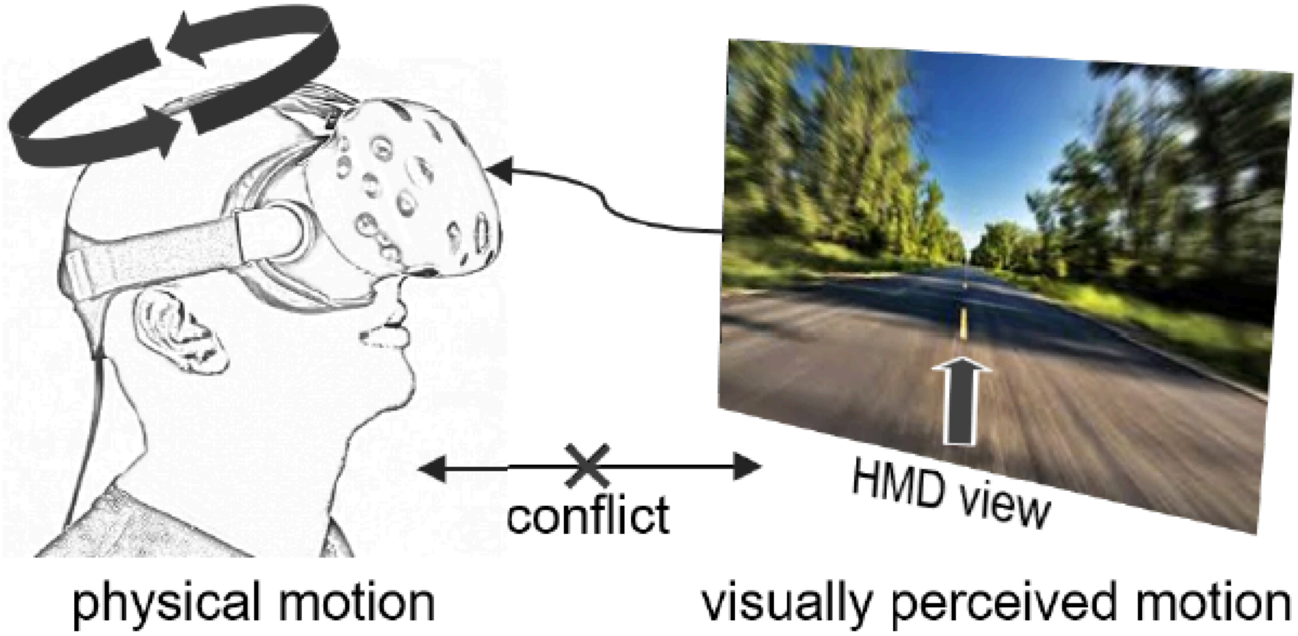
Introduction

- Possible factors causing sickness
  - Wide FoV, time latency, low frame rate and rendering speed
  - sensory conflict between the visual perception by the virtual stimuli and the vestibular perception by actual head motion



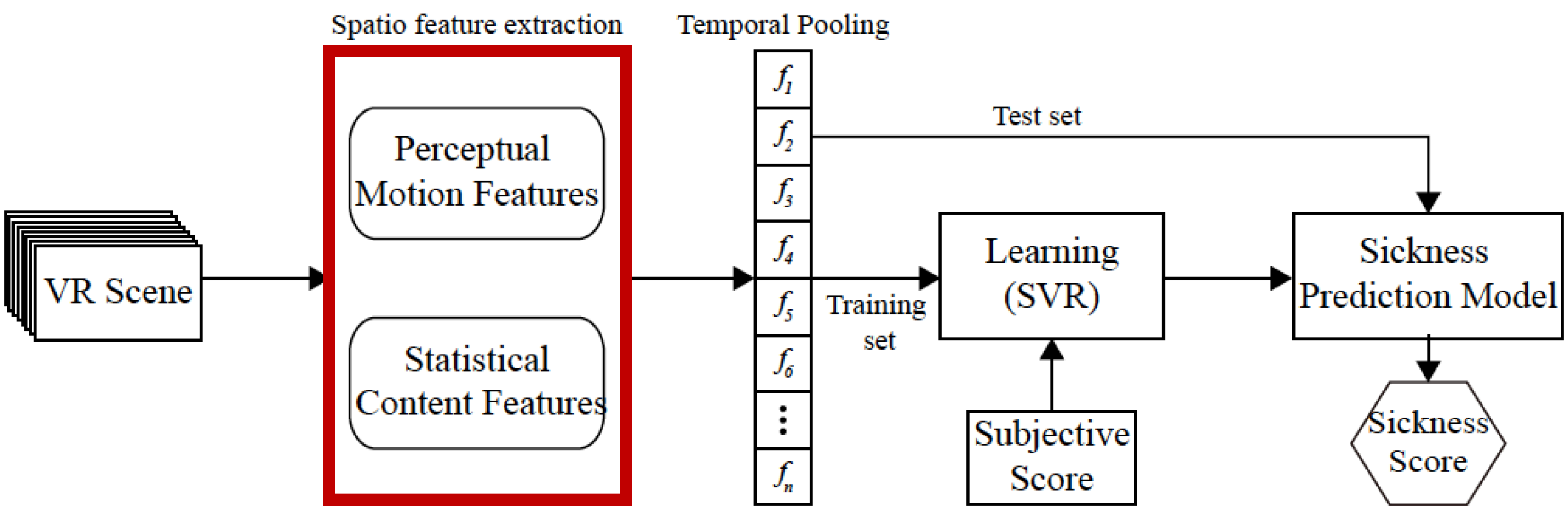
Goal

- Explore an objective VR sickness prediction framework dealing with the recent HMD based VR contents
  - Perceptual motion features: user's head rotation and virtual camera rotation in virtual space
  - Statistical content features: distribution of the spatial texture, motion of objects and background

⇒ objective VR sickness predictor (VRSP)

  - consisting of 36 contents with 10 scenarios
  - 80 subjects

VR Visual Sickness Predictor

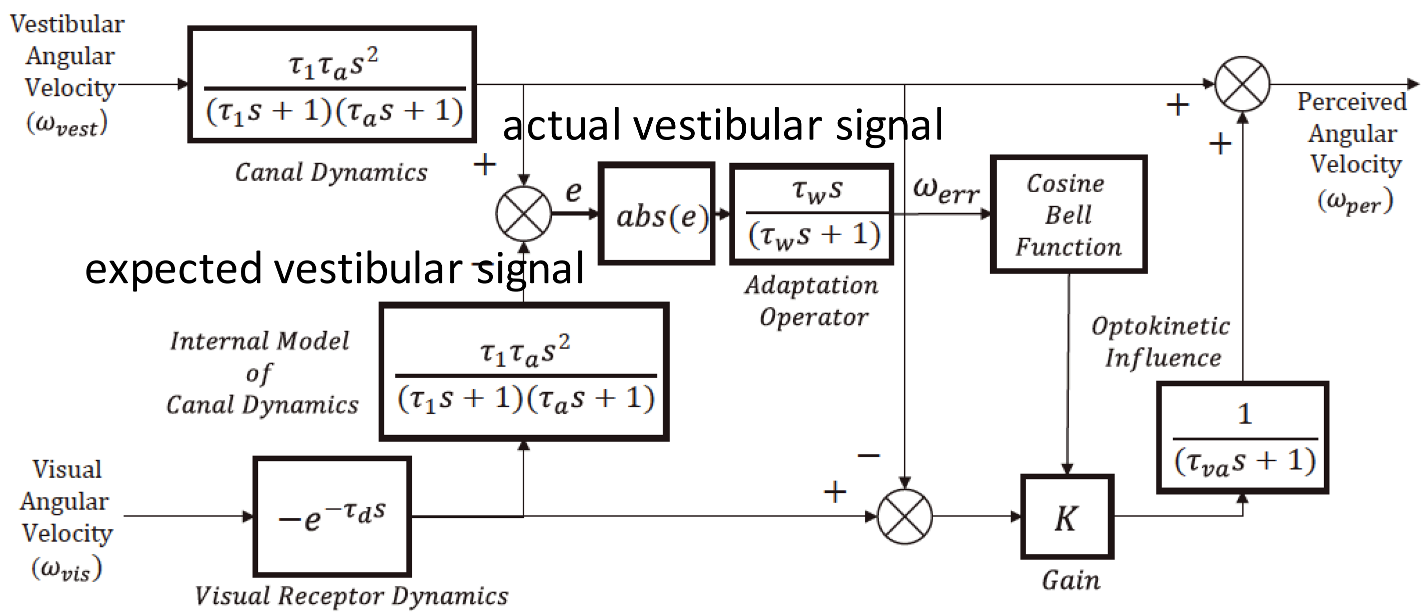


VR Visual Sickness Predictor

- Perceptual motion features
  - User head angular velocity ω_{vest}
  - Visual angular velocity ω_{vis}
  - Perceived angular velocity ω_{per}

$$\omega_{vest}^{t} = \left(P_{vest}^{t} - P_{vest}^{t-1}\right) \times \gamma \ (degree/sec),$$
$$P_{vest}^{t} = \left[r_{vest}^{t},\ p_{vest}^{t},\ y_{vest}^{t}\right],$$

$$\omega_{vis}^{t} = \omega_{vest}^{t} - \omega_{cam}^{t} \ (degree/sec),$$
$$\omega_{cam}^{t} = \left(P_{cam}^{t} - P_{cam}^{t-1}\right) \times \gamma,$$
$$P_{cam}^{t} = \left[r_{cam}^{t},\ p_{cam}^{t},\ y_{cam}^{t}\right].$$



VR Visual Sickness Predictor

- Statistical content feature
  - Texture features: the distribution of the spatial texture has a great effect on the motion perception of the HVS

$$E^t = \sqrt{\int_{\Omega} CSF(\Omega)|B(\Omega)|d\Omega},$$

  - Motion features: the distribution of motion affects visual sickness considerably

$$V^t(x,y) = \frac{1}{N_x N_y} \sum_{x=1}^{N_x} \sum_{y=1}^{N_y} \sqrt{u^t(x,y)^2 + v^t(x,y)^2},$$

  - Temporal Pooling: the human perception of the video content is influenced by the scene characteristics in numerous consecutive frames in the time domain

$$\mu_m = \frac{1}{T} \sum_{t=1}^{T} f_m^t,$$

$$\sigma_m = \frac{1}{T} \sum_{t=1}^{T} (f_m^t - \mu_m)^2,$$

$$l_m = \frac{1}{d_{max}} \cdot \left(\frac{1}{N_p^l} \sum_{n<N \cdot p/100} d(n) \right),$$

$$h_m = \frac{1}{d_{max}} \cdot \left(\frac{1}{N_p^h} \sum_{n>N \cdot (100-p)/100} d(n) \right)$$

VR Sickness Assessment Dataset

- create a reference scene which includes diversified textures using a Unity 3D engine
  - 36 VR scenes
  - HTC Vive
  - 400x300 pixels frame resolution

Object Movement	Camera Movement	Content Component
- Horizontal - Vertical - Diagonal - Forward - Backward	- Roll - Pitch - Yaw - Horizontal - Vertical - Forward - Backward	- Texture - Field of View - Visual Guidance

Experiment Results

- Subjective test environment
  - 80 subjects, 21-50 years
  - 1-5
  - Individual scores and MOS
- Setup
  - SVR with linear kernel
  - 80% for training and 20% for testing
  - Repeated 1000 times
- Metrics
  - Pearson linear correlation coefficient (LCC) and Spearman rank-order correlation coefficient (SROCC)

MOS and Individual Scores

- MOS

LCC	Mean	Median	Std.
$\mathbf{F}_{vest}$	0.484	0.492	0.063
$\mathbf{F}_{per}$	0.682	0.688	0.054
$\mathbf{F}_{con}$	0.421	0.439	0.079
$VRSP$	0.724	0.728	0.081

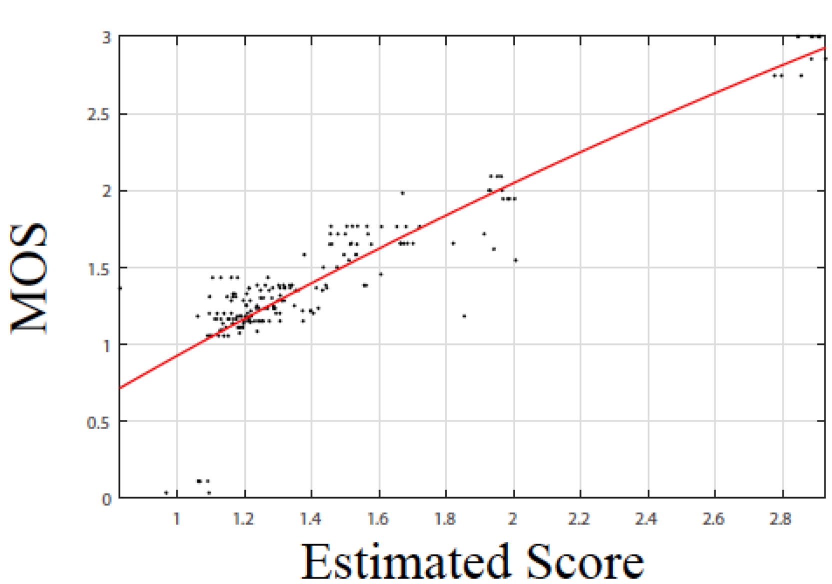
SROCC	Mean	Median	Std.
$\mathbf{F}_{vest}$	0.434	0.451	0.110
$\mathbf{F}_{per}$	0.643	0.647	0.050
$\mathbf{F}_{con}$	0.434	0.457	0.084
$VRSP$	0.710	0.733	0.048

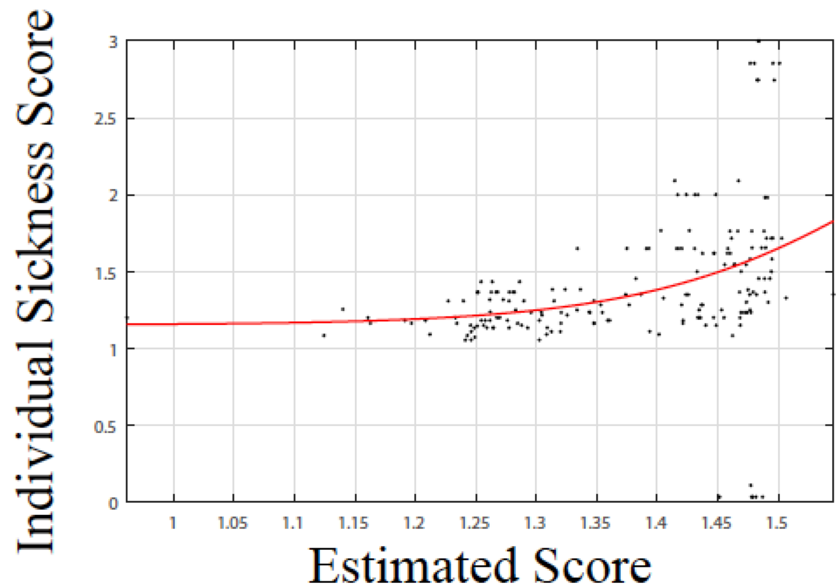
- Individual scores

LCC	Mean	Median	Std.
$\mathbf{F}_{vest}$	0.413	0.420	0.068
$\mathbf{F}_{per}$	0.601	0.612	0.091
$\mathbf{F}_{con}$	0.322	0.343	0.070
$VRSP$	0.671	0.676	0.103

SROCC	Mean	Median	Std.
$\mathbf{F}_{vest}$	0.473	0.477	0.047
$\mathbf{F}_{per}$	0.627	0.634	0.087
$\mathbf{F}_{con}$	0.389	0.391	0.094
$VRSP$	0.688	0.692	0.098

MOS and Individual Scores





Conclusion

- predicting VR sickness on HMD viewing
  - by suitably characterizing the visual-vestibular interaction model and contents features
  - predicted from human head movement and the perceived scene in the HMD
- Future work
  - develop a database with gaming scenario, natural experience (360 videos) and human subject scores on them