Use of Kinect™ in rehabilitation

Gilles Lattion

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Introduction

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- Movement tracking device
- Applications
  - Rehabilitation after stroke to prevent falls
  - Cognitive rehabilitation
- Affordable device at large scale
- Can be used at home
- Stimulating environment

Microsoft Kinect™

Physiology aspects

- Balance and postural control:
  - Assessment of the alignment of the spine, head and lower limbs
  - Analysis of the balance through the center of gravity
  - Relevant to avoid falls in case of stroke rehabilitation or Parkinson's disease

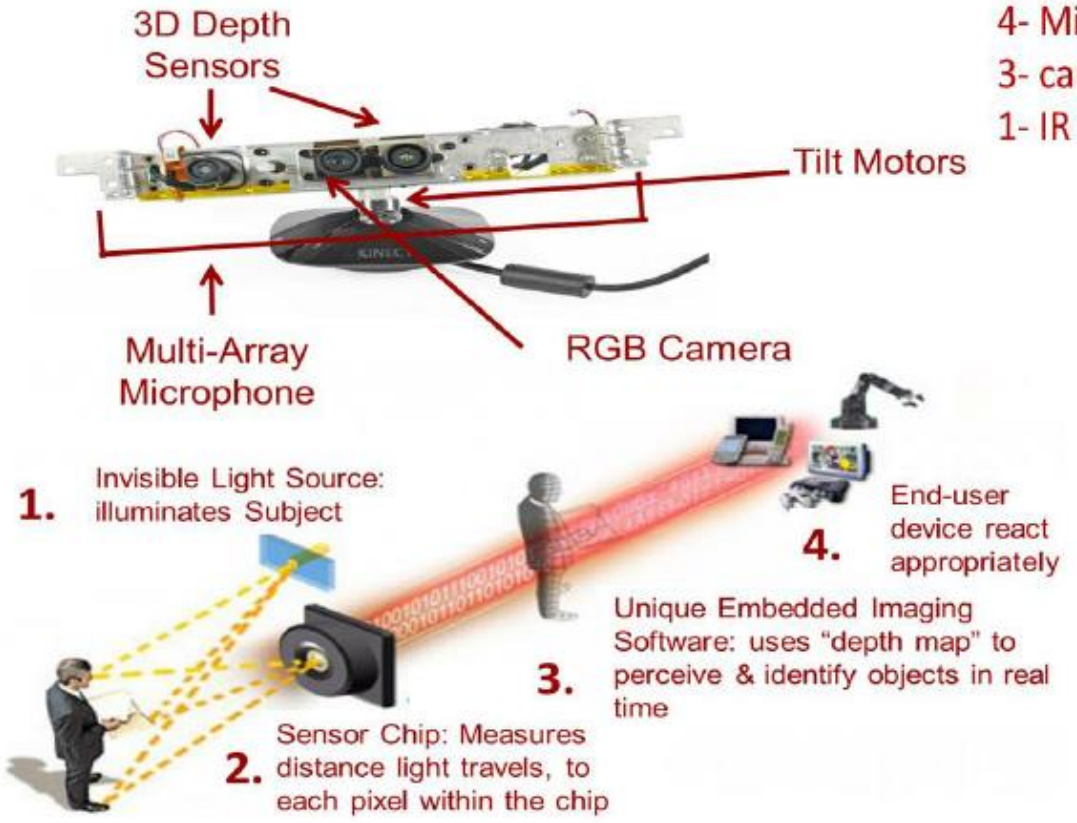
- Gait Analysis:
  - Walking pattern, step counts
  - Gait speed, rythm and symmetry
  - Lower limbs impairments rehabilitation

Physiology aspects

- Muscles strengthening:
  - Provide a stimulating environment to strengthen and retrain muscles to rejuvenate debilitated functions (gym, virtualized therapist)

- Joint angles and range of motion:
  - Tracking of key joints (e.g., shoulder, elbow, hip, knee)
  - Assessment of flexibility
  - Targeted rehabilitation in case of asymmetry of movement (hemiplegia)

Specifications



4- Microphones
3- cameras
1- IR transmitting diode.

Technical description

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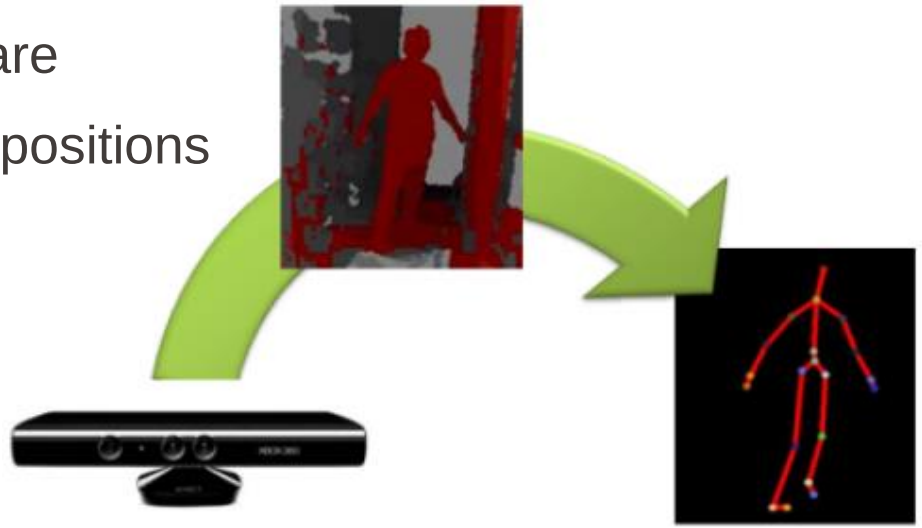
- Analysis of the data
  - ➢Movement detection software
  - ➢Decomposition of key joint positions

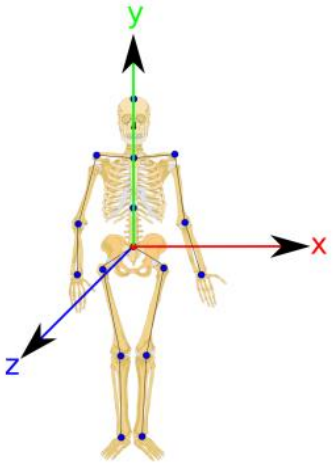


Technical description

Example of a movement detection algorithm

- Joint position at time t:

$$a = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$



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Technical description

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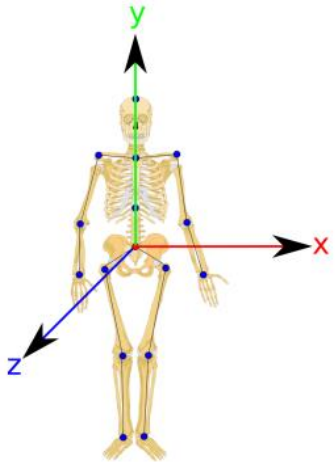
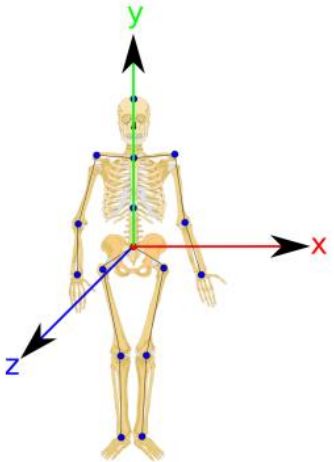


- Pose: union of joint positions at time t:

$$P(t) = \bigcup_{a \in \mathcal{A}} a(t) = \bigcup_{a \in \mathcal{A}} \begin{bmatrix} x_a(t) \\ y_a(t) \\ z_a(t) \end{bmatrix}$$

Technical description

Example of a movement detection algorithm



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$$a = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

- Pose: union of joint positions at time t:

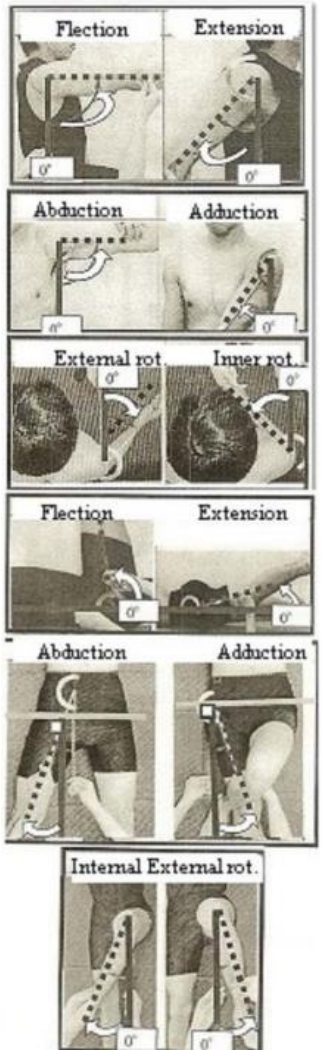
$$P(t) = \bigcup_{a \in \mathcal{A}} a(t) = \bigcup_{a \in \mathcal{A}} \begin{bmatrix} x_a(t) \\ y_a(t) \\ z_a(t) \end{bmatrix}$$

- Action: matrix of poses at different time:

$$A = \begin{bmatrix} a_1(t_0) & \dots & a_1(t_N) \\ a_2(t_0) & \dots & a_2(t_N) \\ \vdots & \ddots & \vdots \\ a_{|\mathcal{A}|}(t_0) & \dots & a_{|\mathcal{A}|}(t_N) \end{bmatrix} = \begin{bmatrix} x_1(t_0) & x_1(t_1) & \dots & x_1(t_N) \\ y_1(t_0) & y_1(t_1) & \dots & y_1(t_N) \\ z_1(t_0) & z_1(t_1) & \dots & z_1(t_N) \\ \vdots & \vdots & \ddots & \vdots \\ x_{|\mathcal{A}|}(t_0) & x_{|\mathcal{A}|}(t_1) & \dots & x_{|\mathcal{A}|}(t_N) \\ y_{|\mathcal{A}|}(t_0) & y_{|\mathcal{A}|}(t_1) & \dots & y_{|\mathcal{A}|}(t_N) \\ z_{|\mathcal{A}|}(t_0) & z_{|\mathcal{A}|}(t_1) & \dots & z_{|\mathcal{A}|}(t_N) \end{bmatrix}$$

Technical description

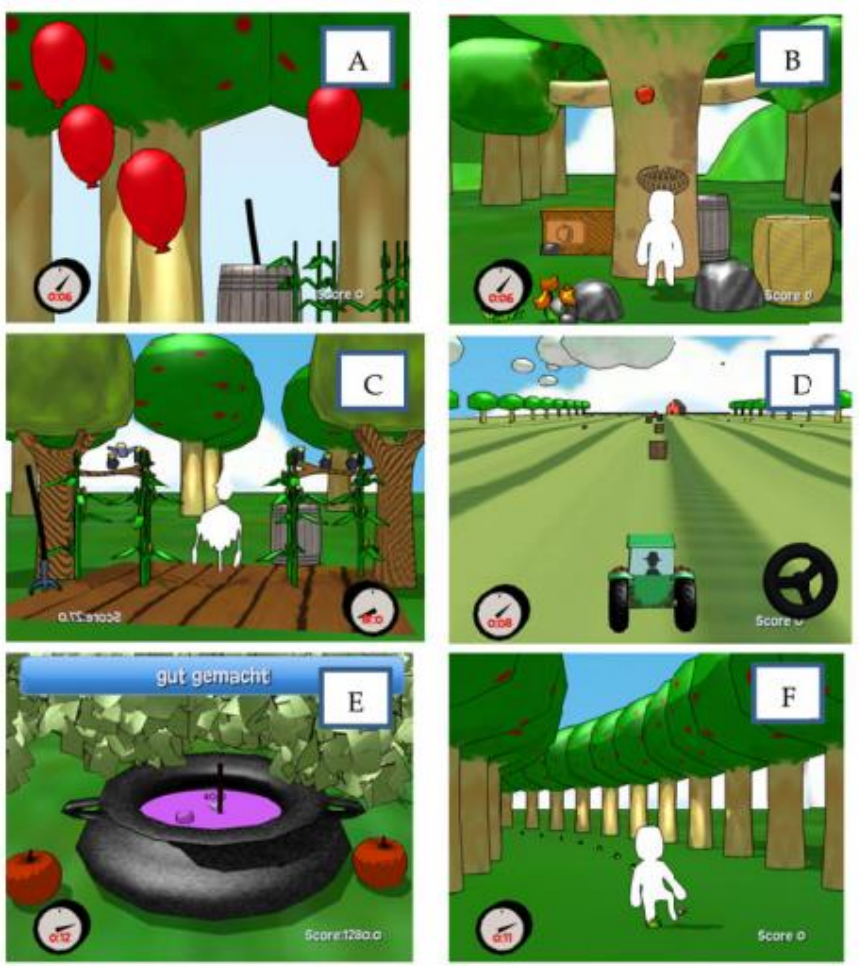
- Typical physiotherapeutic exercises:
  - Adduction/Abduction of shoulders
  - Flexion of shoulders
  - Extension of elbows
  - Flexion of elbows
  - Flexion of thigh
  - Adduction/Abduction of thigh
  - Flexion/Extension of knees



Technical description

Interactive games

- A: Ballon Popper
  - Train neglected areas
- B: Fruit Catcher
  - Train lateral weight shift
- C: Scare Crow
  - Train static equilibrium
- D: Hay Collect
  - Reflexes and perception
- E: Mix Soup
  - Balance, upper-arm and cognitive rehabilitation
- F: Animal Hurdler
  - Stepping exercises



Technical description

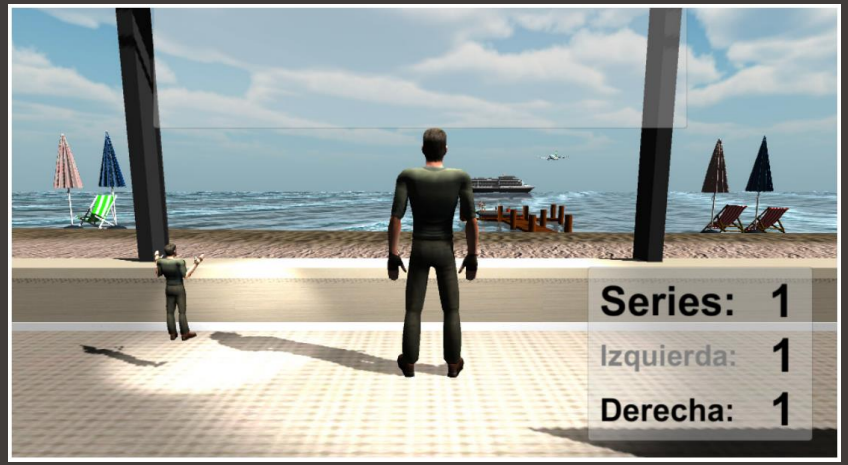
Wearable devices

- Heart-rate monitoring

Aerobics scene

Virtual reality

- Gym environment



Physical strength scene

Medical significance

- Over 35 million stroke patients in the world
- 70 million people suffer from disorders such as hemiplegia and impaired cognitive functions caused by physical accidents (Stroke, car crash,…)
  - ➢Providing them rehabilitation is a world health concern

- Physical injury is the 5th cause of death and is mostly caused by falls in elderly people (684’000 deaths per year)
- In US, approximately $80 billion (2% of the budget) are spent each year for healthcare related to non-fatal falls among older adults
  - ➢Need to keep the elderly population fit

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Clinical applications

- High correlation of upper limbs motion detection between Kinect™ and optoelectronic devices (Marker-based systems) found in Bonnechère et Al. Study (2018)

- Comparison of physical performances between young healthy adults, elderly adults and chronic stroke patients:
  - Up to 328 parameters can be obtained for upper limbs
    - ➢Hand selection analysis by experts
    - ➢Machine learning analysis

- Multiple digital physical therapy tools using the Kinect™ device, such as Reflexion Health or Jintronix, have received the FDA approval

Product aspects

- Very affordable ($150 at launch)
- Easy to set-up
- 35 million units sold (2010-2017)
- Recent alternative: Azure Kinect

- 3D sensing technology market in expansion:
  - ➢Time of flight (autonomous cars)
  - ➢Structured light (facial recognition)
  - ➢Ultrasound and X-ray imaging (medical applications)

Future perspectives

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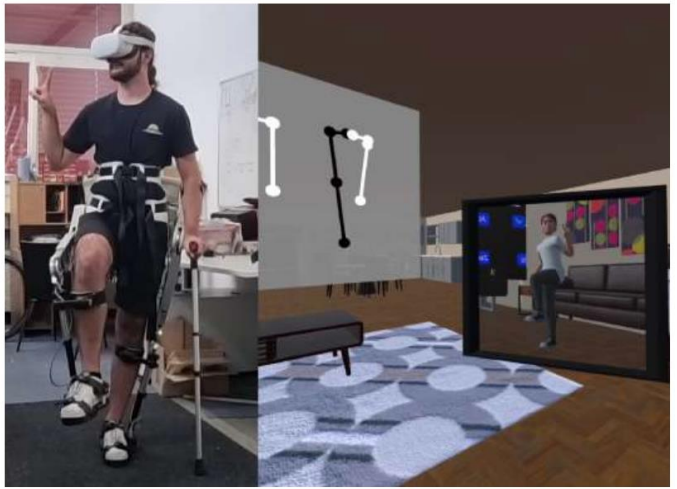
- Limitations:
  - Lack of accuracy for some internal joints rotations (shoulder)
  - Difficulties in handling softwares for older patients
  - Not suitable for severly disabled patients

- Future trends:
  - Newer algorithms (AI, Machine learning)
  - Intuitive software handling
  - Virtual reality headset
  - Exoskeleton-assisted exercises



Questions ?

Thank you for listening !