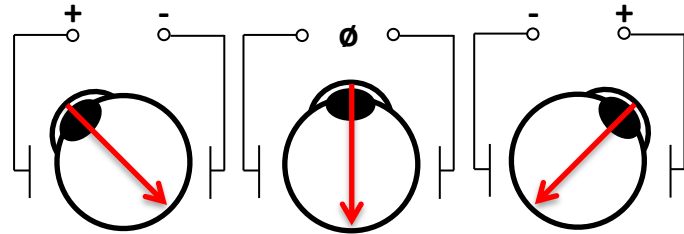
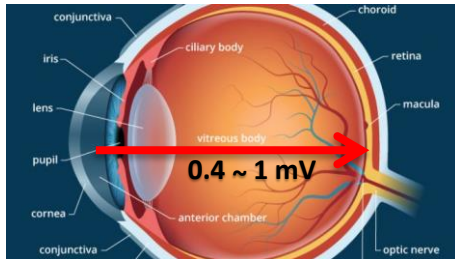


Electrooculogram

Introduction:

Electrooculogram (EOG) measure differential potential between electrodes on skin around eyes. Signal is generating by eyeball movement and varying in respect to distance of cornea to electrodes.



The voltage gradient is producing by different potentials between cornea and retina.

Fixation:

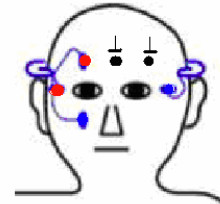
The basic ability of human eye is focusing and targeting (fixation) to the point, that is projected to macula (fovea). Eye muscles preserve image in macula also during movement. The fixation can be voluntary (refocusing to another point) or automatic during tracking.

Saccades are a quick, simultaneous movement of both eyes between two or more phases of fixation in the same direction. They are occurred during fast refocusing, searching or reading of text.

Recordings of signals:

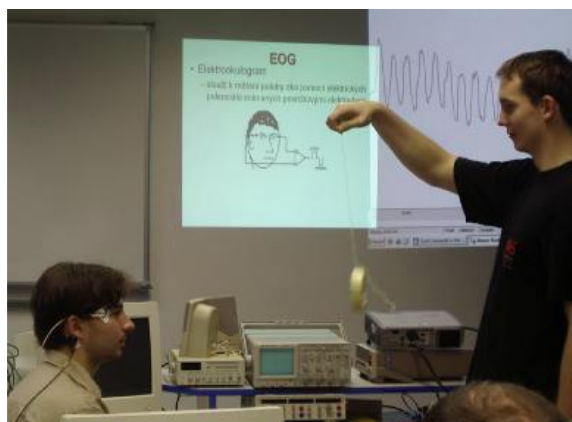
Put the two bipolar pairs of electrodes around the eyes: in horizontal line for X-axis, vertical line for Y-axis:

- + horizontal lead next right eye
- + vertical lead above right eye
- horizontal lead next left eye
- vertical lead below right eye
- ref ground electrodes on the forehead



1. Tracking of pendulum:

Tested subject is relaxed and sits approx. a meter far from pendulum. The subject tracks the pendulum without head movement. After stopping the pendulum, the subject simulates eye movement like during tracking. Eyes without fixation to moving object cannot generate continuous signal and produce saccades. Use only X-lead. **Use sampling frequency 200 Hz.**



2. Text reading:

ReadPřečtěte ukázkový text a signál horizontální roviny (X) porovnejte s textem. **Vzorkovací kmitočet je 200 Hz.**

The rainbow passage

When the sunlight strikes raindrops in the air,
they act as a prism and form a rainbow.

The rainbow is a division of white light into many beautiful colors.

These take the shape of a long round arch,
with its path high above, and its two ends apparently beyond the horizon.

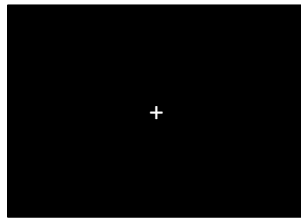
There is, according to legend, a boiling pot of gold at one end.

People look, but no one ever finds it.

*When a man looks for something beyond his reach,
his friends say he is looking for the pot of gold at the end of the rainbow.*

3. Voltage change of angular misalignment:

Track the switching marker on the projection screen. The markers variate between left and right field of vision and sequentially increase the distance. Measure maximal distance between points and distance from screen to eyes for angular misalignment calibration. Use only X-lead with **sampling frequency 10 kHz**.



Starting position



Ending position

4. 2D eye movement:

Five markers ID:1-5 are sequentially projected in scheme below. Use X and Y leads to recognition of markers sequence. **Sampling frequency is 10 kHz**.

Training sequence changes markers after a second in order:
[1, 2, 3, 4, 5, 1].

Testing sequence generates random markers.



Scheme of markers positions.

Aims:

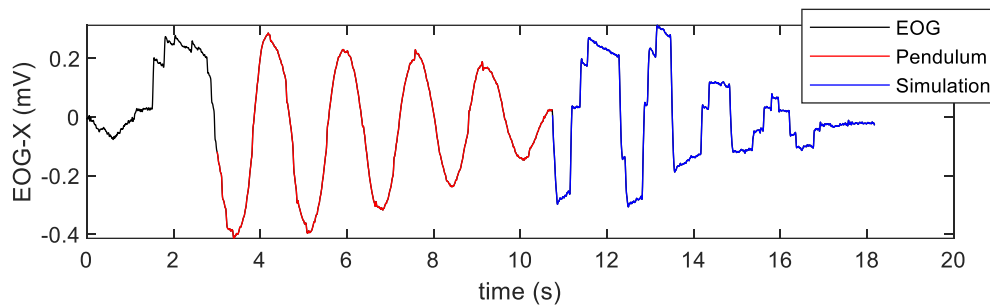
- Record the EOG signals
 - Show signal from fixed EOG to pendulum and “simulated tracking”
 - Show saccadic eye movement during text reading
- Correlate the EOG voltage with angular misalignment
- Recognize projected sequence in 2D space
 - Use k-means algorithm (k-means)

Useful functions:

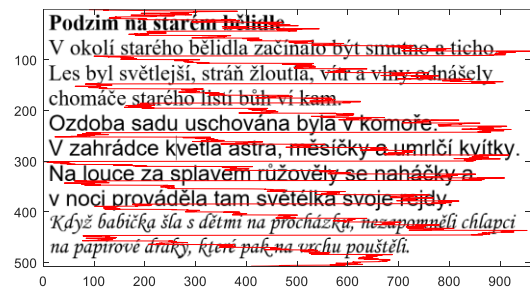
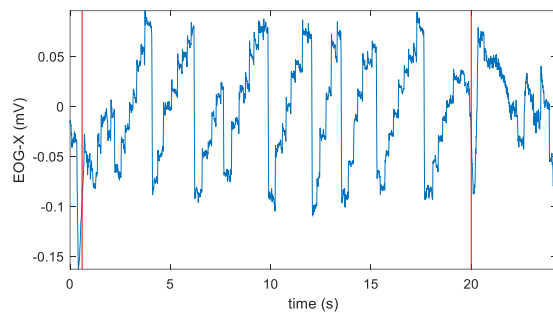
`imread; image; kmeans; atand; sort`

Help:

- 1) Load and show EOG signal. Highlight the continuous fixed part and saccade part.

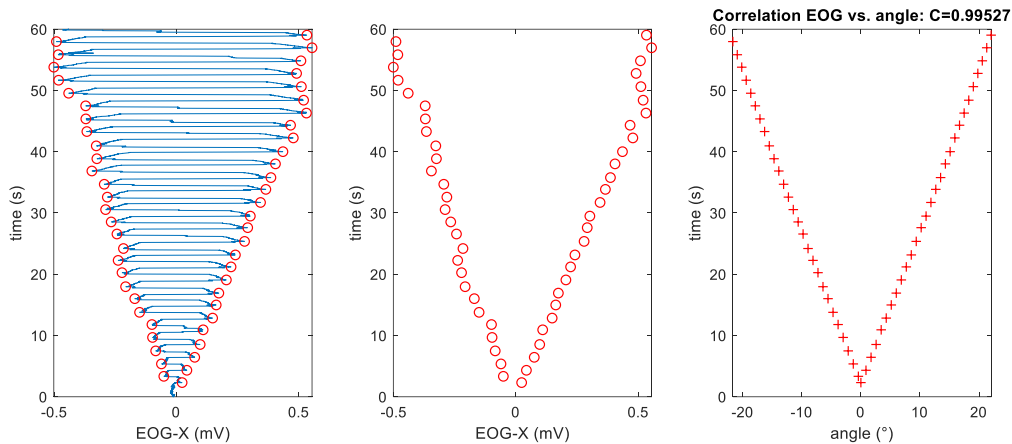


- 2) Print-screen the reading text and save it as image. Plot the EOG signal over the image. Crop inappropriate parts of signals before and after reading. Normalize EOG signal into 0-1. Generate pseudo-time axis for vertical plotting over the image. Compare line in text with EOG, focus on number of words and saccades.



```
img=imread('text.PNG');  
...  
image(img); axis image; hold on  
timg=linspace(1,size(img,1),size(eog,1)); % pseud-time axis  
% normalization 0-1  
eog=eog-min(eog);  
eog=eog/max(eog);  
eog=size(img,2)*eog;  
plot(eog,timg,'r')  
...
```

- 3) Show EOG signal during angular misalignment. Detect local extremes (min. and max.) and plot their voltage. Generate the sequence of angular misalignment and calibrate its based on the subject distance from screen and maximal distance of projected markers. Compute maximal angular velocity.



```

p=find(diff([0;eog>th])>0); % indexes of leading edges
n=find(diff([eog>th;0])<0); % indexes of downward edges
s_pos=[];
for i=1:length(p)
    ... % local maxima
end

s_neg=[];
for i=1:length(p)-1
    ... % local minima
end
s_s=sort([s_pos;s_neg]); % extreme indexes sorting
...
plot(eog(s_s),t(s_s),'ro');
...
S=... % subject distance from screen (m)
D=... % maximal distance of markers (m)
DIST=linspace(0,D/2,length(s_s)).*(-1).^(1:length(s_s)+1);
angle=atand(DIST/S);
C=corr(angle(:),eog(s_s));

PP=... % maximal peak-peak voltage of EOG
degree_mV=... % maximal field of view in degrees to peak-peak voltage ratio

degree_velocity=(max(abs(diff(eog)))*degree_mV)./(1/fs); % degrees per
seconds

```

How long require change of eye fixation from left to right field of view (140°).

4) Recognize 2D EOG (X-Y) sequence of markers. Use k-means algorithm with starting initialization of centroids by the scheme.

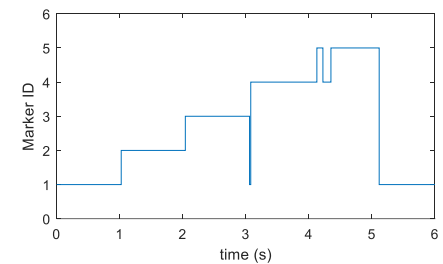
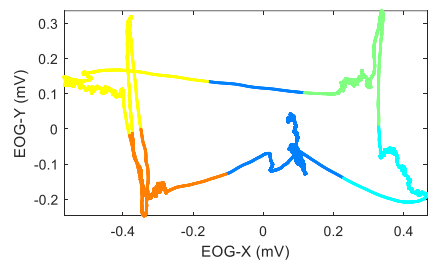
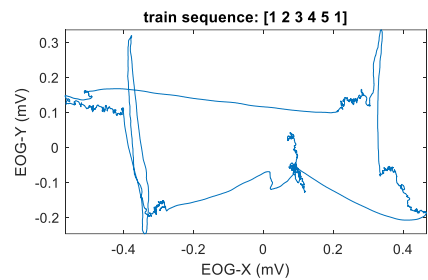
```

...
plot(eog(:,1),eog(:,2));
...
% starting centroids for markers 1-5
p1=[0 0];
p2=[max(eog(:,1)) min(eog(:,2))];
p3=[max(eog(:,1)) max(eog(:,2))];
p4=[min(eog(:,1)) max(eog(:,2))];
p5=[min(eog(:,1)) min(eog(:,2))];

% k-means
[idx,C]=kmeans(eog,5,'start',[p1;p2;p3;p4;p5]);

subplot(312)
cc=jet(5); % 5 colours of JET
for i=1:5
    plot(eog(idx==i,1),eog(idx==i,2),...
        '.','Color',cc(i,:))
    hold on
end
...
stairs(t,idx); % Classification in time

```



Recognize of testing sequence.