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Designing for Special Needs

"A universal design for a computational input device."

James A. Wronecki, Donivan Potter
East Tennessee State University, Johnson City

The industrial design of traditional computational input devices such as keyboards and mice on the consumer market today often do not lend themselves to the needs of individuals with physical limitations. To help such individuals the coauthors, a graduate art student and an industrial design professor set out to design a new input device.

To appropriately constrain the design a case study was chosen based on the needs of a computer artist with a physical disability. To help the artist the device needed to eliminate physical barriers caused by the keyboard and mouse and ideally would provide a more natural method of creating digital art such as digital drawings, models, and animations.

The new design integrates digital pen and mouse technologies with a new industrial design to provide the artist with natural pen and mouse based input interactions. The form of the device conveys the pen metaphor while an additional sculpted surface positioned near the pen tip affords a natural thumb rest while providing a place to house two input buttons. The new pen mouse shape informs the user as to how it should be held. When grasped like a pen with the thumb at a natural resting position the user can accurately perform multiple input tasks with the pen tip and nominal left and right thumb movements.

The design enables the user to hold the input device in a more comfortable position and thus reduces repetitive strain injury, stress, discomfort, and fatigue. The design enables the user to remain productive for longer periods without adding further physical injury. The device enables our case subject to work and to contribute to society and because of its universal design is considered to be a viable input device for many types of computer users.

To design an input device for both special needs and universality a specialized universal design process was adopted. This design methodology, outlined in this paper, sought to integrate specific constraining ergonomic factors, a new broad based industrial form, and adaptable digital pen technologies to optimize the device's functionality.

The factors, form, and function inherent in the device are discussed in detail below.

The Factors

To meet the specialized needs of our subject's physical limitations the coauthors began their universal design process by addressing several specific ergonomic constraint factors. These factors such as limited movement of the case subject's wrists, digits, and thumbs suggested that we begin our design process by first accessing the usability of existing consumer input devices.

Our assessment of input devices was based on the case subject's limited wrist movement /rotation and the deformation /inflexibility of the thumbs and digits. The subject's zero degree back wrist movement disqualified rigid forms with raised surfaces as they strain wrist tendons which further constricts the digits and cause more pain. A limited fifteen degree wrist movement further tightens our subject's physically taunt wrist tendons and in turn eliminated devices requiring wrist action such as the traditional mouse and large trackballs. A full range of movement in the forefingers warrants their use for almost all tasks by our case subject. However, repeated bending and straightening of the forefinger by our case subject causes excessive joint wear, tendon tightness, and runs the increased risk of the knuckle slipping off the joint. Since the case subject tends to use the forefinger for common left, middle, and right mouse input functions and keyboard shortcuts these symptoms are intensified by use of the traditional mouse and keyboard. Even minor repetitious actions such as bending and straightening of the forefinger while scrolling with the middle wheel mouse button tend to cause joint pain and stiffness in our case subject's digits.

Long term mouse use by our case subject with the primary forefinger has resulted in physical deformation to the forefinger and other digits for a variety of factors. The elevated surface shape of the mouse, the position of the input buttons, and width forces the case subject to stretch and strain the wrist and digits into an unnatural and painful posture. The now depressed an unnatural resting state of the subject's middle finger combined with limit downward only movement causes the middle finger to interfere with any surface. In a normal mouse posture the subject's middle finger presses down on both the middle and right mouse buttons. To avoid unintended inputs and elevated surface strain by and of the middle finger the case subject contorts the middle finger and the other digits into an unnatural work position. A bent and inflexible ring finger caused by short leaders tightens wrist tendons and limits motion of the pinky finger. With limited computer input use the pinky finger is used as a stabilizer when drawing traditionally with a pen. Finally, a ten percent loss in the range of movement in the case subject's thumbs limits thumb reach and grasping motions required when using some input devices such as mini-trackballs and gyroscopes.

Through continued research and analysis of commercial computational input devices such as the mini-trackball, gyroscope, touchpad, keyboard, and spaceball the author's were unable to find a viable commercial product solution. We found that product adaptability and marketability were often at odds as these devices were either too limited or too general in their usability approach. By going back to the artistic heritage of our case subject however, we found that a pen based input device could provide a natural, comfortable way for our case subject to input digital information in a traditional artistic manner. Further research into pen based stylus's led us to investigate a digital pen and tablet solution offered by Wacom Inc.

We found the Wacom pen tablet product offering to be the technological solution to our mapped out idea. However, the position of the input buttons on the Wacom pen were found to be unusable by our case subject and were considered to be cumbersome to use by the pen/tablet users we polled. At this point we realized the need to design a new pen mouse form which would both meet our specialized ergonomic constraint factors while utilizing the existing technological functionality provided by the Wacom pen and tablet. To support the use of the digital pen mouse by other digital artists who found the pen to be cumbersome to use the author's decided to parallel our specialized needs design approach with a universal industrial design process.

The Form

The Wacom pen is a nicely stylized comfortable pen with small input buttons located above the natural pen gripping position of the forefinger. The position of the buttons on the Wacom pen suggests that they are to be are to be pressed by the user's forefinger. Because normal grasping of a pen requires the use of the thumb, fore, and middle finger our test users found it difficult to release one's grasp of the pen in order to depress the mouse buttons located higher up on the pen. We found that the existing Wacom pen design forces the user to loosen and often loose one's grip on the pen in order to satisfactorily depress and utilize the buttons. The difficulty and uncertainty of buttons use led our test users to reach for and use the buttons with their thumbs.

We found that both approaches caused fumbling with the pen, clicking errors, stress, and straining of the wrist, thumb, and digits. These field observations led the authors to conclude that a more stable pen grip, effective button position, and form use affordance formally designed into pens shape could provide a more viable and effective pen mouse alternative input device.

To prevent the stated long term risk factors to the case subject's forefinger and to provide a more stable grip to all users we decided it best to use the thumb for input button functions. To further grip stability a thumb rest affordance was integrated into the pens shape. Input buttons were placed near this visually identifiable thumb rest to enable users to press input buttons with a small amount of left and right thumb movement. These thumb input functions require less strain, fatigue, and provide greater long term usability for our case subject and are thought to provide universal access to other digital pen users. Finally, the right handedness and more severe limitations of our case subject's left hand warranted the design of the device for right hand use. However, a left hand version of the pen can be created by mirroring the form along the Z axis of the pen body to create a left handed shape.

In addition to the specialized and universal ergonomic design constraint factors mentioned thus far the pen's form was also limited by engineering constraints. The size and shape of the Wacom pen's internal electronic components, the carbon fiber input buttons selected to be used, and the limitations set by the tolerances of Universities rapid prototyping machines were all additional factors which influenced the final form.

Operating within the design parameters defined above the form of the device was derived through a process which started with small thumbnail sketches and refined to a few concept design sketches. A soft model was sculpted by the artist and case subject to form fit to the hand. The soft model was then constructed digitally by creating a polygon surface model with 3-D

program. This model was then interpreted and designed for manufacture. A 3D solid digital model was constructed and exported to meet the technological and physical constraints of University's stereolithography machine. With an ABS plastic 3D model printout in hand a working prototype was constructed in cooperation with the Manufacturing Technology and Electrical Engineering leaders in our Universities Technology Department.

The Function

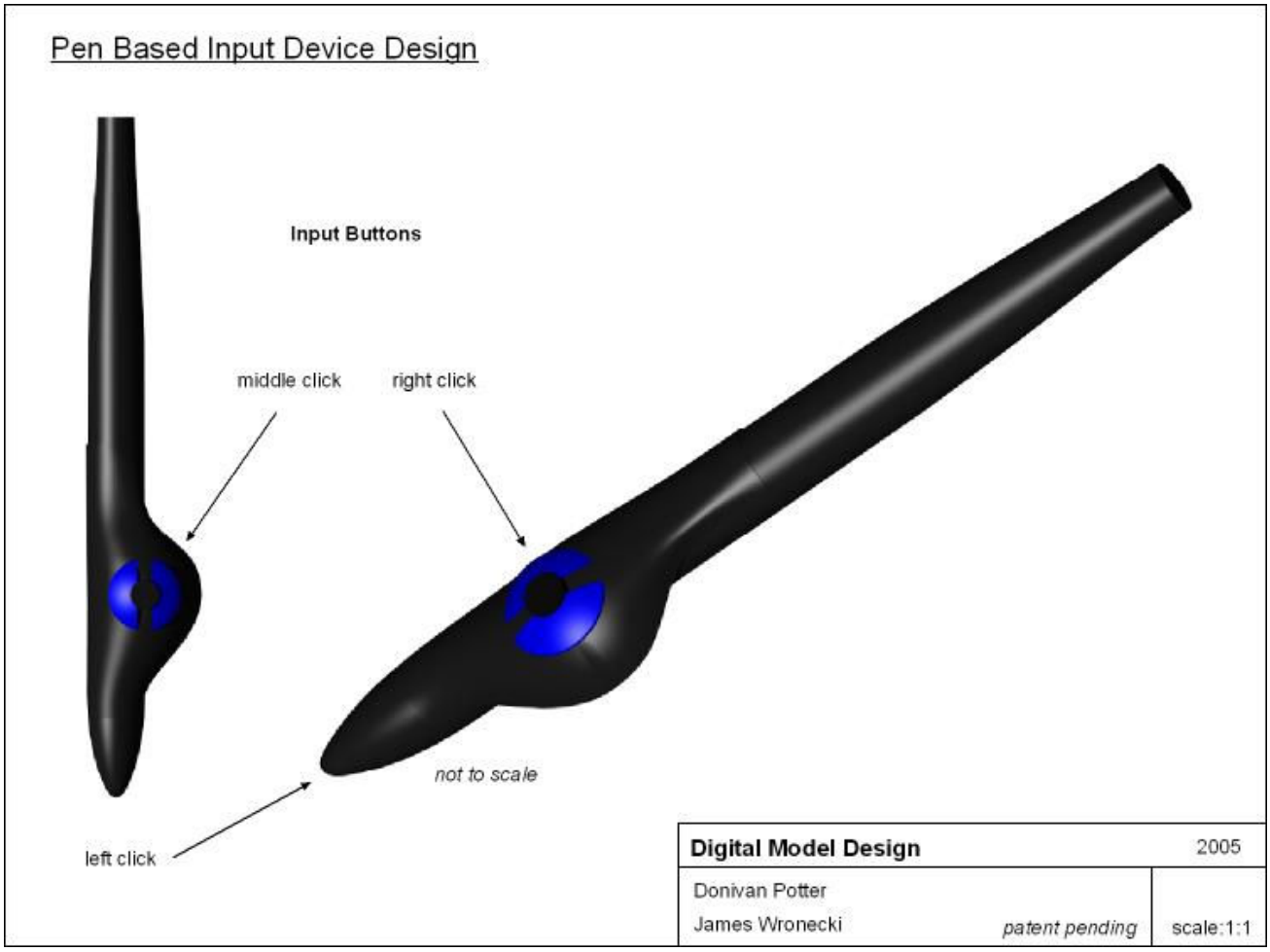
While the factors and form were important to the success of the device the functional ability of the device to support the specific needs of the 3-D artist was considered critical. These specific needs included the need for three input buttons to allow navigation, interaction, and modeling in a 3D environment. Interacting in a 3D digital environment requires the user to pan, zoom, and rotate objects in a virtual environment. When using the pen mouse input device the user can firmly press the pen tip on the tablet to invoke left mouse clicks, select objects and to *zoom in* the software's virtual camera. Two buttons positioned to the left and right of the thumb affordance on the device provide middle and right button clicks and invoke rotate and pan software functions correspondingly. Here it is important to note that a Wacom pen software control panel allows users to program the pen's input buttons to whatever mouse button functions or keyboard functions they need. This is important as the left, middle, and right buttons can control pan, zoom, or rotate functions depending on the preferences of the software package. By supporting the user's ability to program buttons and mouse clicks standardized 3D controls can be realized to allow the user to perform cross platform 3D modeling and animation modeling without an additional device.

To test the device two prototypes were developed which differed in the scale of the thumb affordance and distance between the two input buttons housed within it. The first prototype requires a small thumb size and a very small thumb movement to operate the buttons. The second prototype fits a larger thumb yet requires a greater range of movement by the users thumb. Since our case study subject has a larger thumb size and a limited range movement we decided on a third in-between size. We believe that this final refined form satisfies the specific specialized ergonomic needs of our case subject while affording a more universal design with the potential to be a better pen based input device for the greater population.

Conclusion

In designing the device it became apparent that a computational input device should adapt to our case subject's specialized needs. We found that by investigating our subject's difficulties we also realized our own issues in using the multiple input devices that we use every day. We think that humans tend to adapt to the devices in their lives rather than mandating that their devices adapt to best fit their needs. It also became clear that it is possible to design for specific specialized needs while also meeting universal design needs. The pen mouse presented in this paper is thought eliminate the ergonomic constraint factors which plagued our case subject. The new pen mouse form is thought to be aesthetically pleasing, comfortable, and accurate to use. The adaptable programmability of the underlying Wacom technology utilized is also thought to provide viable alternative to artists with a variety of specialized physical and software needs. We

recommend the device to artists with specialized needs and suggest that this new industrial design can provide a more useful alternative to the current Wacom pen design and it's user base.



James A. Wronecki is a designer/educator with diverse experience in academics and digital design medias. He received his Masters of Industrial Design from The University of the Arts in Philadelphia, PA and served as an Adjunct Professor at The University of the Arts, Philadelphia University, and The Art Institute of Atlanta. Mr. Wronecki is an Assistant Professor of Digital Product Design within the Technology Department and Digital Media Program at East Tennessee State University.

Donivan Potter is an artist, designer, and graduate student within the Technology Department at East Tennessee State University. He received his Bachelor of Science from East Tennessee State University and Associates of Science in Visual communications from the Art Institute of Fort Lauderdale Florida. He has served as an adjunct professor teaching Design Illustration courses at East Tennessee State University. Mr. Potter is the case subject and is currently using the proposed input device as an active digital modeler and animator.