Telemedicine Imaging: Designing the TotalExam® Camera

GlobalMed

In 2006, GlobalMed set out with the goal to create a handheld real-time camera that was designed specifically for telemedicine and teleconsulting. The TotalExam® camera was released just two years later and was the first handheld camera in the world designed specifically for telemedicine. Today it is used around the world providing clinicians and medical professionals a state-of-the-art telemedicine imaging solution. However, the journey to deploy this technology to the telemedicine market came with many challenges.

The initial objectives of the TotalExam camera were simple - it had to fit comfortably in the hand of the user, regardless if they were left or right-handed, ease of use was critical within the teleconsulting session, and from a technical perspective it required an easy connection to existing CODEC video conferencing systems the standard for early platforms for telemedicine.

Ergonomics

Determining the proper shape of the camera was key to the design. It needed to feel natural in the hand of clinician, allow them to easily capture exam images, be durable, reliable, and house the latest in imaging software and circuitry. The original mock-up design designated "Capricorn," was hand carved out of balsa wood (Fig 1) in the summer of 2006 and trialed with medical personnel to determine the optimal size, shape, and weight for a medical video consult.

Figure 1. The "Capricorn" protype was carved out of balsa wood to help optimize the camera shape.

Image Capture

The second challenge was capturing quality images utilizing the existing video systems. The first TotalExam (Fig 2) concept had a compressed USB2 digital output and used an WXGA (1280x800) sensor running at 30 frames per second (fps). It had no freeze-frame feature, nor did it have any kind of proper color filtering or enhancement for picture quality.

The quality of the image was well received, but unfortunately, it could not connect directly to a video conferencing hardware CODEC because of the lack of an USB2 input. The request was for a camera with an analog "S-Video" output in place of USB2 and one that

Figure 2. The TotalExam Camera

had a real freeze frame button.

With this feedback, a new Micron sensor was mated up to a newly designed "Iceman" circuit that froze the interlaced image in the same manner as a professional video camera. The camera allowed users to connect directly to their video hardware and display both the patients full image as well as a close-up image during an exam. The results were very encouraging, and the customer no longer needed to snap pictures and send them to the receiving side before starting a video teleconsult.

After about a year of prototyping and gaining valuable usability feedback from doctors, nurses, government employees and telemedicine consultants, the TotalExam2 camera was released to the medical community in early 2009 (Fig 3).

Figure 3. The TotalExam2 Camera

The Next Challenge

Fast-forward to 2012. With thousands of TotalExam2 analog cameras delivered to clinicians and medical professionals, new feedback from the customer centered around the need for a camera with higher quality, higher resolution, and the ability to plug into a Windows based computer.

Desktop computers were now the computing platform

for telemedicine and monitor screens had far better resolution. With this in mind, several technical layers

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needed to be peeled away in developing the next generation TotalExam3 digital camera engine (Fig 4).

• The video imagery is live, which means the live video should be uncompressed for the very best clarity.

• The camera engine needed to take freeze frame image "stills" of the uncompromised video being viewed.

• Since the camera is handheld, the engine needed to deal with handshake and thus process an anti-shake algorithm as well as update the video at 60 frames-per-second (fps) instead of the standard 30fps.

• The engine needed to color-process each frame – individually and separately.

• Because of handshake, the engine needed to remember frames both in positive and negative time intervals and be able to select the best frame during freezing.

To meet these new challenges, several design changes were addressed in the TotalExam3:

• A redesigned freeze-frame circuit and a much large memory buffer would enable collecting concise images from real time video.

• To provide high performance processing capability, the team needed to find an imaging sensor and a co-processor that complemented each other.

• The most current technologies for light sensitivity and best-in-class sensor design had to be sought out to ensure the highest quality images for the telemedicine practitioner.

• The pixel size needed to be increased for far better dynamic range, better light sensitivity, and bit-depth resolution.

Figure 4. The TotalExam3 Camera Kit

Dynamic Range and Reduced Noise

Key components to advanced image quality are reduced video noise and increased dynamic range. To meet these requirements, the TotalExam3 engine would use a new sensor technology called BSI or Back-Side-Illumination, (Fig 5).
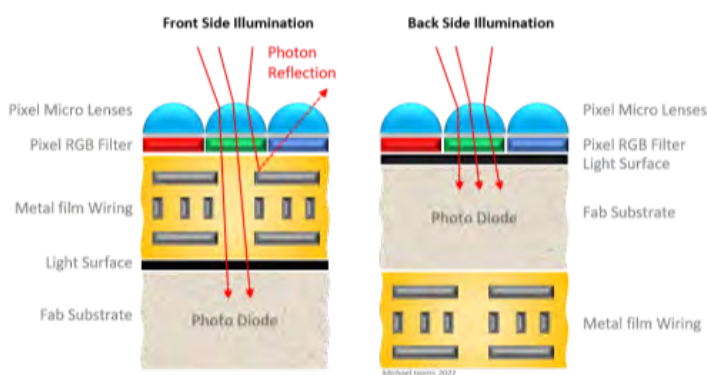

Figure 5. Sensor structure differences between front and back-side Illumination designs.

The BSI technique was invented by Sony and applied into their first professional cameras back in 2009. The clarity and contrast of images achieved with BSI technology is easily demonstrated in Figure 6. This same level of clarity and detail extends to telemedicine exam images ranging from views of the tympanic membrane to the examination of skin lesions.

Before implementing BSI, Sony used only CCD's or charged-coupled-devices. Both sensors have similar technologies but have notable differences which the GlobalMed team needed to consider. Outputs from CCD sensors must be converted from analog to digital whereas the CMOS sensor performed all digital processing directly on the silicon. Therefore,

choosing to use CMOS eliminated the digital-to-analog process resulting in reduced noise and an enhanced dynamic range within the live image.

Figure 6. Two images showing the difference in dynamic range and the resulting image quality between a sensor using traditional front illumination (top) and one using BSI Technology (bottom).

Image Quality versus Pixel Quantity

Having a sensor with more pixels is not better when it comes to image processing and clarity during a HD video call. Capturing more photons of light is the best means to increase dynamic range and gain bit-depth resolution. This idea is illustrated in Figure 7 where both sensors are the same resolution, however the sensor on the left is comprised of a sensor with larger pixels, resulting in a greater surface area to capture light, which provides for an image with superior clarity and finer details.

GlobalMed performed an extensive research on

a range of sensor / co-processor combinations which resulted in the selection of a 1/3" sensor with 3.752um square pixels in a 720p, 1280x720 complement.

Unlike the sensor in the TotalExam2, which had interlaced scanning similar to a television, the team made a final consideration to utilize a progressive scan, which does not rely on interlacing the video fields together. The co-processor takes advantage of the 12-bit parallel bus and performs all color processing. This combination paired together gives the TotalExam3 a 115dB of dynamic range - vastly higher than the original TotalExam2 at 48dB and

most other telemedicine cameras being offered in the market.

The Need for Affordability

As telemedicine expanded, the ability to provide a more affordable imaging solution for remote care use cases surfaced and the TotalExam Lite was born (Fig 8). The TotalExam Lite was targeted to be lightweight and affordable without sacrificing image quality or limiting the features that clinicians had come to expect from the TotalExam3.

Several key elements were built into the TotalExam Lite.

- A greater field of view in the otoscope for the clinician
- Superior imaging, using the same sensor utilized in the TotalExam3
- Advanced manufacturing techniques and the use of a drop proof poly carbonite blend construction
- Optimized color and contrast for better clarity during teleconsults
- Advanced auto-focus algorithm for faster focus
- Intelligent "IceMan" freeze-frame capture for sharper Images
- Patented USB safety lock, ergonomic grip and easy to clean surfaces

The result was a telemedicine general exam camera and otoscope with superior performance and features at a cost that makes it a more sensible option for a wide range of telehealth applications.

Figure 8. TotalExam Lite

Resolution and Image Quality

Fundamental to capturing a highly detailed image is the collection of photons. A common mistake is thinking that a higher resolution sensor provides more pixels and therefore a higher quality image.

Consider the two image sensors shown below. Both sensors are the same resolution (64 pixels). However, the sensor on the left has a larger pixel size resulting in a total surface area of 14.6 microns while the sensor on the right has a smaller pixel size resulting in a surface area of only 4.8 microns.

That is a difference of almost 3 times the area! More surface area means more accumulated photons, which results in more information and better dynamic range.

So, although both sensors have the same resolution, the one with the larger pixel size is far superior in collecting photons and producing a higher quality image.
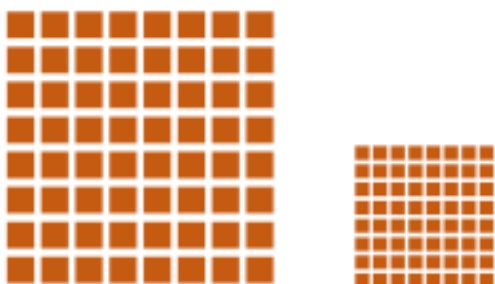

Figure 7. Pixel size verses resolution

Looking Ahead

Medical personnel and professionals continue to demand high image quality and precision freeze-frame capability across the varied range of telehealth environments. At GlobalMed, we recognize these needs and design the technology to create solutions to address them. As sensor technology continues to push the limits of physics with higher pixel counts, thinner materials and substrates, submicron etching and maintaining pixel shape and size, GlobalMed will continue to place these improvements into the hands of telemedicine clinicians throughout the world.

Meet the Author
Michael Harris

Michael Harris is the Chief Innovation Officer with nearly 20 years at GlobalMed.

For over 35 years, Mr. Harris has been dedicated to the craft of innovative product design and philosophies. He influences software application GUI and future medical device designs and ideation at GlobalMed and has an extensive background in camera design and teleconferencing UX/UI philosophies. With several product development and manufacturing companies under his belt, he offers an astute depth to product design and fabrication. He has been a keynote speaker at many telemedical and software development summits around the world and has several patents within the medical device arena. Mr. Harris completed the Electronics Engineering program at NCTI and went on to study Music Theory, Mathematics and finally Industrial Engineering at the University of Wisconsin and CCU. He has a bachelor's in Industrial Engineering Sciences.

About GlobalMed

GlobalMed powers the world's largest, most advanced virtual health platform that supports a patient at any point in the continuum of care. Providers are enabled with integrative software and data-capturing tools to deliver a complete and accurate patient encounter for evidence-based treatment and improved patient outcomes. Providers looking to manage capacity, reduce costs, and deliver responsible medicine, will get all they need from one platform.

With over 40 million consults delivered in nearly 60 countries and specializing in both federal and commercial spaces, GlobalMed's virtual health platform deploys in its highly secure Azure environment and is used worldwide from the VA, DoD, and White House Medical Unit to rural hospitals and villages in Africa. Founded in 2002 by a Marine Corps Reserve Veteran still serving as CEO, GlobalMed is proud to be a Veteran-Owned Small Business (VOSB). Learn more at www.globalmed.com.

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