Food Intake Detection from Inertial Sensors using LSTM Networks

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Problem Description

- Unobtrusively detect food intake cycles during the course of a meal
- Use accelerometer and gyroscope data from an off-the-shelf smartwatch

Food Intake Cycles as Micro-movement Sequences

- *Micro-movement*, an eating-related and limited duration movement of the hand
- *Food intake cycle*, a series of micro-movements leading to, and after a food intake

Table 1: Micro-movements in the *Food Intake Cycle* (FIC) dataset.

Micro-movement	Description
Pick Food	Hand manipulates a fork to pick food from table
Upwards	Hand moves upwards, towards the mouth
Downwards	Hand moves downwards, away from the mouth
Mouth	Hand inserts food in mouth
No movement	Hand exhibits no movement
Other movement	Every other hand movement

- Model each food intake cycle presented in a meal as a sequence of micro-movements starting with **P**, ending with **D** and containing **M**

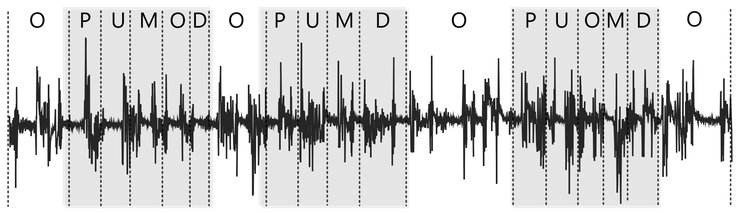

Figure 1: Segmentation of a meal session (solid line) into intake cycles (shaded area) and micro-movements (dotted line).

Proposed Approach

- Use the gyroscope stream to remove gravity from accelerometer
- Extract features $\boldsymbol{f}$ in data frames of 0.2 seconds with 0.1 second step from each of the accelerometer and gyroscope streams
- Convert $\boldsymbol{f}$ into $\boldsymbol{s}$ containing the pair-wise prediction scores of the 10 one-versus-one micro-movement SVM classifiers
- Model temporal evolution with an LSTM(128)-LSTM(128)-D(1) network
- Detect food intakes by local maxima search in $\boldsymbol{d}$

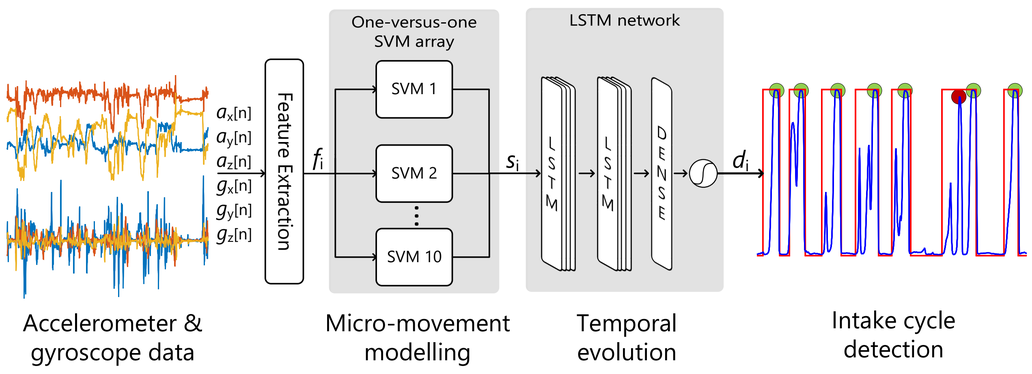

Figure 2: Overall system architecture.

Why LSTM?

- Extension of the Recurrent Neural Network (RNN), specifically designed to solve the long term dependency and vanishing gradient problems
- Output doesn't depend solely on the previous state in time (e.g. Markov Models)
  – Combines input, output and forget gates to retain information over a long period
- Model more efficiently intake sequences that differ greatly from the *ideal* intake sequence due to the insertion of non intake-related micro-movements between intake-related micro-movements (e.g. **O**ther Movement between **M**outh and **D**ownwards)

The Food Intake Cycle Dataset

- Recordings of 10 subjects performing unscripted eating activities in the restaurant of Aristotle University of Thessaloniki
- Accelerometer and gyroscope data from Microsoft Band 2 smartwatch at 62 Hz
- A Go Pro Hero 5 recorded the eating activities and generated ground truth at a micro-movement level

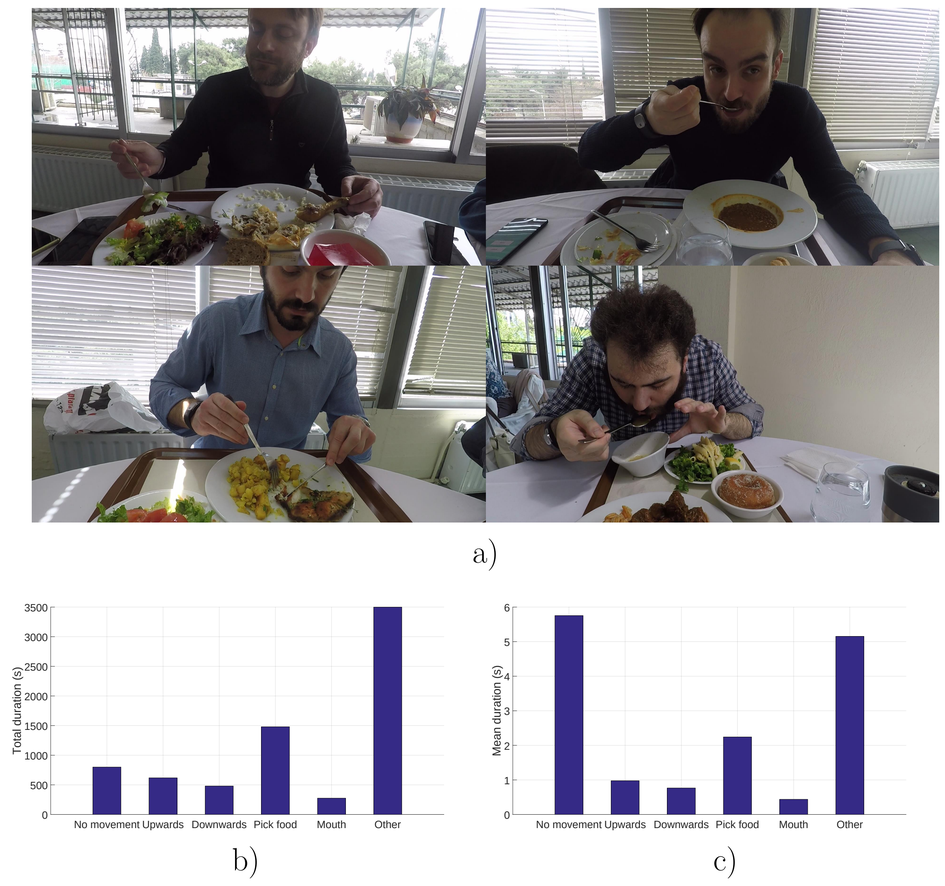

Figure 3: **a)** Screenshots from the groundtruth video stream, taken during data collection. The various eating styles and food types in the *FIC* dataset are reflected. **b)** Total duration per micro-movement in *FIC*. **c)** Mean duration of each micro-movement in *FIC*.

Method Evaluation

- Use Leave One Subject Out (LOSO) cross validation scheme
- Compare our approach against two methods [1][2] found in the literature

Table 2: Numerical results

Method	TP	FP	FN	Prec	Rec	F1
Dong *et al.*[1]	508	683	176	0.426	0.742	0.541
Kyritsis *et al.*[2]	603	193	81	0.757	0.881	0.814
Proposed approach	623.7	89	60.3	0.875	0.911	0.892

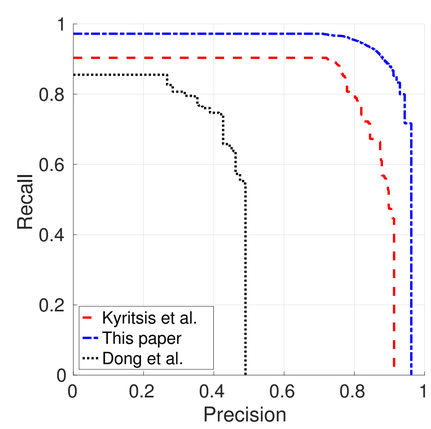

Figure 4: Precision-recall curves of the proposed approach (blue dash-dot line), the approach by [1] (black dotted line) and by [2] (red dash line).

Conclusions

- Explicit modeling of intake cycles as sequences of micro-movements outperforms direct detection approaches
- Combination of micro-movement SVMs and LSTM network for score sequence classification is highly effective

Links

The *FIC* dataset | MUG research | BigO project

[1] Dong Yujie, Hoover Adam, Scisco Jenna and Muth Eric. A new method for measuring meal intake in humans via automated wrist motion tracking. *Applied psychophysiology and biofeedback*, 2012.
[2] Kyritsis Konstantinos, Tatli Christina Lefkothea, Diou Christos and Delopoulos Anastasios. Automated Analysis of in Meal Eating Behavior using a Commercial Wristband IMU Sensor. *39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2017.