Products and applications enabled by tinyML

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Personal Computing devices use-case and applications enabled by smart sensors

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“Hybrid work is here to stay, and it’s the greatest shift in the way people work in our lifetimes”.

Enrique Lores, President & CEOHP
Reconfigurable processing unit that performs a decision tree logic

- Sensor data
- Computation block
- Signal conditioning
- Decision tree
- Finite state machine
Extreme power efficiency with smart sensors

Machine Learning Core

MLC

In-sensor classification engine based on decision tree logic

- Extremely low-power sensors
- Increased accuracy with a better context detectability
- Offloading of the main processor, improving system efficiency

Sensor hub feature, enabling connection of external standard sensors, bringing intelligence at the edge
### Computation Block - Features

**Features:** statistical parameters calculated from Input data / Filtered data

<table>
<thead>
<tr>
<th>Feature Name</th>
<th>Feature Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN</td>
<td>Computes the average of the selected input in the defined time window. <strong>Mean</strong> = ( \frac{1}{WL} \sum_{k=0}^{WL-1} I_k )</td>
</tr>
<tr>
<td>VARIANCE</td>
<td>Computes the variance of the selected input in the defined time window. <strong>Variance</strong> = ( \left( \frac{\sum_{WL} I_k^2}{WL} \right) - \left( \frac{\sum_{WL} I_k}{WL} \right)^2 )</td>
</tr>
<tr>
<td>ENERGY</td>
<td>Computes the energy of the selected input in the defined time window. <strong>Energy</strong> = ( \sum_{k=0}^{WL} \text{input}^2 )</td>
</tr>
<tr>
<td>PEAK TO PEAK</td>
<td>Computes the maximum peak to peak value of the selected input in the defined time window.</td>
</tr>
<tr>
<td>ZERO CROSSING</td>
<td>Computes the number of times the selected input crosses a selected threshold in the defined time window.</td>
</tr>
<tr>
<td>POSITIVE ZERO CROSSING</td>
<td>Computes the number of times the selected input crosses a selected threshold in the defined time window. Only transitions with positive slope are considered.</td>
</tr>
<tr>
<td>NEGATIVE ZERO CROSSING</td>
<td>Computes the number of times the selected input crosses a selected threshold in the defined time window. Only transitions with negative slopes are considered.</td>
</tr>
<tr>
<td>PEAK DETECTOR</td>
<td>Counts the number of peaks (positive and negative) of the selected input in the defined time window.</td>
</tr>
<tr>
<td>POSITIVE PEAK DETECTOR</td>
<td>Counts the number of positive peaks of the selected input in the defined time window.</td>
</tr>
<tr>
<td>NEGATIVE PEAK DETECTOR</td>
<td>Counts the number of negative peaks of the selected input in the defined time window.</td>
</tr>
<tr>
<td>MINIMUM</td>
<td>Minimal value of the selected input in the defined time window.</td>
</tr>
<tr>
<td>MAXIMUM</td>
<td>Maximum value of the selected input in the defined time window.</td>
</tr>
</tbody>
</table>
Machine Learning solutions in sensors: new developer model approach

Shorter development time and better accuracy with use of Machine Learning techniques (decision trees)

Machine Learning Core configuration

Capture data
- Accelerometer
- Gyroscope
- External sensors

Label data
- Filters
- Features

Build decision tree
- Classification
- Results

Embed decision tree
- DT implementation

Process new data
- Real time test

Operating mode

HOW

Unico-GUI

Unico - GUI
HP motion AI
HP use cases

In/Out bag detection (IOB)

The In/Out bag detection feature is designed to solve the laptop overheating problem by setting the system in hibernate when it is carried inside of a bag.

Detect laptop carried In-Bag/Out-Bag classes

- **Enter hibernate when the laptop is carried in a bag**
- **Laptop instant-on when taken out from a bag**

Detect laptop taken out from the bag event

- **Smart power state transition**
- **Avoid the laptop overheating**
- **Optimize the battery usage**
On-Table detection (OTD)

The on-table detection feature is used by the system to activate specific power policies affecting the system clocks, the fans speed and thermals based on the on-table or on-soft-surface output.

Detect laptop used on-table or on-soft-surface classes

- Enhance the user experience
- Manage thermals
- Safeguard the user’s health

Optimize system power policies
Logging IOB / OTD data from HP laptops

HP defined the IOB / OTD user experience, and provided systems having the LSM6DSOX device

ST and HP defined the list of scenarios to be collected for implementing the required user experience

ST developed a specific application to simplify the data collection phase and the labeling

More than 50 ST+HP worldwide employees helped with data collection campaign and testing!
AI model generation

ST UNICO and WEKA tools

ST UNICO tool used to compute the features value related to the dataset

WEKA tool used to find which features better characterize the IOB / OTD motion patterns, and to build the decision tree

ST UNICO tool used to generate the LSM6DSOX device configuration running the built decision trees directly into the embedded Machine Learning Core
Drivers preparation and validation

ST drivers running the IOB / OTD features

ST developed the drivers to be integrated in the HP final product, and a specific application suitable for the validation of the features

HP integrated the ST drivers and completed the validation
Excellent user experience with tiny current consumption

Only 34 µA additional current consumption to run IOB and OTD with MLC

The MCU wakes up only when a new IOB or OTD output is detected

<table>
<thead>
<tr>
<th>LSM6DSOX sensor</th>
<th>Current consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerometer and gyroscope</td>
<td>550 µA</td>
</tr>
<tr>
<td>IOB and OTD features</td>
<td><strong>34 µA</strong></td>
</tr>
<tr>
<td>Total</td>
<td><strong>584 µA</strong></td>
</tr>
</tbody>
</table>

Energy saving

Always-on features

Enhanced user experience

If implemented on the Application Processor, the computation current consumption for these features could be approximately 10 time more than above numbers.
Our technology starts with You
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