Albert 2 Technology Overview

Albert 2 combines cutting edge Computer Vision, Machine Learning, Natural Language Processing, and Cloud Analytics to deliver a state-of-the-art, easy-to-use foot scanner

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Abstract

Albert 2 is a fully-integrated foot scanning system engineered to help customers find the right fitting footwear and orthotics and provide an enhanced customer experience at retail. The quick, easy-to-use, two-feet-at-once scanning process takes 20 seconds or less, and can capture both static and dynamic pressure, as well as 360˚ 3D measurements of the foot. The accurate, complete foot data is then used to help customers find the best fitting footwear or orthotics on the first try, based on their unique foot profile. The life-like, 3D animated Albert character guides users through the scanning process, while also responding to voice commands, creating a one-of-a-kind, interactive customer experience. The customer's unique foot scan data can then be sent via email, allowing users to access their information after they leave the store. This white paper provides a detailed overview of the technology behind Albert 2.

At Aetrex, we believe finding the right fit for one's feet starts with an accurate understanding of the three-dimensional profile of the feet. This requires a 360˚ capture of each foot, including the underside, accurate measurement of the foot length, width, instep, arch height, girth, and arch type among other parameters, and an industrial grade Cloud-based platform (Fig. 1 Albert 2 Architecture) to convert the data into business intelligence for retailers and consumers. Depending on the device configuration, the Albert 2 scanner can perform a comprehensive pressure scan, a 3D depth scan and obtain accurate foot measurements in under 20 seconds. The Aetrex Cloud Platform uses Machine Learning to turn these accurate foot measurements into intelligent recommendations for orthotics and footwear. The AI-Powered Albert Voice Assistant provides conversational style answers to questions that a customer might have regarding their feet, the recommended orthotics products, or any other topic in the area of foot science and health. After the scan, customers leave with a personalized Foot Passport on their mobile device that they can access securely at any time. This personalized email summarizes their unique scan report and includes orthotics and footwear recommendations based on their foot profile. The Foot Passport can be connected to the retailer's eCommerce platform allowing the retailer to stay connected with their customers, presenting long-term revenue opportunities. Aetrex's Web API provides a restful, secure interface to the Aetrex Cloud that the retailer CRM systems can connect to and retrieve data from. This allows retailers to ingest data into their systems and manage their customers with their own CRM platforms. Retailers also have access to a Cloud Analytics portal to monitor their scans, run and schedule reports, and conduct product and inventory planning for the future.

Fig 1. ***Albert 2 Architecture***

What We'll Cover in This White Paper

This white paper will provide an overview of the technology behind these key features of Albert 2:

- Patent-pending 360˚ 3D Foot Reconstruction with depth cameras and pressure sensors
- Machine Learning based Footwear Recommendations
- AI-Powered Albert Voice Assistant
- Access Anywhere Secure Mobile Foot Passport for Consumers
- Restful Web API for Retailer Omnichannel Integration
- Scalable Big Data Cloud Analytics

360˚ 3D Reconstruction of the Foot

Albert 2 features four Intel® RealSense™ depth cameras and 5,184 gold plated sensors offering it a unique ability to capture the foot, holistically. The Intel cameras are well suited for high accuracy 3D scanning applications and with a rolling shutter on the depth sensor, they offer very high depth quality per degree. Aetrex's premium pressure plate technology is designed to capture the complete underside of the foot providing data about customers' unique arch depth and pressure points. Aetrex uses a unique, patent-pending approach to surface fitting that uses partial differential equations to form a smooth and dense (non-triangulated) 3D surface from the data obtained from the cameras and the pressure sensors. A coarse initial voxelized estimate of the foot in the form of a solid volume made up of grid voxels (a 3D binary mask) is obtained using depth carving methods, by intersecting the depth hulls computed from each of the four calibrated depth cameras. The initial estimate is computed quickly but is always volumetrically under-estimated as well as non-smooth due to the inherent nature of depth carving methodologies (Fig. 2 Initial Coarse Reconstruction).

However, once this initial carved estimate is obtained it is converted into an iso-surface representation by applying a signed distance transform to the binary mask. The resulting 3D signed distance function then serves a starting scalar Level Set Function which is evolved according to geometric partial differential equations (PDE's) discretized to match the structure of the uniform 3D grid.

The PDE evolution is calculated to most efficiently decrease a surface fitting cost which penalizes the average depth mismatch between the visible surface points for each camera and the depth values acquired at these same points by the same cameras. The fitting cost also includes a smoothness criterion which penalizes noisy, bumpy, or otherwise non-smooth structure. The trade off between measured and reconstructed depth fidelity and smoothness is tuned to obtain the desired level of smoothness along different portions of the reconstructed foot. Evolution occurs until the final shape of the foot converges to the best combination of smoothness and average depth mismatch across all four cameras (Fig. 3 Fully Evolved Surface). Prior to discretization, this evolution corresponds to a gradient descent PDE flow, while its final discrete implementation takes the form of an iterative explicit Euler update of the discretized PDE using finite differences.

Pressure Image Integration

A further advantage of the iterative PDE approach (beyond direct control of smoothness already discussed above) is the ability to also directly incorporate additional information about the underside of the foot, which is not visible to any of the four depth cameras, via a pressure map image obtained by pressure sensors underneath the foot plate. By choosing the bottom of the 3D cartesian grid to correspond with the top of the foot plate, the reconstructed foot surface can be left open (in the form of a topological hole) along the higher pressure portions of the 3D grid boundary which corresponds to the place of direct contact between the plate and the foot. The 3D boundary of this surface hole can be compared with the boundary of the 2D region which appears in the measured pressure map. The mismatch between these two boundaries can then be added to the surface fitting cost, which will in turn change the behavior of the computed gradient descent PDE to now achieve not only a balance of matching average depth and surface smoothness, but of matching pressure boundary shape for the underside of the foot as well. The ability to blend all three of these factors without the appearance of artificial artifacts in the final fitted 3D surface is the key strength of the PDE approach. It also ensures a strong degree of geometric reality within the reconstructed result by directly enforcing its physical compatibility with the fused collection of personalized sensor measurements. (Fig. 4 Underside after Pressure Integration).

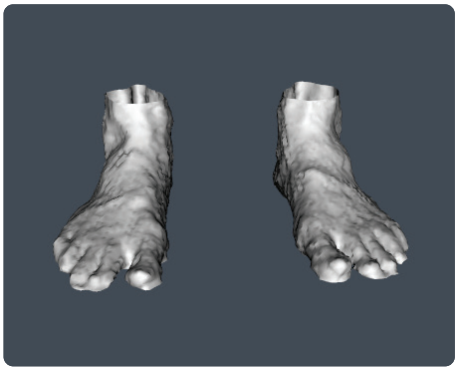

Fig 2. ***Initial Coarse Reconstruction***

Fig 3. ***Fully Evolved Surface***

Fig 4. ***Underside after Pressure Integration***

Fig. 5 ***Albert 2 Rendering of the 3D Foot***

3D Measurements

The measurements for each foot are computed from the minimum bounding box for the convex hull of the foot. Once the minimum bounding box is obtained all the Aetrex measurements are performed conforming to the recommendations provided by Aetrex to the IEEE 3D Body Processing forum [1]. The foot length, for example, is measured as the distance from the pternion (the maximum point of the heel curve) to the acropodion (the end of the most prominent toe). The reader is referred to this document for further information.

3D Printed Custom Orthotics

The 360˚ foot scan created by the technology provides a major direct benefit to retailers and consumers: the ability to custom print orthotics that match precisely to the individual's foot. This is done in partnership with EOS, the world's leading technology supplier in the field of industrial 3D printing of metals and polymers. The data received from the scanner provides 256 degrees of varying pressure which gets translated into a complex pressure map with numerical values (the higher the number, the higher the pressure). It is then transferred to the 3D printing production facility in real time where it's converted into a 3D CAD drawing incorporating various geometries that match precisely to the customer's scan and under foot data. The geometric shapes are designed and engineered to alleviate pressure or provide support to each designated area of the foot. The CAD files are sliced into numerous layers and are sent to the 3D printer where the product is created from the ground up. The benefits of Aetrex's 3D Printed Custom Orthotics make the product a win-win for consumers, retailers, and the environment alike. For consumers, the Aetrex product offsets an individual's foot pressure, alleviates pain, brings the ground up to the foot, and places the body back to its best alignment possible. Retailers benefit from a product that requires no inventory, offers high margins and no markdowns, is seasonless, and provides unmatched consumer satisfaction. The added benefit of 3D printing is the reduction of waste, and in the case of Aetrex's 3D Printed Custom Orthotics, the material is recyclable and gets incorporated back into the production process.

FitHQ - Machine Learning Based Footwear Recommendations

Background

Shoe fitting has traditionally been a challenging problem because shoes run small or large depending on the brand, style, or season. Customer preferences play a role, too and these may range from a snug fit to a roomier fit. At Aetrex, we believe proper shoe fitting needs to take all these factors into consideration. We believe shoe size (which is derived from foot length) cannot be the sole factor in determining the fit – instead a true fit solution needs to consider the holistic 3D profile of the foot and combine it with customer preference information to recommend the best fitting shoes for a customer.

Machine Learning

Aetrex's FitHQ footwear recommendations are based on a Machine Learning model that considers several different parameters of the foot – including, but not limited to the length, width, instep height, arch height, and arch type – and matches them against actual customer preferences based on verified shoe purchase and return data. This model has been in place at several retailers and is constantly learning and getting better as new customers scan and make purchases. A retailer that carries popular shoe brands will be able to bootstrap their FitHQ program instantaneously from previously trained models. A retailer that carries brands not seen by the model before can get a new model trained in a matter of weeks and get it deployed. Aetrex FitHQ can check the inventory of the store and present only the styles and sizes being carried by the store at the time of the scan, improving customer experience. Getting started with the Aetrex FitHQ program is straightforward - Aetrex has published a technical implementation document [2] that retailers can use to implement FitHQ for their shoes. A retailer's technical team can work in partnership with Aetrex's Technical Support Team to ensure a smooth FitHQ integration.

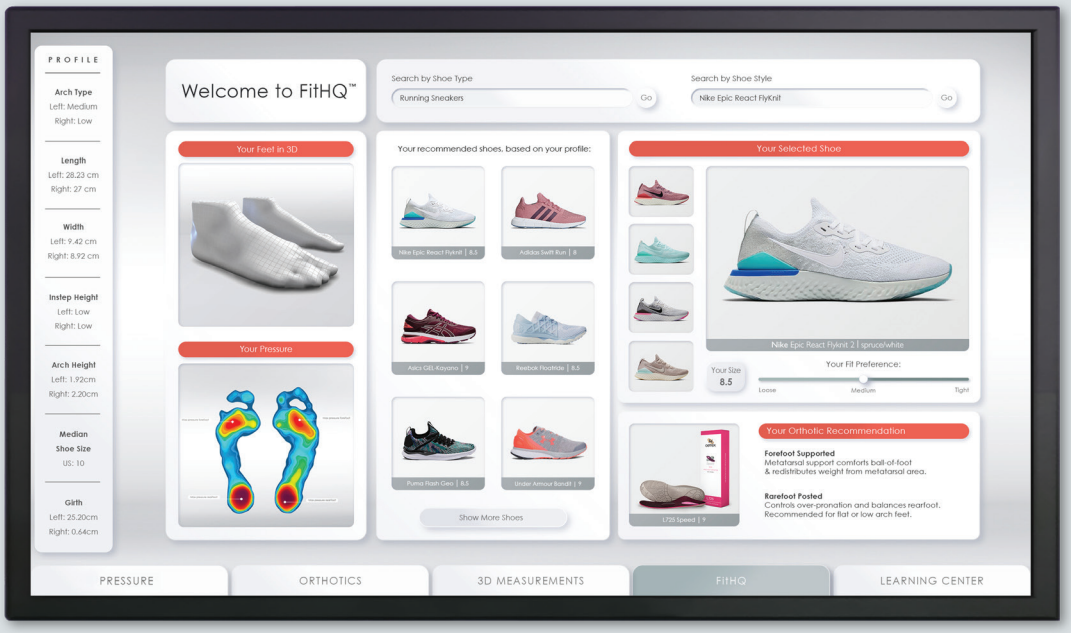

Fig.6 ***Albert 2 FitHQ***

Voice-Activated Learning Center

Albert Voice Assistant & Foot Science Vocabulary

Aetrex has partnered with Harman (a Samsung company) to create Albert Voice Assistant, an AI-Powered, Foot Science domain-specific speech recognition platform that provides Albert 2 customers with conversational style access to content regarding their foot scan and overall foot health. Customers can ask Albert about their own foot scan, e.g., "Hey Albert, what is arch type?" Or about any foot health topic, e.g., "Hey Albert, what is metatarsalgia?" Albert recognizes these questions instantaneously and provides a response in the form of a video, audio or text. These responses are hosted by the Albert Learning Center, a first-of-its-kind repository of learning content covering 500+ topics in the area of Foot Science. The spoken questions are processed by the Albert 2 client and the Aetrex Cloud platform by invoking an AI model specifically trained for Foot Science vocabulary. This model has been optimized for accents across the world and for speed of delivery.

No Touch Experience

In addition to providing a voice-based, conversational style help for customers, Albert's Voice Assistant also provides retail associates with a no-touch experience for operating the scanner. Associates can speak one of 30+ simple commands to operate the scanner without having to touch it. For example, the agent can say "Hey Albert, start scan" to start a scan or "Hey Albert, go to orthotics" to get Albert software to navigate to the orthotics page.

Fig. 6 ***Albert 2 Learning Center. Watch voice-activated video demo here***

Mobile Foot Passport

Personalized Scan Report

After completing the scan, Albert 2 customers get a personalized scan report, referred to as their Foot Passport, sent to their email or phone number. Alternatively, they can simply scan

a barcode on their mobile phone to go to their Foot Passport. Once they have opened their personalized Foot Passport, they can save it on the home screen of their mobile device with the click of a button. The Foot Passport provides a summary of the important foot readings including the pressure scan, the 360˚ 3D view of the feet, all the important measurements, and the recommended orthotics and footwear as configured by the retailer. Footwear and orthotics recommendations are pulled in real time from the Aetrex server which provides customers with the latest, in-season, available product listings.

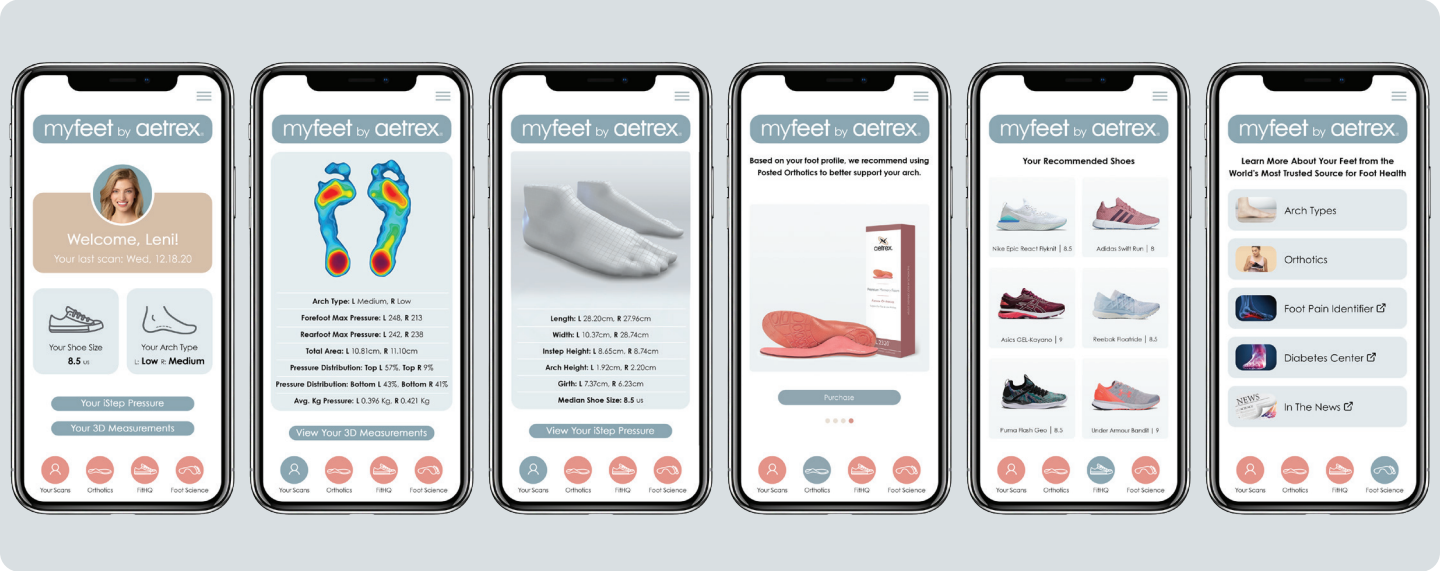

Fig.7 ***Mobile App Foot Passport***

Integration into Retailer eCommerce Website

The Foot Passport orthotics and footwear recommendations can be configured to redirect the user to the retailer eCommerce website to complete the transaction. This allows retailers to continue to sell their products to customers even after the customer leaves the store.

Restful Web API

Integration with Retailer eCRM

Aetrex exposes a secure, restful API to the scan data stored on the Aetrex Cloud on behalf of the retailer. Retailers can use this to do several things: 1) they can retrieve scan data for a specific customer, based on their email or phone number, from the Point of Sale (POS) at the time of sale, or 2) they can retrieve scans on a periodic basis - daily, or weekly or at some other frequency of their choice - to move the scans into their own CRM system. Ingesting data into their CRM systems opens several options for retailers to market to these customers. Retailers also have the option of retrieving the footwear recommendations for a customer on an as needed basis. They can do this, for example, from their eCommerce website during a customer visit for the customer to choose from.

CRM API Implementation

Albert CRM API is a simple interface for retailer CRM systems to ingest data from the Aetrex Cloud. Retailers can choose to retrieve data on a regular, periodic basis or on an as-needed basis. Retailers are referred to [3] for details regarding the API definitions. The retailer technical contact will work with the Aetrex Tech Support Team to confidentially obtain credentials that can be used to retrieve the security tokens needed for this interface.

Cloud Analytics

Secure Storage & Retrieval

All the scans performed on Aetrex Technology scanners are stored securely on the Aetrex Cloud on behalf of customers. While retailers can ingest these into their own systems or retrieve data on an as-needed basis in real time, they can also access them by logging into the Cloud Analytics portal, referred to as the Aetrex Control Panel.

Analytics

The Aetrex Control Panel can be accessed securely using login credentials received from the Aetrex Tech Support Team. Once inside the portal, retailers can generate scan reports at a store level or agent level at any desired time interval – be it daily, monthly, yearly or cumulative. They can also schedule reports to be sent to them on a regular basis or log into a specific store account and obtain individual scans. A manager responsible for a few stores, for example, might set up an account to monitor the performance of those stores. A store associate might log into a specific store, retrieve the scan of a customer that was completed in the past, and sell a pair of orthotics or shoes to that customer. Most importantly, the Aetrex Control Panel provides useful analytics to customers by summarizing their foot traffic in terms of gender and shoe size distribution that can be used for product and inventory planning.

Fig.8 ***Cloud Analytics Portal***

Conclusion

The Albert 2 scanner is a ground-breaking device that combines the best of what technology has to offer. It is supported by a Global Tech Team that includes Computer Vision and Deep Learning Engineers, Academic Research Consultants, Full Stack Developers, Hardware Engineers, Firmware Specialists, Automated Testing Specialists, and Project Managers. Teams are based in New Jersey, USA, Tel Aviv, Israel, and Bangalore, India, providing Aetrex with near 24x7 tech productivity and an ability to offer tech support to retailers seven days a week.

References:

[1] IEEE 3D Body Processing Forum, 2020
[2] Aetrex FitHQ Implementation Guide
[3] Aetrex CRM API Implementation Guide

For details regarding this document or for additional information, including the implementation guides, please refer to your Aetrex Sales Contact or the Aetrex Tech Support Team: 1-800-644-3514, or Email: istephelp@aetrex.com.