Training Simulation for Complex Cognitive Tasks: Visual Scan Patterns in Helicopter Navigation

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The Team

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- Quinn Kennedy, PhD (Co-PI, psychologist)
- Ji Hyun Yang, PhD (Co-PI, research fellow)
- Michael Day (engineer/programmer, MS student)
- Interns
  - Noah Lloyd-Edelman, Chris Edgar, and Edgar Rizo

- NMSO and ONR sponsored work

Helicopter overland navigation

- Cognitively complex and demanding task
  - Continuous monitoring of system and environment parameters
- Challenges of training novice helicopter pilots
  - Timely advice
  - Safety

Research idea

- Currently, instructors have very few salient cues to rely on to assess trainee's navigation performance during flight.
  - Specifically, trainees' cognitive states, e.g, when trainees are lost, do the trainees realize it?
- What could be an useful cue to indicate trainees' cognitive states?

Background

- IFR flight: Experts looked at instruments more often than novices, and novices dwelled longer than experts (Bellenkes et al., 1997).
- VFR flight: More fixations and shorter dwell times also were associated with good landings, providing indirect evidence that these visual strategies cause expertise differences in landing performance (Karsarkis et al., 2001).
- VFR flight: Novice pilots were more likely to fly OTW (Ottati et al., 1999).

- Eye tracking measures can be used to determine level of visual processing load (Van Orden et al., 2001).
- Modeled cognitive states – engaged vs. relaxed, normal vs. distracted, fatigued vs. alert – from eye movement and pupil size (Marshall, 2007).
- More experienced users focused on content-oriented concepts, whereas less experienced users spent too much on concepts of which they were uncertain. Also shorter attention spans and more scattered gazes (Yan Liu et al., 2008).
- People tend to trade the cost of frequent ocular movements with the cost of maintaining information in working memory when dealing with complex visuomotor tasks (McCarley & Kramer, 2007).

- Mean dwell is not a good measure for distinguishing between flight tasks (Katoh, 1997).
- Fixation durations are log-normally distributed (Velichkovsky et al. ,2000).

Research objectives

- Investigate potential improvements to training simulation by analyzing the influence of flight expertise on visual scan patterns in helicopter overland navigation
- Understand cognitive processes associated with helicopter overland navigation

METHODS

Design of experiment

- Hypotheses
  - 1. Experts and novices have little difference in flight RMS error.
  - 2. Expert pilots have clearly defined visual scan strategies (more fixations, shorter dwells, more view changes, etc.) than novices.
- Independent variables
  - Expertise of pilots are defined with;
    - Total flight hours
    - Instructing experience
- Dependent variables
  - Flight performance
  - Eye tracking parameters
    - Scan time, dwell duration, number of fixations per view, OTW-MAP view changes
- Navigation task design
  - Twenty nine Palms, 11 legs with various route difficulties

Elevation map & satellite image

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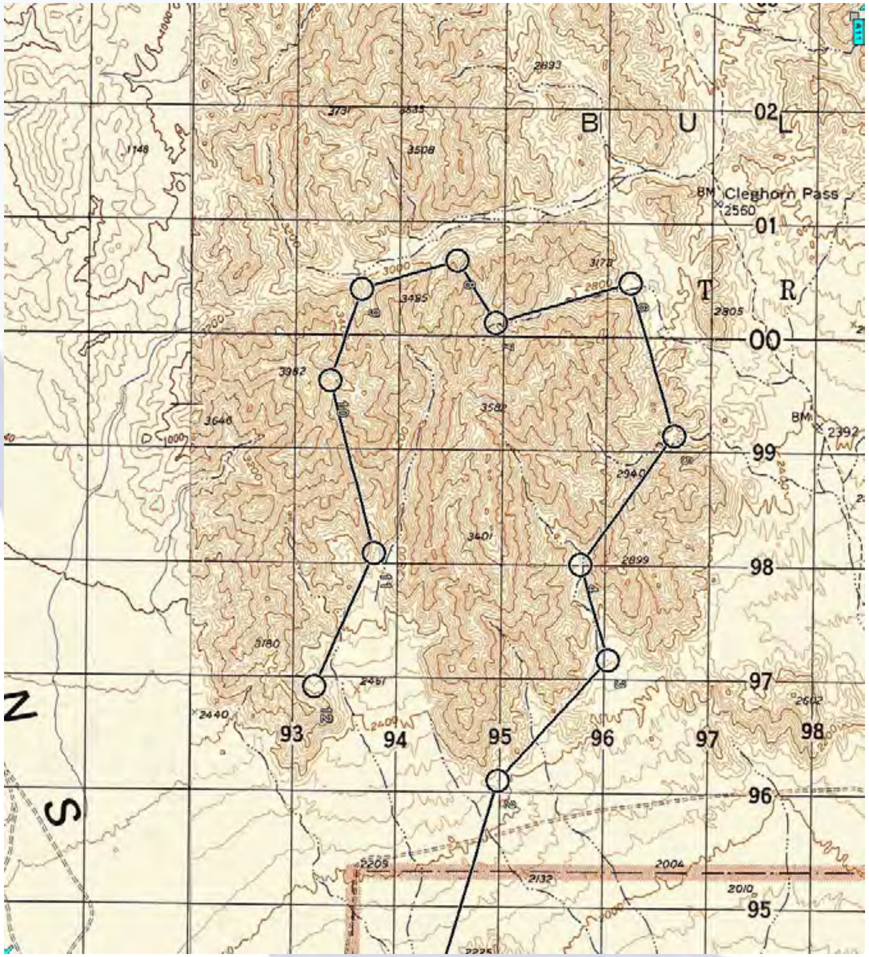
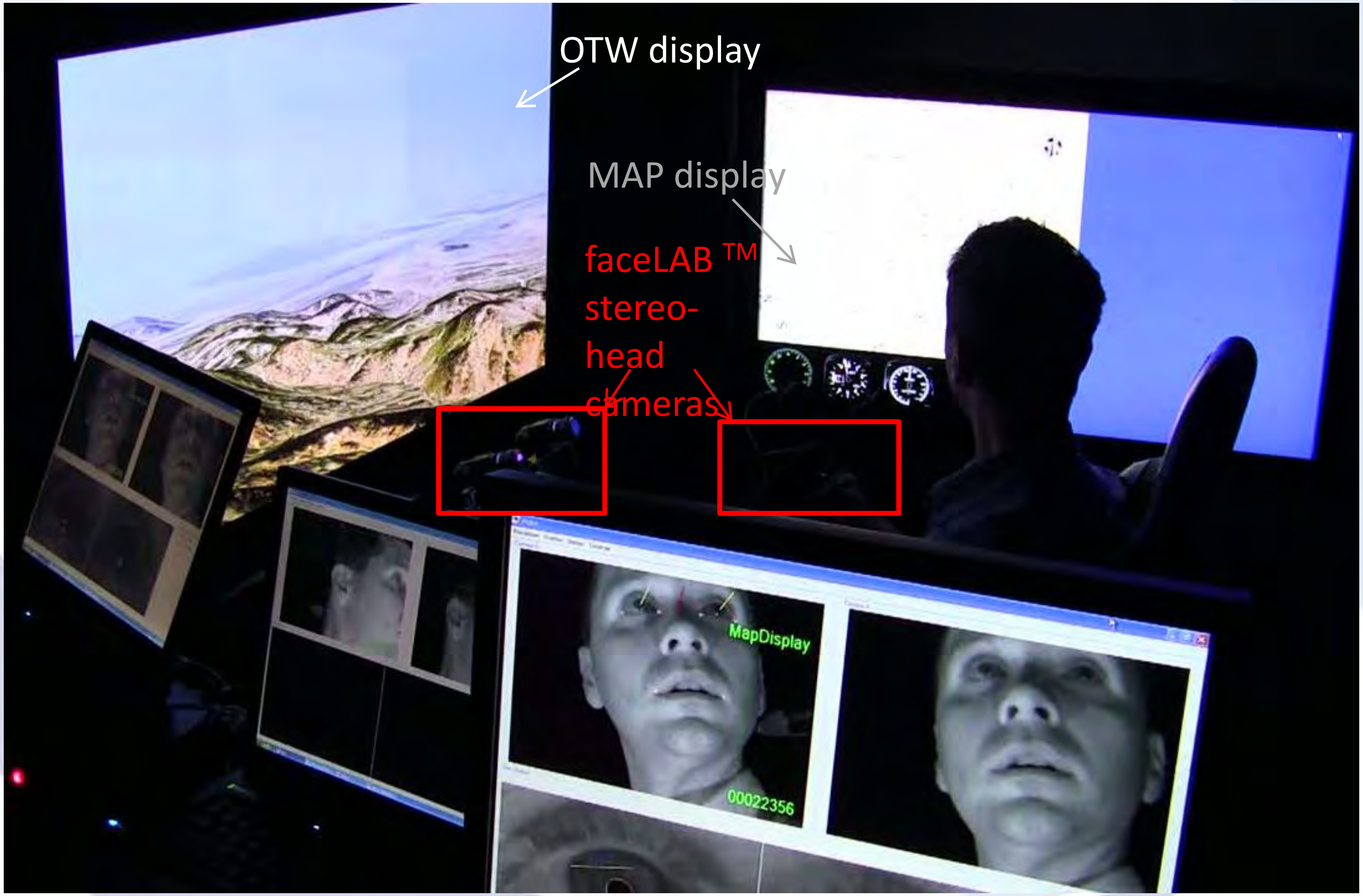


Experiment procedure

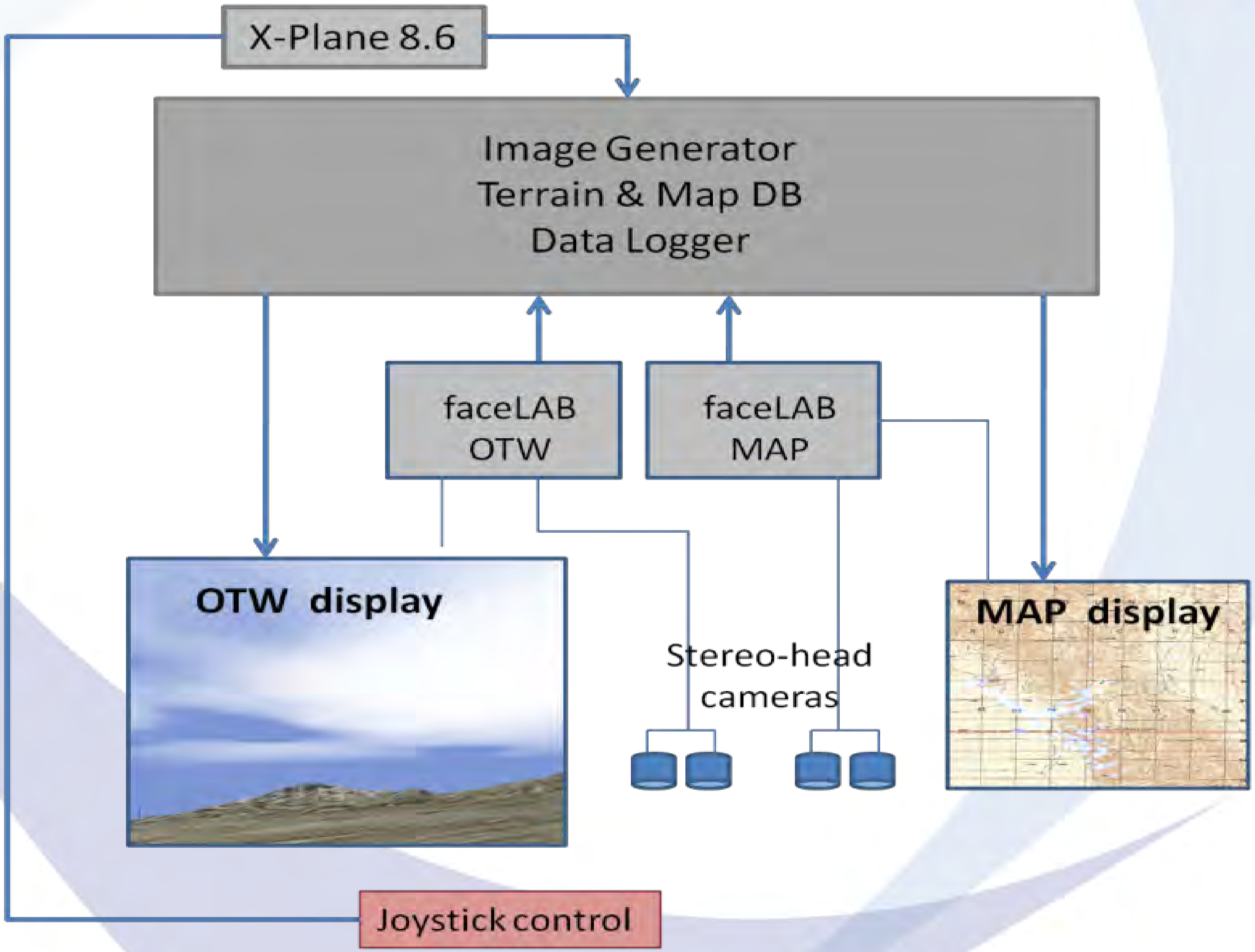
- IRB approval
- Participant recruiting
  - Military personnel who at least took overland navigation classes
- Interview, pre-questionnaire
- Informed consent form
- Eye tracking device calibrated
- Practice flight (~ 7min)
- Map study time (up to 10 min)
- Main flight (~ 5min)
- AAR, post-questionnaire

1 ~ 1.5 hrs

Experimental set-up



Lab diagram


X-Plane 8.6
Image Generator
Terrain & Map DB
Data Logger
faceLAB
OTW
faceLAB
MAP
OTW display
Stereo-head
cameras
MAP display
Joystick control

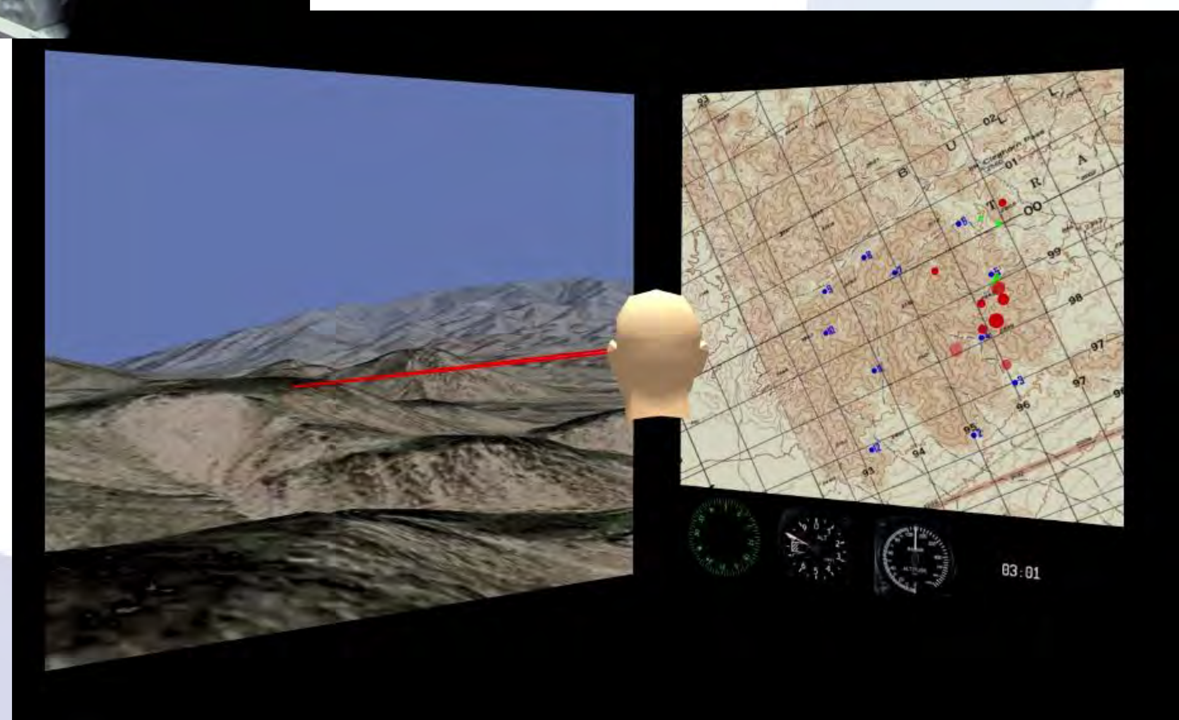
Participants

I.D.	Age	Branch	Total flight hours	Overland navigation hours	Instructing experience
02	40	USAF	0	0	Instructor
03	33	Navy (Brazil)	0	0	None
04	30	USN	1,150	100	None
05	37	USN	3,100	15	None
06	33	USN	1,600	850	Pilot instructor
07	30	USN	1,000	600	None
08	33	USMC	1,450	1,450	None
09	37	USMC	1,500	1,300	None
10	33	USN	2,300	1,800	Pilot instructor
12	37	USN	2,400	300	None
13	34	Army	0	0	Instructor
14	29	N/A	0	0	None
15	28	USN	850	30	None
16	36	USN	2300	300	None
18	38	USMC	2700	2500	Pilot instructor

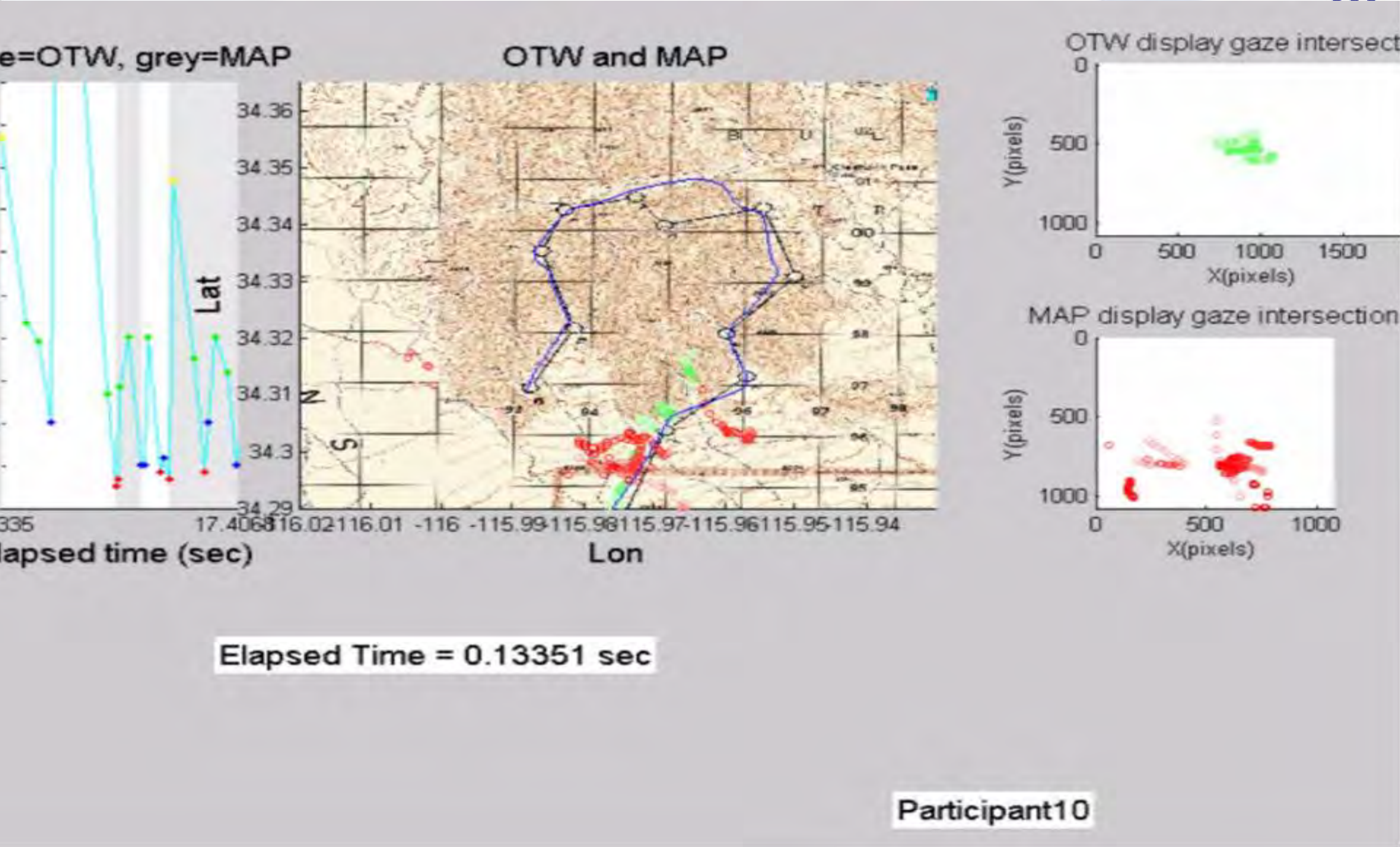
RESULT

Actual scene

3D replay

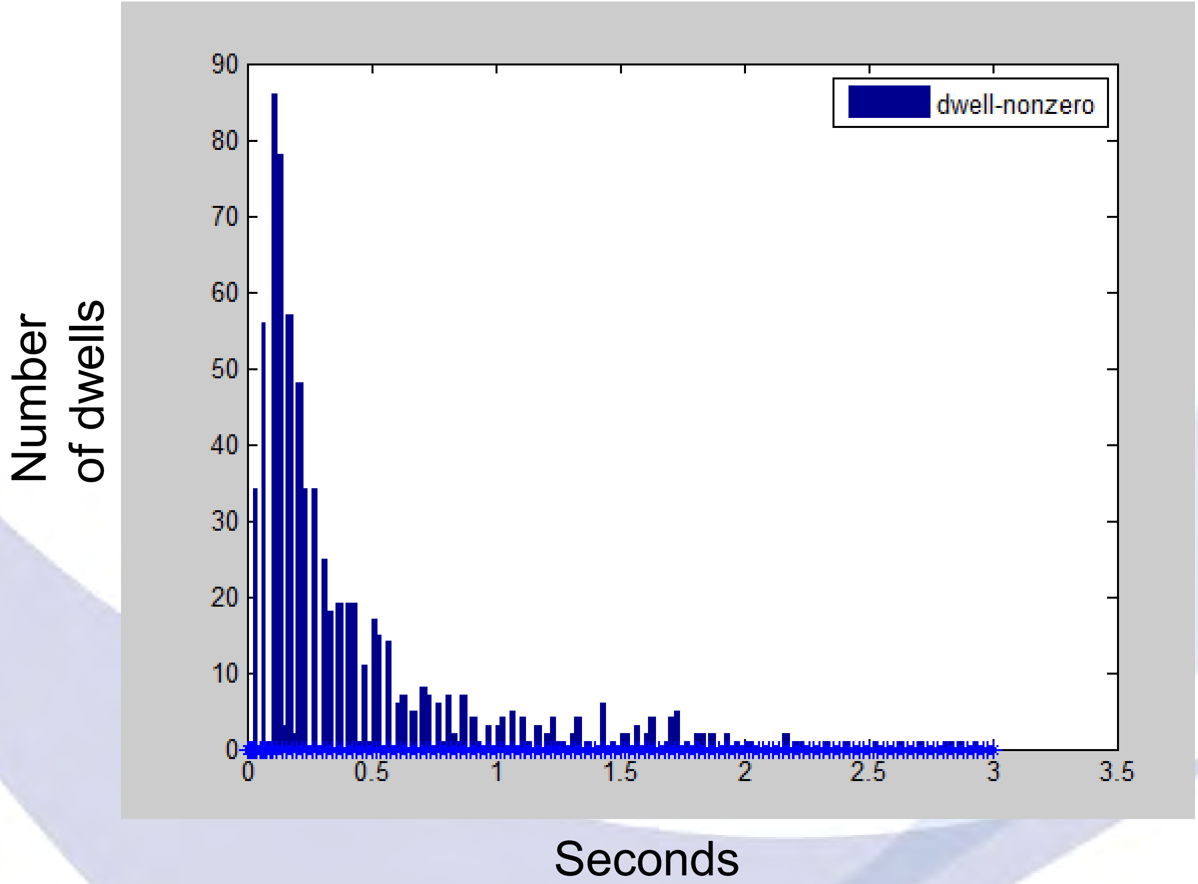


Flight path and visual scan patterns



Dwell duration distribution

- Log-normally distributed dwell durations



Multiple regression model

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2$$

$$x_1 = \text{instructing experience}$$

$$x_2 = \text{total flight hours}$$

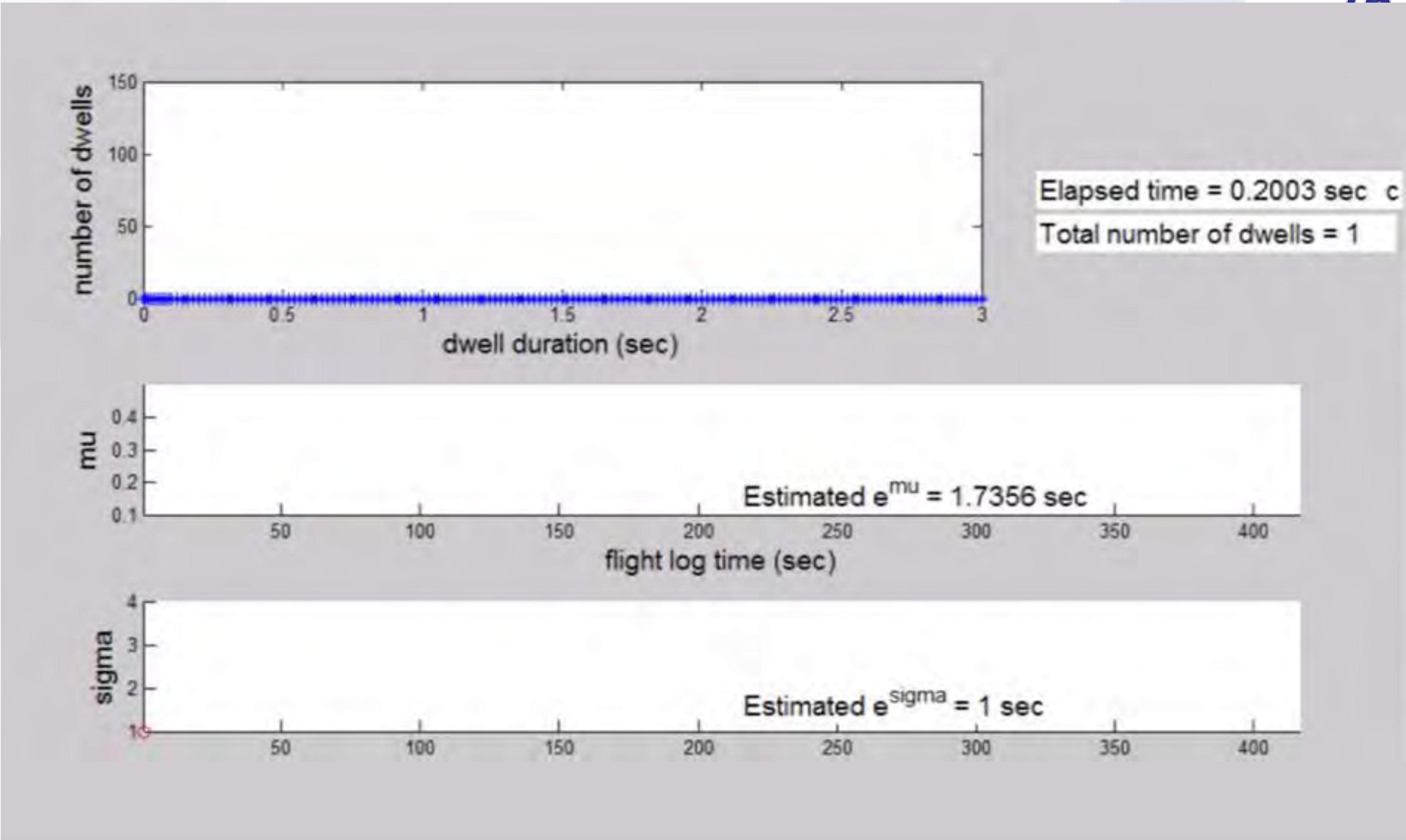
Variable name	beta1 (SE)	beta2 (SE)	F	adjusted R^2
RMS	-.28 (.32)	-.09 (.32)	.46	-.11
Median OTW dwell	-.11 (.24)	-.68** (.24)	4.36**	.38
OTW and MAP view changes	-.08 (.27)	.61** (.27)	2.64*	.23

** p<.05
* p<.1

Conclusion

- Phase 1 completed.
  - Provided a promising result for training simulation improvement.
- Future work
  - How to present the findings to the instructors?
  - Extend to Wide Field-of-view simulator
  - Develop a haptic map interface
  - Modeling cognitive processes
  - And more!

Future work- dwell parameter estimation



Wide FOV and Smart MAP display

Assess cognitive processes

Want to know more??

- Don’t forget to stop by WA212B tonight for the live demo!
- You will be able to hear more details and original findings of our study at CDR Sullivan’s Ph.D. thesis defense!

Thank you!

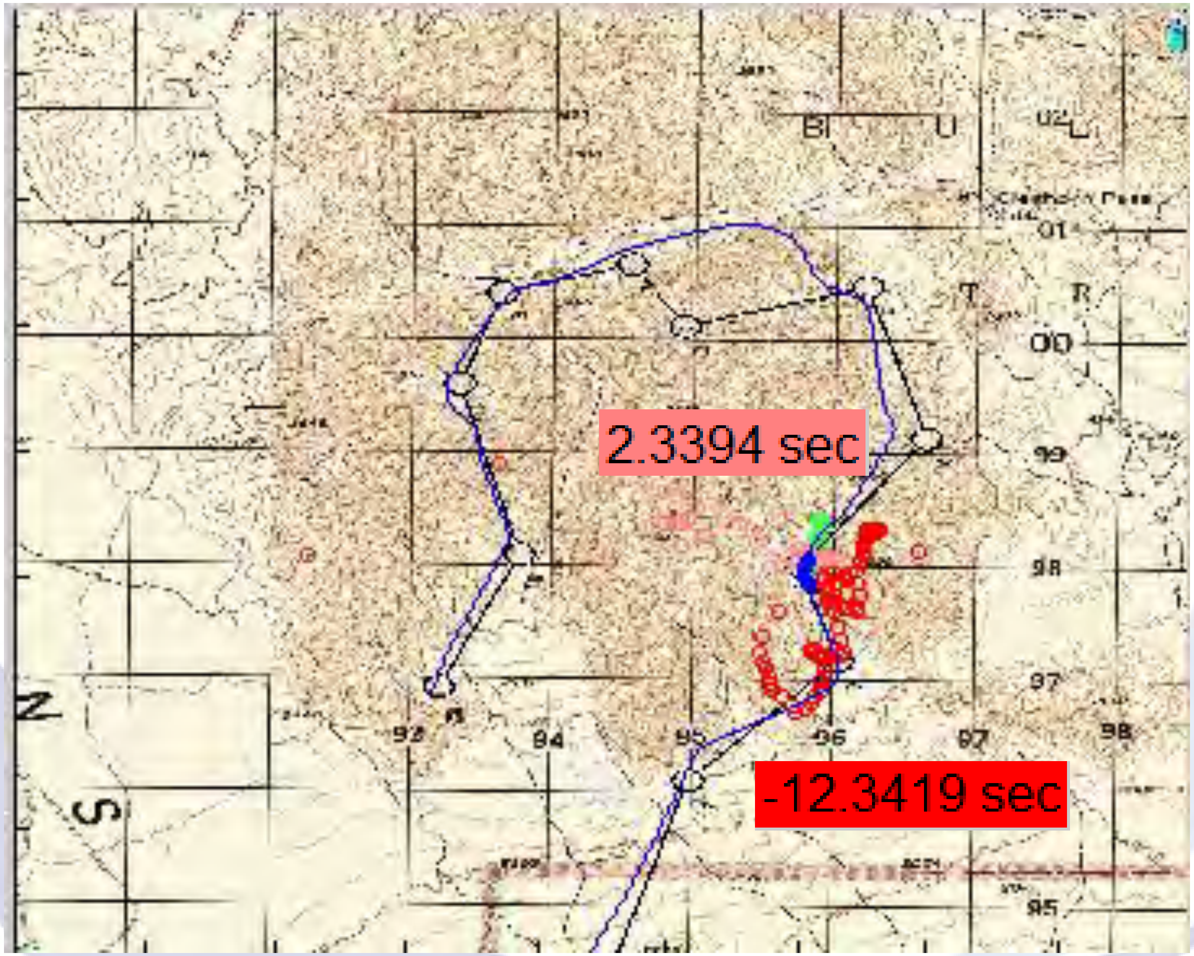
Q & A

Backup slides

Interactive MATLAB movie if possible

- Dwell estimation
- Check if we can run MATLAB at the conference room.

Expert: visual scan patterns



Qualitative analysis

- Lead/Lag pattern
- Compare expert/novice scan patterns

Visual scan pattern comparison

Expert

Novice