3.7. Bluetooth pedals: PageFlip Cicada and Airturn BT-105

Virtually all of the apps expect the musician to swipe or tap the screen to turn pages. While this avoids clumsy handling of physical sheets, it still requires a musician to take their hands off their instruments to tap or touch the screen. PageFlip recognizes this problem and has introduced a \$79 wireless Bluetooth dual-pedal footswitch that syncs with the iPad and any other computer. The PageFlip product, known as the PageFlip Cicada, is shown in Fig. 15(a). It allows the user to tap the right pedal to advance to the next page, or tap the left pedal to go backwards. Any number of such pedals can be paired to their respective computer in the same room with standard Bluetooth pairing. This prevents one pedal from activating another musician's display.

It is important to note that the two pedals in a dual-pedal configuration serve the same function as the left/right or up/down arrow keys, or the Page-Up/PageDown keys on a computer keyboard. The software that displays the digital sheet music can interpret these commands to advance through the music. If the music was scanned from a printed book, then it is likely to be saved as a PDF file or in a popular image format such as JPG, TIFF, or PNG. PDF files can be viewed using Adobe Acrobat while the image files

can be displayed using any native image viewer on the computer system. These different viewers use different keys to trigger page turning. In order to accommodate a wide variety of viewing programs, a switch on the PageFlip pedal allows the user to select among the most popular choices: PageUp/PageDown, left/right arrows, up/down arrows, and even left/right mouse clicks. The pedal is hardware- and software-neutral. If the Bluetooth pedal is to be used with a computer that is not equipped with Bluetooth, simply plug the Bluetooth dongle (included) into the computer's USB port to begin using the Bluetooth pedal. This will add wireless hands-free support for sheet music page turning on all computers, including keyboard-compatible apps on the Apple iPad.

Airturn has also introduced a Bluetooth transmitter device (Fig. 15(b)). However, like its USB counterpart, the transmitter is not embedded in a pedal. Instead, the musician must connect an external pedal to the transmitter, thereby adding to its cost. The \$125 configuration shown in Fig. 15(b) shows its typical use: two external pedals must be attached to the Airturn BT-105 Bluetooth transmitter. The PageFlip Cicada Bluetooth pedal is an all-in-one device: the Bluetooth transmitter is embedded in the pedal, which allows the user to connect an external pedal of their choice (if desired). Furthermore, the PageFlip Cicada comes included with a dongle that plugs into the USB port of a computer to serve as the Bluetooth receiver in a computer that is not already equipped with Bluetooth. Therefore, it is the lowest-cost wireless solution that works with any notebook and tablet computer, whether or not it is equipped with Bluetooth.

3.8. Conclusion

There are many ways to acquire digital sheet music: (1) scan or download sheet music and save it as a PDF file, (2) enter, convert, edit or mark score with software designed for easy viewing and turning (e.g., Mu-

Table 2
Advantages and disadvantages of page turning solutions

Products	Advantages	Disadvantages
Fully-automatic	Directly accessible to conventional books. Turns any number of pages per session.	Susceptible to turning multiple pages at once. Most expensive option.
Semi-automatic	Directly accessible to conventional books. Fast/accurate turning of preprocessed pages. Lower cost than fully-automatic page turner.	Requires preprocessing: page preloading or attachments. Limited to turning preprocessed pages.
Digital	Error-free and instantaneous page turning. Cheap pedal can trigger page-turn cycle. Facilitates portable digital library. Free classic works available online.	Not directly accessible to conventional books. Requires book scanning or digital content. Requires laptop PC for storage and display.

sicReader), (3) compose with notation software such as Encore, Finale, Sibelius, or Mozart and save into a PDF file, (4) or simply copy-and-paste from one file into MS Word or Powerpoint. Once these files are in the computer they can be displayed using standard programs such as Adobe Reader or MS Office, depending on the file format.

The chief advantages of using digital sheet music are portability, accuracy, speed, and silent page turning features. Despite these advantages, several challenges with this approach remain, as outlined in Table 2. First, the user must purchase an expensive laptop or tablet computer to exploit the storage and display of digital sheet music in a portable system. This may not be a major limitation as the requisite hardware is already available in many modern households and prices are steadily declining. In the early days of digital page turning, vendors such as FreeHand sold dedicated hardware bundled with their software for composing and viewing sheet music in electronic form. The tepid response to this offering reflected musicians' reluctance to commit to a proprietary document standard and to expensive single-purpose hardware. In contrast, by tapping into widely accepted document standards (e.g., PDF) that are viewable on general-purpose laptops, no additional commitment to hardware or software is necessary beyond that which is already widely available to mainstream users. Furthermore, leveraging widely used standards taps into economies of scale that makes adoption available at lower cost.

Another challenge of digital page turning is that users must acclimate themselves to the annotation capabilities of their favorite display software to write notes upon the digital score. Many people find it easier to annotate paper than digital content, which assumes that a tablet PC is available with a stylus. Leading vendors offering full-featured tablet PCs running Windows include Lenovo, HP, Toshiba, Fujitsu, Motion Computing, and Dell. Although tablet PCs are more expensive than their non-tablet counterparts, their integration of

stylus-based writing tools make them an indispensable resource for content creation and display.

The Apple iPad runs a limited iOS operating system that does not provide full-featured stylus support as found on Windows. While the iPad offers intuitive multitouch and swipe support, handwriting must be performed with a finger rather than a stylus. This mode of handwriting remains unnatural and imprecise to many people, compared to what fuller-featured tablet PCs offer. Windows Journal, for instance, provides the best writing experience on any tablet computer. Although the iPad does not include a stylus, accessory makers have already stepped in to fill the gap by offering stylus accessories that work with the iPad screen that requires capacitive input. Overall, the high growth rate of Apple iPads, advanced stylus-based tablets, and conventional laptops are decidedly indicative of the long-term trend towards the adoption of digital document libraries and their powerful impact on musicians at all levels.

One additional concern shared among some musicians is the risk in relying on digital content in the event of a computer crash or loss of battery/AC power. This would make the digital music unavailable during a performance. In practice, computer crashes are highly unlikely in the middle of a reading session, and power failure can be mitigated by connecting to AC power or carefully monitoring battery usage.

The collection of drawbacks associated with digital page turning is very modest compared to their potential advantages. In general, the effort to transfer sheet music to the computer is a worthwhile investment of time and money given the convenience it offers. Laptops, netbooks, and tablet computers are growing more affordable and accessible over time. Furthermore, users are increasingly satisfied with the reliability of computers to support straightforward display applications. This satisfaction is reflected in the explosive growth of low-cost laptops, netbooks, and tablet computers (including the iPad). This augurs well for the rapid adoption of the digital solution to automatic page turning.

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