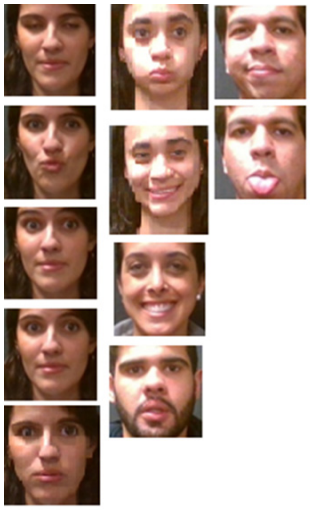
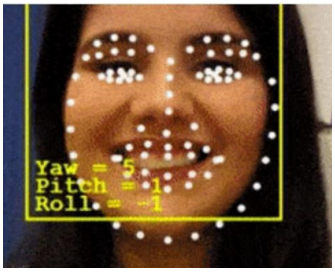
SOLUTION BRIEF

Healthcare
Artificial Intelligence

Computer Vision Solutions from HOOBOX Enable Independent Mobility for Quadriplegics



Facial expressions recognized by Wheelie.



Imaging and inferencing facial expressions.

Intel® AI technologies Enable Facial Expression Detection for Wheelchair Control

Facial recognition technology has been around for many years. Active use of facial *expression* detection, however, is just gaining traction. Facial expressions—both conscious, such as a smile, and unconscious, such as a quick smirk or frown—contain a lot of information when interpreted accurately.

Engineers and developers at HOOBOX are using hardware and software technologies from the Intel® artificial intelligence portfolio to optimize their algorithms that detect and interpret facial expressions, giving tetraplegic (quadriplegic) individuals new autonomy to control their wheelchairs with just a glance.

The Wheelie

According to the World Health Organization, 250,000 to 500,000 people around the world suffer spinal cord injuries (SCI) each year,[1] severely limiting their mobility. A 2018 study at the Hôpital du Sacré-Coeur de Montréal in Canada reveals that factors of physical mobility have the largest effect on an SCI patient's quality of life—especially those that are tetraplegic.[2] Mobility for SCI patients is often enabled through a motorized wheelchair with complex body sensors that require special learning to operate.

The Intel-based HOOBOX solution removes the complexity of mobility for SCI patients, restoring independent mobility, autonomy, and self-esteem. The Wheelie uses natural movements people have done all their lives. With an Intel® RealSense™ camera and specialized AI algorithms, the Wheelie detects 11 different facial expressions, such as a kiss, smile, frown, or surprise, and translates them into motorized wheelchair controls.

Patients' facial expressions are captured with a camera and interpreted by algorithms run on a small Intel® NUC Mini PC mounted on the chair. The interpretation is done in real time, and it is fast enough to execute a responsive motion change for both a comfortable experience and user safety.

The solution, available in a kit called Wheelie 7, takes only seven minutes to install in any motorized wheelchair available on the market.

"Together, Intel AI technologies and the Intel AI Builders program transform prototype algorithms into production-ready optimized solutions that solve large-scale, real-world problems. This is a game-changing opportunity for AI startups and the AI community at large."

- Hoobox CEO Paulo Pinheiro.

The **Intel® AI Builders program** is an ecosystem of industry-leading independent software vendors (ISVs), system integrators (SIs), original equipment manufacturers (OEMs), and enterprise end users who have a shared mission to accelerate the adoption of artificial intelligence across Intel® platforms. Members gain valuable access to technical enablement resources, co-marketing opportunities and are candidates for match-making and Intel Capital investment to help drive adoption of AI solutions in the enterprise.

More than Mobility

Autonomy and self-esteem: the Wheelie allows people with movement-limiting conditions to get their autonomy back.

11 FACIAL EXPRESSIONS

Choose five of 11 available facial expressions to control the motorized wheelchair.

KIT WHEELIE 7

The Kit Wheelie 7 comes with all you need to control a wheelchair with facial expressions.

7-MINUTE SETUP

The kit only takes seven minutes to install on any motorized wheelchair.

NO BODY SENSORS

No body sensors are involved; the kit is non-invasive.

NO TRAINING

The Wheelie is fully compatible with your facial expressions with no training required.

IMMEDIATE RESPONSE

The Wheelie features real-time facial analysis with high precision.

AI Acceleration with OpenVINO™ Toolkit

Early machine learning development for facial expression recognition at HOOBOX used multiple binary Support Vector Machine (SVM) classifiers, which achieved excellent results. But the company always seeks to improve the performance for its solutions. Computer vision and neural network optimization solutions have shown impressive achievements in recent years. Thus, development migrated from a classical machine learning approach to one based on computer vision and neural networks deployed using the OpenVINO™ toolkit.

Product Scalability for Enabling Regular (2D) Cameras

HOOBOX began their work with machine learning inference using computer vision techniques and 3D cameras using **Intel® RealSense™ technology**. These cameras offer rich information with depth tracking that can be used in detailed image analytics. The technology originally appeared in their Wheelie control system.

While the solution with 3D cameras was effective, HOOBOX wanted to broaden the potential market by enabling it to work with regular 2D cameras. To achieve the same 99.9% accuracy rate (with near-real-time frames per second) as the 3D camera, HOOBOX needed more sophisticated algorithms. Recent advances in deep learning would enable such solutions but would require significant optimization to match real-time performance.

Over 18.3X[3] Speedup with OpenVINO™ Computer Vision Optimizations

OpenVINO toolkit, short for Open Visual Inference and Neural network Optimization toolkit, provides developers with improved neural network performance on a variety of Intel® processors and helps them further unlock cost-effective, real-time vision applications. The toolkit enables deep learning inference and easy execution across multiple Intel® platforms, providing implementations that can span from the cloud down to edge devices. This open source distribution provides flexibility and availability to the developer community to innovate deep learning

and AI solutions. With the help of Intel, HOOBOX developers employed the OpenVINO toolkit to accelerate inferencing of their facial recognition software.

The first assessment done within OpenVINO toolkit and HOOBOX's solution was based on InceptionV3* topology. Intel engineers helped HOOBOX integrate OpenVINO toolkit within their solution and achieved a 7.12X improvement (figure 1) in inference time, running on the integrated Intel Graphics Processing Unit (iGPU) of an Intel® NUC7i7BNH.[4]

Next, the Hoobox team tried MobileNet* which provided higher accuracy. Implementing OpenVINO toolkit with the CPU improved inference performance by 18.33X (figure 2), as MobileNet has layers that run faster on a CPU. Integrating this within the rest of their solution, HOOBOX was able to achieve real-time performance and accuracy greater than 92% which was required for the solution to be commercially successful.

Future Applications

Human facial expressions change as a person experiences different states of health. It has long been known that these expressions are valuable to clinicians and other caregivers.[5] Even when unconscious or with other cognitive impairment, facial expressions can indicate important information about a patient.[6]

HOOBOX has developed a prototype device using facial recognition algorithms for detecting behaviors, such as drowsiness, ten levels of pain, agitation and sedation levels, and spasms. The technology can even detect when a person will sneeze before sneezing.

Inferencing Performance Optimized w/ OpenVINO™ Toolkit
OpenVINO vs. Baseline - Intel® NUC7i7BNH (Higher is better)

Topology: **InceptionV3** Data type: **FP32**

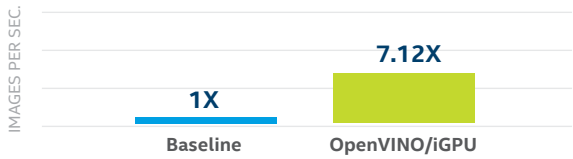


Figure 1. *Optimizations with OpenVINO™ toolkit results on a NUC7i7BNH using FP32 data type.*[3]

Topology: **MobileNet** Data type: **FP32**

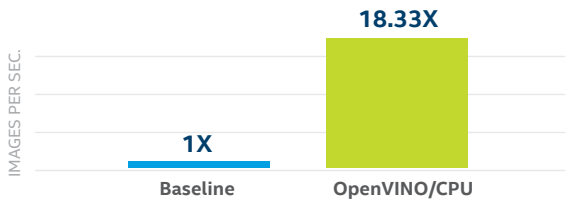


Figure 2. *Optimizations with OpenVINO™ toolkit results on a NUC7i7BNH using FP32 data type.*[3]

Such a solution could be installed in hospitals to alert caregivers on patient conditions and similar use cases.

The prototype design was developed and tested on an Intel® Xeon® Platinum 8153 processor.[7] With OpenVINO toolkit, performance achieved 25.85X (figure 3) acceleration using multi-inferences, up to 16 processes at the same time on a single node. The same optimization was repeated using the MobileNet topology where the gains were even better, reaching a speed-up of 95.64X (figure 4) using multi-inferences.

Inferencing Performance Optimized w/ OpenVINO™ Toolkit
Multi-Inference Performance - Intel® Xeon® Platinum 8153 Processor (Higher is better)

Topology: **InceptionV3** Data type: **FP32**
Multi-inference using 16 processes

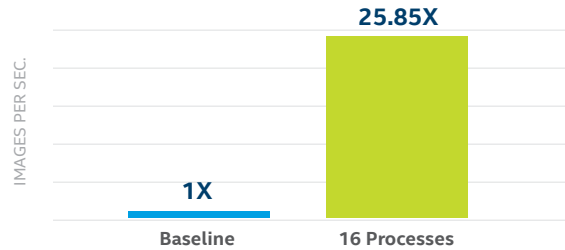


Figure 3. *Optimizations with OpenVINO™ toolkit results on a Intel® Xeon® Platinum 8153 processor using FP32 data type and multi-inference.*

Topology: **MobileNet** Data type: **FP32**
Multi-inference using 16 processes

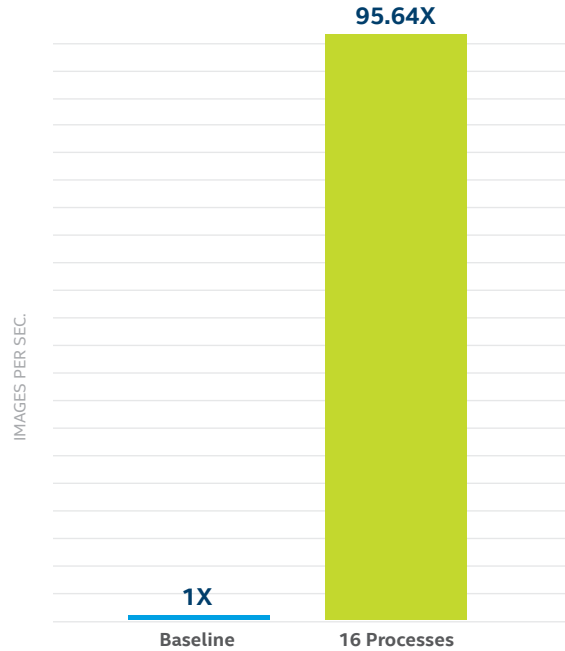


Figure 4. *Optimizations with OpenVINO™ toolkit results on a Intel® Xeon® Platinum 8153 processor using FP32 data type.*

Baseline OpenVINO™ v2018.3.343

Summary

Using advanced Intel-based computer vision technology, HOOBOX creates systems for monitoring people and detecting their behaviors in the health, transportation, security, and retail sectors. HOOBOX innovation with human facial expression detection is offering new possibilities for patients and healthcare workers, wherever identifying behavior—and not just identity—is needed. HOOBOX's solutions are aimed at taking advantage of a person's best abilities to counteract limitations, not only improving mobility and autonomy, but also enhancing self-esteem.

Hoobox CEO Paulo Pinheiro is part of the Intel® Software Innovator program, a global developer community focused on discovering and supporting innovative developers in a variety of technical fields. The Innovator program has supported Paulo since 2015 with Intel® hardware and opportunities to demonstrate and present early innovation such as the Wheelie, integrated with Intel® RealSense™ Technology.

Learn More

For more information about HOOBOX solutions, visit **http://www.hoo-box.com/index.html**

For more information about the Wheelie, visit **http://www.hoo-box.com/index.html#thewheelie**

For more information about Intel Computer Vision technologies, visit **https://software.intel.com/en-us/openvino-toolkit**

ai.intel.com

[1] http://www.who.int/news-room/fact-sheets/detail/spinal-cord-injury

[2] Goulet, Julien, et al. American Journal of Physical Medicine & Rehabilitation: August 28, 2018 (https://spinalnewsinternational.com/quality-life-mobility/)

[3] CPU: Kaby Lake, Sockets: 1S, Processor: i7-7567U, 4 Cores, Total Memory: 32Gb, OS: Ubuntu 16.04, Kernel: Linux 4.15.0-29-generic, Complier: gcc5.4, TensorFlow Version: TensorFlow V1.10, https://github.com/tensorflow/tensorflow, revision 656e7a2b347c3c6eb76a6c130ed4b1def567b6c1, OpenVINO Version: 2018.3.343

[4] CPU: Kaby Lake, Sockets: 1S, Processor: i7-7567U, 4 Cores, Total Memory: 32Gb, OS: Ubuntu 16.04, Kernel: Linux 4.15.0-29-generic, Complier: gcc5.4, TensorFlow Version: TensorFlow V1.10, https://github.com/tensorflow/tensorflow, revision 656e7a2b347c3c6eb76a6c130ed4b1def567b6c1, OpenVINO Version: 2018.3.343

[5] Craig, Kenneth D. APS Journal 1(3): 153-162, 1992 (https://www.jpain.org/article/1058-9139(92)90001-S/pdf)

[6] Snow AL and JL Shuster Jr. Assessment and treatment of persistent pain in persons with cognitive and communicative impairment; Journal of Clinical Psychology, Nov. 2006, 62(11): 1379-1387

[7] CPU: Skylake, Sockets: 2S, Processor: 8153, 64 cores,TDP:125W, Total Memory: 376Gb, OS: CentOS7, Kernel: Linux 3.10-693.el7.x86_64, Complier: gcc5.4, Framework Version: TensorFlow V1.10 https://github.com/tensorflow/tensorflow, revision 656e7a2b347c3c6eb76a6c130ed4b1def567b6c1, OpenVINO Version: 2018.3.343

For data for training and inference, HOOBOX has acquired proprietary datasets with a wide variety of facial expressions from a wide cross section of users from diverse backgrounds. All performance results shown in Figures 1, 2, 3, and 4 are based on these proprietary datasets.

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