# Classification Algorithms for Saccade-related Oculomotor Plant Metrics

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**Abstract:** this report presents a description and the pseudocode for the algorithms that were designed to classify saccade-related Oculomotor Plant metrics. Presented algorithms were verified with the stimulus that was designed to evoke saccades of fixed or random amplitudes with Tobii x120 eye tracker with sampling frequency of 120Hz. These algorithms were developed in the Human Computer Interaction Laboratory at the Department of Computer Science at Texas State University-San Marcos.

## Metrics Related to Saccades with either Horizontal or Vertical Movement Component

1. **Average Saccade Amplitude/Duration Ratio**

   The relationship between saccade's amplitude and it's duration (the values related to vertical and horizontal components might be different). For example a slow saccade, saccade duration is longer than indicated by amplitude.

   Pseudo Code:

   *saccade_duration_in_seconds = current saccade (offset - onset ) in seconds*
   *saccade_amplitude/duration_ratio = current_saccade_amplitude/saccade_duration_in_seconds*

   This ratio will be calculated for all available saccades, for a particular subject and, average and standard deviation of it will be calculated as metrics.

2. **Average Saccade Latency**

   Time between the onset of the stimuli appearance and the onset of a saccade. Expectation is that for people with TBI, saccade latency will have a higher values. Normal people have this value at around 200 ms

   Pseudo Code:

   The code will go through the stimulus saccade and compare stimulus onset less than or equal to the saccade onset. If this is true then check whether the next stimulus saccade available. If next stimulus saccade available then, get the half of the time between next stimulus onset and current stimulus onset. Add this value to the current stimulus saccade onset set and see whether the onset of the saccade is between the onset of the current stimulus saccade and the stimulus saccade onset + half of (next stimulus saccade onset - current stimulus saccade onset). Select saccades satisfy all above and get the latency by saccade onset - stimulus onset in seconds. After detecting the latency of the first saccade which satisfy

these conditions under the stimuli, all the other saccades discarded by breaking the loop and move to the next set of stimuli.

```
For all stimulus saccades
    For all saccades detected
    If  (stimulus saccade onset in seconds <= current saccade onset in seconds)then
            If (current stimulus saccade is not the last on the list) then
                    If (next stimulus saccade onset >= current saccade onset) then
                            If ( (current stimulus saccade onset + (next stimulus saccade onset - current
                            stimulus saccade onset)*0.5) >= current saccade onset )     then
                                    Latency = current saccade onset - current stimulus saccade onset
                                    break;
                            End
                    End
            End
    End
 End
End
```

The Latency will be calculated for all available saccades, for a particular subject and, average and standard deviation of it will be calculated as metrics.

### 3. Average Hypermetric Amplitude (Overshoot)

The amount of the amplitude overshoots the fixation target.

Pseudo Code:

Design of this metric based on several criteria's,

- Consider only saccades counted within the latency
- Consider for positive hyper saccades and negative hyper saccades
- Assume hyper saccades are less than 30ms duration from the next corrective saccade
- Assume hyper saccades make immediate corrective saccades in the opposite direction to fixate on the stimuli target

**Positive hyper** saccades, are saccades which the offset of the saccade is greater than the onset of the saccade. First loop will go through the saccades detected within the latency values (onset of current stimulus and onset + half of the (offset of next stimulus - onset of current stimulus)). These latency saccades are considered for the hyper saccades. Another loop will go through the detected saccades and these saccades used as corrective saccades after a hyper saccade (Overshoot). For a particular corrective saccade, map the previous saccade from the saccade detected from latency. If onset of corrective saccade is greater than the latency saccade and latency saccade is in positive direction and onset of corrective saccade - onset of latency saccade is less than 30ms duration and corrective saccade in opposite direction then we have a hyper saccade (the selected latency saccade).

*For all saccades detected within the latency*

```
For all saccades detected for corrective saccades
    If (corrective saccades onset >= latency_saccades offset) then
        If (latency_saccade is in positive direction) then
            If ( (corrective saccades onset- latency_saccade offset) is greater than 30ms and
            corrective saccades is in opposite(negative) direction) then
                    hyper saccade in positive direction
            End
        End


        If (latency_saccade is in negative direction) then
            If ( (corrective saccades onset- latency_saccade offset) is greater than 30ms and
            corrective saccades is in opposite(positive) direction) then
                    hyper saccade in negative direction
            End
        End
    End
End
```

**4. Average Hypometric Amplitude (Undershoot)**

The amount of the amplitude undershoots the fixation target.

Pseudo Code:

Design of this metric based on several criteria's,

- Consider only saccades counted within the latency
- Consider for positive hypo saccades and negative hypo saccades
- Assume hypo saccades are less than 30ms duration from the next corrective saccade
- Assume hypo saccades make immediate corrective saccades in the same direction to fixate on the stimuli target

**Positive hypo** saccades, are saccades which the offset of the saccade is greater than the onset of the saccade. First loop will go through the saccades detected within the latency values (onset of current stimulus and onset + half of the (offset of next stimulus - onset of current stimulus)). These latency saccades are considered for the hypo saccades. Another loop will go through the detected saccades and these saccades used as corrective saccades after a hypo saccade (Undershoot). For a particular corrective saccade, map the previous saccade from the saccade detected from latency. If onset of corrective saccade is greater than the latency saccade and latency saccade is in positive direction and onset of corrective saccade - onset of latency saccade is less than 30ms duration and corrective saccade in same (positve direction as latency saccade) direction then we have a hypo saccade (the selected latency saccade).

```
For all saccades detected within the latency
    For all saccades detected for corrective saccades
```

```
        If (corrective saccades onset >= latency_saccades offset) then
            If (latency_saccade is in positive direction) then
                If ( (corrective saccades onset- latency_saccade offset) is greater than 30ms and
                corrective saccades is in same(positive) direction) then
                        hypo saccade in positive direction
                End
            End


            If (latency_saccade is in negative direction) then
                If ( (corrective saccades onset- latency_saccade offset) is greater than 30ms and
                corrective saccades is in same(negative) direction) then
                        hypo saccade in negative direction
                End
            End
        End
    End
End
```

5. **Number of Hypermetria to total number of stimuli Saccades ratio**
   Percentage value of the ratio: number of Hypermetria to total number of saccades.

   This metric will calculate the relationship between number of hyper saccades available to the total number of stimuli saccades in a subject file, and the % value of it.

   Metric Hypermetria will count total number of hyper saccades and with the count of total number of stimuli saccades, the metric ratio can be easily calculated.

6. **Number of Hypometria to total number of stimuli Saccades ratio**
   Same as above, except this will consider Hypo Saccades (Undershoots)

7. **Difference between the amplitude of the hyper saccade and the stimulus**

   *hypermetric_amplitude_stimuli_difference = absolute value of the (offset of the hyper saccade - onset of the stimuli saccade)*

8. **Difference between the amplitude of the hypo saccade and the stimulus**

   *hypormetric_amplitude_stimuli_difference = absolute value of the (offset of the hypo saccade - onset of the stimuli saccade)*

9. **Average Peak Velocity/ Amplitude ratio**

The relationship between Saccadic Amplitude and maximum velocity as an average value for a particular subject.

The metric will calculate peak velocity by looping from onset of a saccade to offset of it and assigning maximum velocity value for the peak velocity and using it to calculate the ratio with the current saccadic amplitude.

Pseudo Code:

```
For each saccade onset sample to offset sample
    If (peak_velocity < velocity measured for that eye record) then
        peak_velocity = velocity measured for that eye record
    End
End

peak_velocity_amplitude_ratio = peak_velocity/ amplitude degree of the saccade detected
```

**10. Average Skewness Ratio**

The ratio of the time to reach maximum velocity (the acceleration phase - peak velocity) to the total duration of the saccade. For normal subjects, skewness ratio is around 0.5 for small saccades and 0.2 for large saccades.

Pseudo Code:

```
time_increment = 0
time_to_peak_velocity = 0
saccade_duration = offset of the saccade detected - onset of the saccade detected in seconds
For each saccade onset sample to offset sample
    time_increment = time_increment + eye tracker data sampling rate
    If (peak_velocity < velocity measured for that eye record) then
        peak_velocity = velocity measured for that eye record
        time_to_peak_velocity = time_increment
    End
End

skewness_ratio = time_to_peak_velocity / saccade_duration
```

**11. Express Saccades Percentage**

Very short latency saccades that can be elicited when the novel stimulus is presented after the fixation stimulus has disappeared (gap stimulus). In another words, during gap paradigm, human subjects generate express saccades with short reaction times with latencies are as low as 100ms. Gab paradigm is in which fixation target is switched off before visual target is switched on. Express saccades are probably a laboratory phenomenon, being unlikely to occur in natural viewing conditions, in which a number of visual stimuli are simultaneously present.

We calculate the percentage value of this to the total number of saccades.

Pseudo Code:

```
% The first loop is the saccade before the express saccade, and next loop
% is for the express saccade calculation, which starts from t+1 of the
% previous saccade. This is because the express saccade is always 1 or more
% greater than the previous saccade. Both previous saccade and express
% saccade checked to verify there amplitudes are greater than 1deg. In the
% final if condition, the latency between the onset of the express saccade
% and offset of the previous saccade are check to verify whehter it is less
% than or equal to 100ms duration.
```

*for all detected saccades -1*
*if (the 1st loop saccade amplitude is greater than 1 deg) then*
*for all detected saccades starting from adding one to the previous saccades*
*if (the 2nd loop saccade amplitude is greater than 1 deg) then*
*if ( (offset of first loop saccade - onset of 2nd loop saccade) < 100ms )*
*increase express saccade counter by one;*
*End*
*End*
*End*
*End*
*End*

**12. Slow Saccades percentage**

- Slow/Fast Saccades: If the peak velocity fall outside the normal peak-velocity amplitude relationship.
- Defined by the following equation
- peak velocity = $V_{max}$ (1- $e^{-amplitude/C}$)
  Where, C is a constant for slow C=21, and $V_{max}$ =500 deg/sec for normal subjects.

We calculate the percentage value of this by slow saccades to the total number of saccades.

**13. Normal Saccades percentage**

- Slow/Fast Saccades: If the peak velocity fall outside the normal peak-velocity amplitude relationship.
- Defined by the following equation
- peak velocity = $V_{max}$ (1- $e^{-amplitude/C}$)
  Where, C is a constant for normal C=14, and $V_{max}$ =500 deg/sec for normal subjects.

We calculate the percentage value of this by normal saccades to the total number of saccades.

**14. Fast Saccades percentage**

- Slow/Fast Saccades: If the peak velocity fall outside the normal peak-velocity amplitude relationship.
- Defined by the following equation
- peak velocity = $V_{max}$ $(1- e^{-amplitude/C})$
  Where, C is a constant for fast C=8. and $V_{max}$ =500 deg/sec for normal subjects.

We calculate the percentage value of this by fast saccades to the total number of saccades.

## 15. Dynamic Overshoot percentage

At the end of a saccade, an oppositely directed, post-saccadic movement occasionally occurs and appears to be as fast as a small saccade (0.25-0.5 degree). Such small saccades have been called dynamic overshoots

We calculate the percentage value of this to the total number of saccades.

Pseudo Code:

Whenever a saccade changes its direction from the initial direction, and the amplitude of the change is between .25 - .50 deg measure, then we have a Dynamic overshoot.

implementation first check whether the saccade is bigger than 1deg of its amplitude. Then it will go through sample by sample in the saccade and get initial direction by checking the sign of the onset-offset of the saccade. Then it will check other sample points till a change of direction happens. If the first point that the change of direction happens, the program will check whether the amplitude of the onset of the change and the next sample which should be between .25 and .50deg measure. If this is true, then we found a Dynamic overshoot and break the loop to check the next consecutive saccade. If this is false then move to next sample and do the same, till the 3rd sample point in the same direction.

## 16. Average horizontal Dynamic Overshoot amplitude

From the above dynamic overshoot calculation, it is possible to obtain average of all the dynamic overshoot amplitudes available.

## Metrics Related to Saccades with Both Horizontal and Vertical Components

1. **Average saccade Amplitude**
   This will count the total amplitude of saccades and average after filtering out micro saccades and corrupted saccades.

2. **Micro saccade percentage**
   Saccades below the minimum saccadic range degree. Percentage calculated by the micro saccades to the total number of saccades detected.

3. **Corrupted Saccade percentage**
   Saccades corrupted by the eye tracker signal output. This percentage value is calculated by corrupted saccades to the total number of saccades detected.

4. **Slow Saccades percentage**

   - Slow/Fast Saccades: If the peak velocity fall outside the normal peak-velocity amplitude relationship.
   - Defined by the following equation
   - peak velocity = $V_{max}$ $(1- e^{-amplitude/C})$
     Where, C is a constant for slow C=21, and $V_{max}$ =500 deg/sec for normal subjects.

   We calculate the percentage value of this by slow saccades to the total number of saccades.

5. **Normal Saccades percentage**

   - Slow/Fast Saccades: If the peak velocity fall outside the normal peak-velocity amplitude relationship.
   - Defined by the following equation
   - peak velocity = $V_{max}$ $(1- e^{-amplitude/C})$
     Where, C is a constant for normal C=14, and $V_{max}$ =500 deg/sec for normal subjects.

   We calculate the percentage value of this by normal saccades to the total number of saccades.

6. **Fast Saccades percentage**

   - Slow/Fast Saccades: If the peak velocity fall outside the normal peak-velocity amplitude relationship.
   - Defined by the following equation
   - peak velocity = $V_{max}$ $(1- e^{-amplitude/C})$
     Where, C is a constant for fast C=8. and $V_{max}$ =500 deg/sec for normal subjects.

   We calculate the percentage value of this by fast saccades to the total number of saccades.

7. **Dynamic Overshoot Percentage 2D**
   At the end of a saccade, an oppositely directed, post-saccadic movement occasionally occurs and appears to be as fast as a small saccade (0.25-0.5 degree). Such small saccades have been called dynamic overshoots

   We calculate the percentage value of this to the total number of saccades.

   Pseudo Code:

   Whenever a saccade changes its direction from the initial direction, and the amplitude of the change is between .25 - .50 deg measure, then we have a Dynamic overshoot.

   implementation first check whether the saccade is bigger than 1deg of its amplitude. Then it will go through sample by sample in the saccade and get initial direction by checking the sign of the onset-offset of the saccade. Then it will check other sample points till a change of direction happens. If the first point that the change of direction happens, the program will check whether the amplitude of the onset of the change and the next sample which should be between .25 and .50deg measure. If this is true, then we found a Dynamic overshoot and break the loop to check the next consecutive saccade. If this is false then move to next sample and do the same, till the 3rd sample point in the same direction.

   values for horizontal and vertical dynamic overshoots are calculated separately and then get the 2D value.

8. **Average (2D) Dynamic Overshoot amplitude**
   The amplitude value of the dynamic overshoot in the 2D case.