UPPER LIMP MOVEMENT ANALYSIS OF PATIENTS WITH NEUROMUSCULAR DISORDERS USING DATA FROM A NOVEL REHABILITATION GAMING PLATFORM

A. Chytas, D. Fotopoulos, V Kilintzis, T. Loizidis, I. Chouvarda

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OVERVIEW

- Motor Control
- Physical Rehabilitation
- Gaming as a Health Service (GaaHS)
- Analysis
- Results

PARTNERS

ΑΠΟΚΑΤΑΣΤΑΣΗ

ARISTOTLE UNIVERSITY OF THESSALONIKI

Laboratory of Computing, Medical Informatics and Biomedical-Imaging Technologies

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MOTOR CONTROL

- Motor control is considered one of the most difficult set of functionalities of the human body.

- A process or a set of sub-processes, during which humans move and coordinate their muscles and limbs so they can perform a motor skill.

- Humans from birth train in motor control (Motor Learning) through the integration of sensory-motor information. Movements are consolidated in the Central Nervous System (CNS)
  - ❑observation
  - ❑repetition

PHYSICAL REHABILITATION

- Certain pathologies can affect the CNS, resulting in the loss of cognitive functions of the brain.
- Impacts several motor functions
  - ❑ partial
  - ❑ complete loss
- Rehabilitation programs aim to detect any motor deficits of each patient and help them regain control of their movements through motor learning.
- The standard method of doing that, is the repetition of a movement's correct form, so that it can be permanently stored in the CNS.
- The repetitive training of isolated movements is a fundamental principle behind improving the outcome of motor rehabilitation.

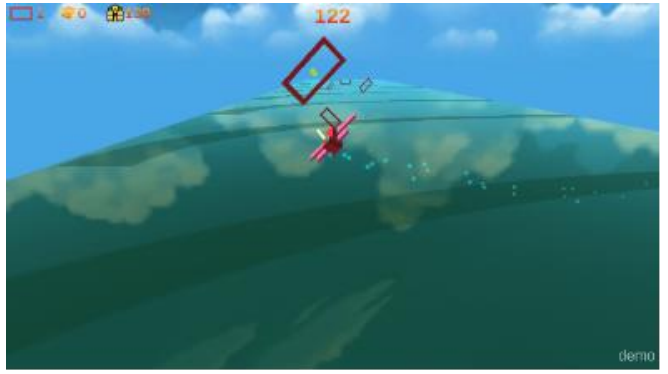
EMERGING TECHNOLOGIES

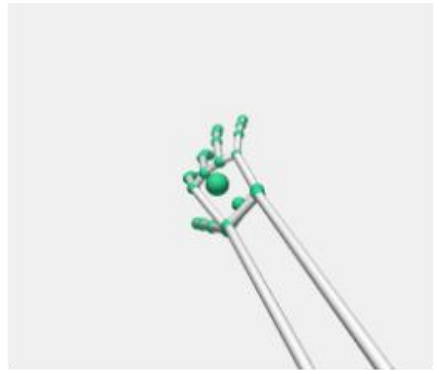
- Technology can assist physical rehabilitation and conventional treatment methods
- A new domain that combines exergames, gamification mechanisms and traditional rehabilitation methodologies
- Therapeutic solutions, that combine novel software and hardware components are implemented to facilitate the rehabilitation
- Facilitate the process of Motor Learning
- Executing a series of repetitive and functional movements
  - ❑efficiently
  - ❑in a less monotonous way.

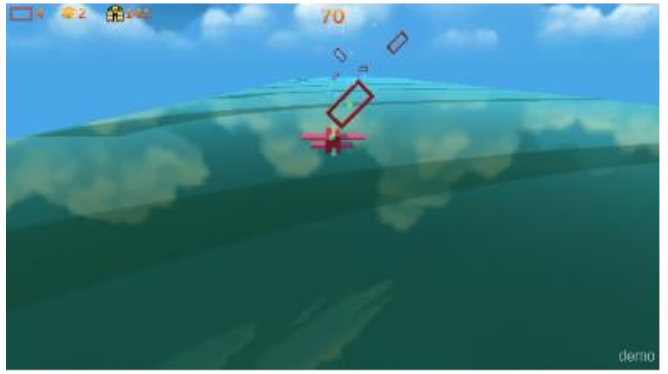
MILORD

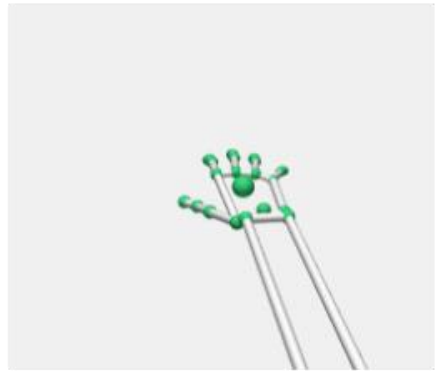
- Using a custom crafted game
- Leap motion sensor controller

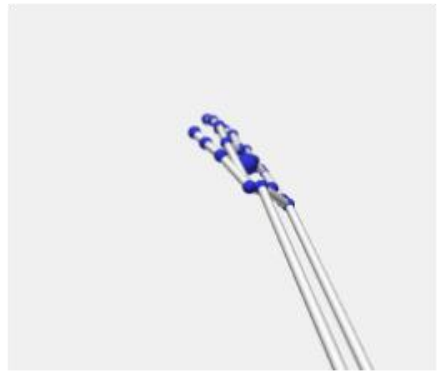
- User controls an avatar via his hand
- Navigates the avatar through gates
- Gates appear in a 3x3 grid in a pseudorandom order
- Emulate movements used in physiotherapy
- Physical rehabilitation is a strenuous procedure
- Making it more pleasant!

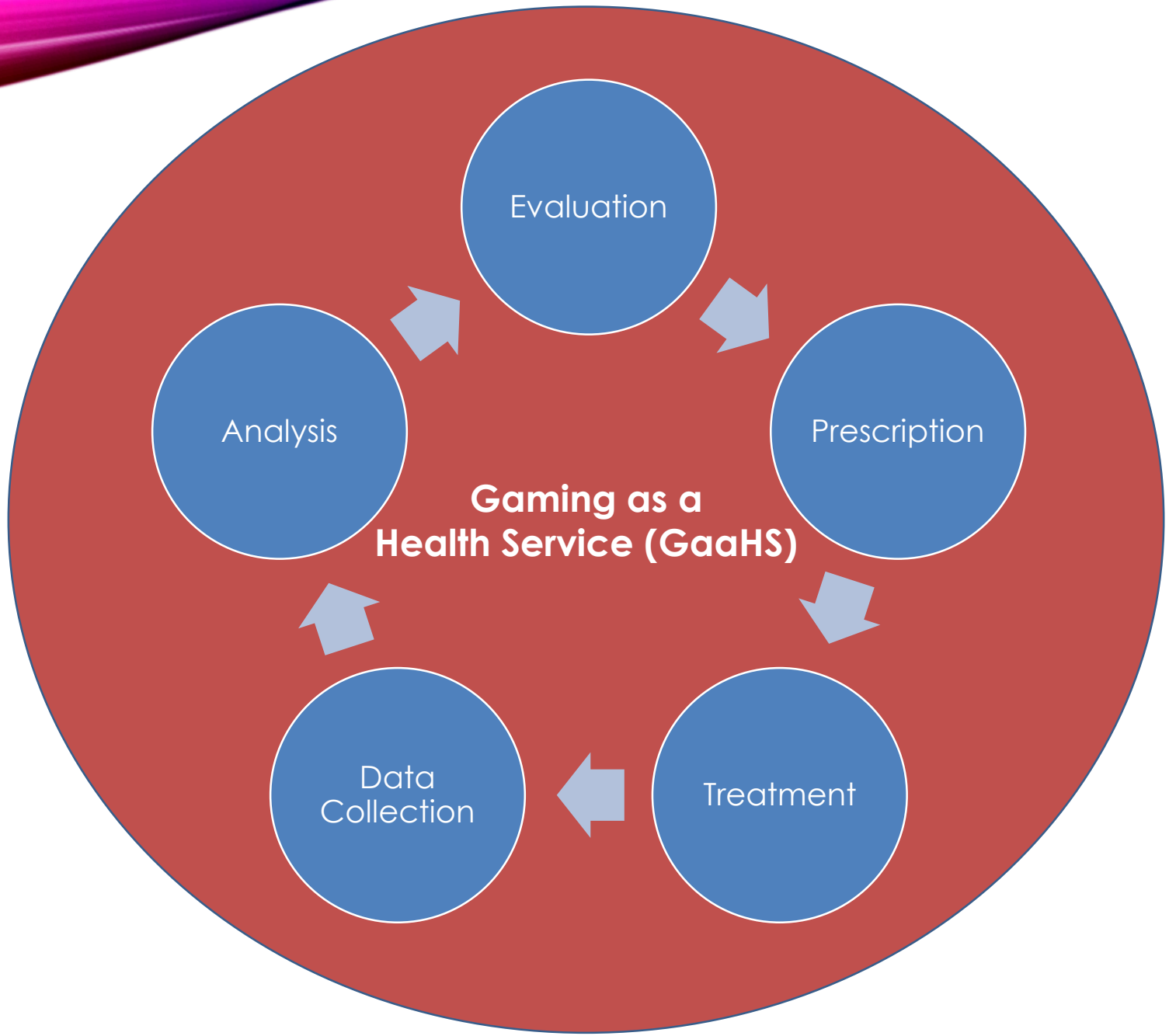










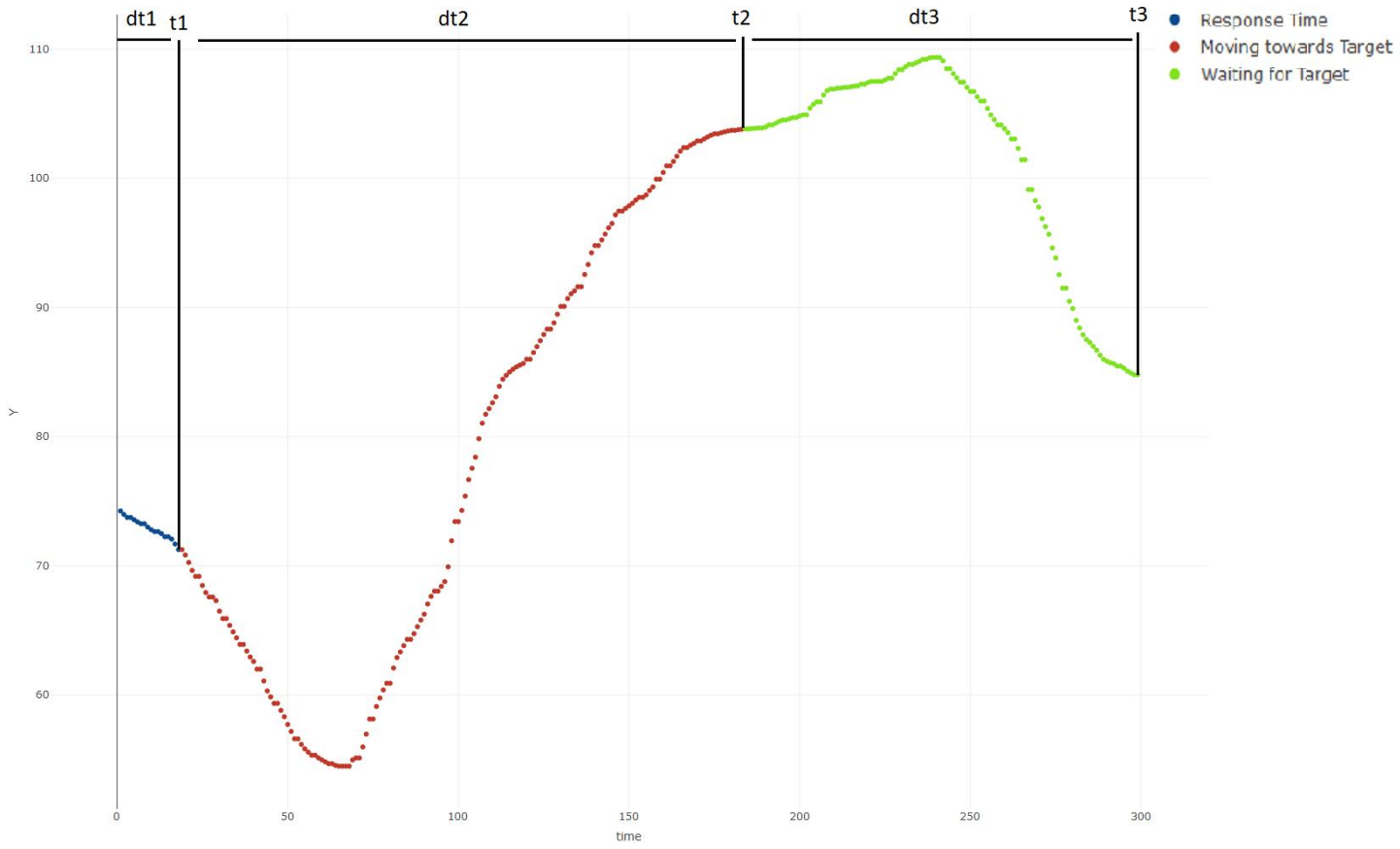

Evaluation
Prescription
Treatment
Data Collection
Analysis
Gaming as a Health Service (GaaHS)

MOVEMENT ANALYSIS

Examine the movement from gate to gate.

Split the movement into 3 parts

- Response (DT1: t0-t1)
- Actual Movement (DT2: t1-t2)
- Stabilize (DT3: t2-t3)

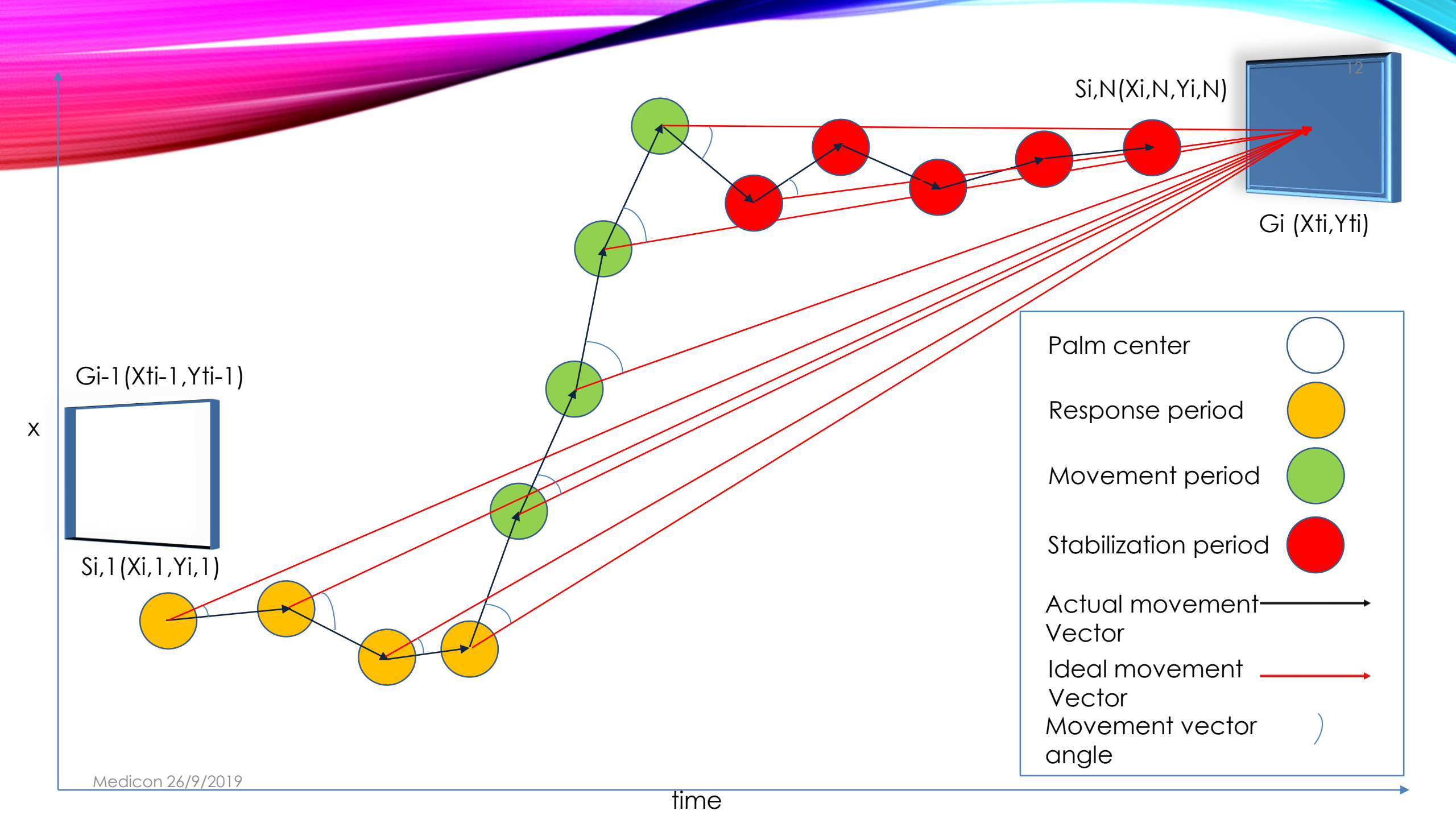


MOVEMENT ANALYSIS

- Response (DT1: t0-t1): it refers to the period of time after the user has reached the Gi gate and when they become aware of the upcoming gate Gi+1 and they begin to move towards it. Steady period.

- Movement (DT2: t1-t2): it refers to the period of time where the user is moving from Gi towards the upcoming gate G_{i+1}. Movement period.

- Stabilization (DT3: t2-t3): it refers to the period of time after the user has arrived to the X, Y coordinates that correspond to the G_{i+1} gate and is waiting to reach it (plane pass through the gate). Steady period.


Si,N(Xi,N,Yi,N)
Gi (Xti,Yti)
Gi-1(Xti-1,Yti-1)
Si,1(Xi,1,Yi,1)
x
time
Palm center
Response period
Movement period
Stabilization period
Actual movement Vector
Ideal movement Vector
Movement vector angle

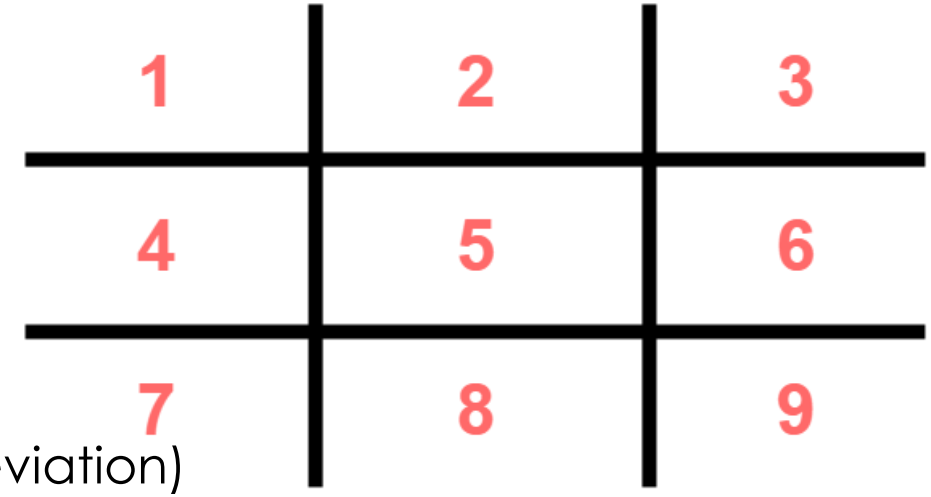
DATA

Raw data

- Palm center position per frame, time of gate collision, gate grid position
- One subject under physical rehabilitation, suffering from a neuro-muscular
  - ❑ 43 games
- 3 healthy subjects
  - ❑ 8 each (24 total)

Features extracted

- Duration of each segment
- Distance covered by the user
  - ❑ on each segment (dt1,dt2,dt3)
  - ❑ ratio to minimum distance required
- Acceleration / velocity (average values, standard deviation)
  - ❑ on each segment (dt1,dt2,dt3)
  - ❑ per axis (X, Y) and as a 2D movement



Gates grid position

STATISTICAL ANALYSIS

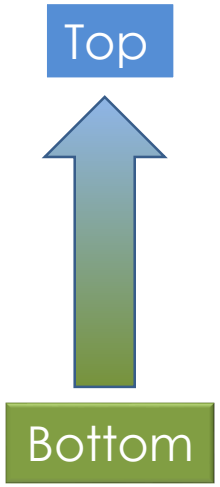
- The gates were grouped based on the type of movement, vertical, horizontal, diagonal and the direction (e.g. to to bottom etc.)
- Checked for normality using the Shapiro–Wilk test.
- Normal: analysis of variation (AOV) /non-normal Mann-Whitney U test
- p-values corrected using the Bonferroni correction
- Statistically significant features selected($p<0.05$)
- Those features checked for correlation (0.8) and out of those the best performing features were selected.

RESULTS

Left → Right

Features	Control		Patient		p-value
	Mean	Sd	Mean	Sd	
DT2	359.20	278.65	702.8	434.5	0.0000005
Mean Velocity DT2 Start	68.85	37.84	47.19	16.66	0.0000107
Mean Velocity DT2X	70.94	31.38	51.55	16.85	0.0000002
Sd Velocity DT2 Y	8.75	13.49	14.25	13.31	0.0000002
Sd Acceleration DT2 X	29.31	21.41	47.74	67.77	0.0000023
Sd Velocity DT3	34.19	16.87	21.60	10.02	0.0000022
Total Distance	108.01	43.84	80.16	27.96	0.0199482
Total Distance T3	60.50	18.81	39.07	10.65	0.0000011
Min Distance Final	4.75	6.68	1.75	1.43	0.0000004
Ratio	4.21	3.68	2.26	0.65	0.0000111

RESULTS



Features	Control		Patient		p-value
	Mean	Sd	Mean	Sd	
Mean Velocity DT2 Start	63.72	34.39	25.99	12.94	0.0000005
Mean Velocity DT2 Y	37.65	27.43	23.44	11.34	0.0000107
Sd Acceleration DT2 Y	23.98	60.63	21.00	22.68	0.0000002
Sd Velocity DT3	39.67	24.30	20.31	7.78	0.0000002
Total Distance	111.2	57.79	66.90	20.32	0.0000023
Total Distance T1	24.50	19.90	11.87	11.85	0.0000022
Total Distance T3	63.63	21.73	36.51	14.77	0.0199482
Min Distance Center Final	7.41	5.20	4.43	2.19	0.0000011
Ratio	2.80	1.54	1.61	0.42	0.0000004

RESULTS

- Mean Velocity DT2 Start
- Mean Velocity DT2
- Sd Acceleration DT2
- Sd Velocity DT3
- Total Distance
- Total Distance T3
- ratio (Total Distance / Minimum distance required)

- higher values in normal subjects than the patient

- This is expectable since the patient's neuromuscular disorders lead to limited mobility and as such the patient's hand is moving at a slower pace.
- Greater value of the patient's sdAccDT2X for the left to right movement suggests trouble maintaining a steady horizontal acceleration.

CONCLUSIONS

A preliminary proof of concept on how to quantify the movement in a meaningful way and express differences between normal and pathological movement.

Next step

- Collect data (control and patients) refine the algorithms
- Establish a baseline for the healthy population
- To a quantifiable evaluation of the patients' progress and response to rehabilitation.

Long-term goal

- Provide a gaming as a health service (GaaHS) platform
- The user plays games based on physician provided settings
- Data are collected safely and automatically
- Analyzed and evaluated by the physician
- The physician monitors the progress and can readjust the rehabilitation treatment accordingly

Thank you for your attention!

Questions

http://milord.med.auth.gr/

http://dentlab.med.auth.gr:5858/apps/milord2/