Realtime patient tracking and reposition in radiotherapy with TOF-based depth camera and CNN-based auto calibration

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The aim of this work is to develop realtime patient movement tracking system for accurate and safe radiation therapy.

Purpose

Realtime patient movement tracking

- Immobilizing and monitoring a patient during radiation treatment are important elements of accurate radiation therapy.

- Although patient's movement is restricted mostly using immobilization devices, patient's stationariness needs to be observed by therapists.

- RGB cameras are used in clinic but visual measurement cannot verify patient's small movement from reference position quantitively.

- Therefore, a system of real-time patient tracking with time-of-flight based depth cameras was developed for quantitive monitoring of patients.

Material & Methods

- Three Azure Kinect (Microsoft, USA) were used. Azure Kinect consists of infrared (IR) projector, depth camera (IR sensor), color camera (CMOS sensor).

Calculating calibration parameters with CNN

- For extrinsic calibration of the cameras, convolutional neural networks (CNN) based auto calibration process was executed.

- The auto calibration program using CNN gets RGB images of depth cameras, and calculates each camera's extrinsic calibration parameters automatically using image's feature.

Visualization using calibration parameters

- Firstly, depth camera coordinates points are transffered to color camera coordinate system.

- Secondly, pointclouds of each camera in color camera coordinate system are combined using extrinsic calibration parameters generated by auto calibration program.

Patient tracking and calculating position difference

- Depth camera stream buffer data at a specific time (camera calculated reference position data) were stored. (Fig 1)

- In order to compute patient's position difference from the reference position, continous buffer data were compared with stored reference position data and colorization of each pixel of 3D pointcloud was differenciated from reference pixel color if moved position differs larger than 3 mm. Translation experiment with patient couch and human body phatom (Atom phatom, CIRS Inc., US) was performed. (Fig 2)

- The developed process was verified. Camera and process accuracy was assessed by comparing with measurements with an electronic laser distance measuring equipment (Disto D810, Leica Geosystems, Switzerland) and with CT position data after matching the camera coordinates and CT coordinates for a human body phantom.

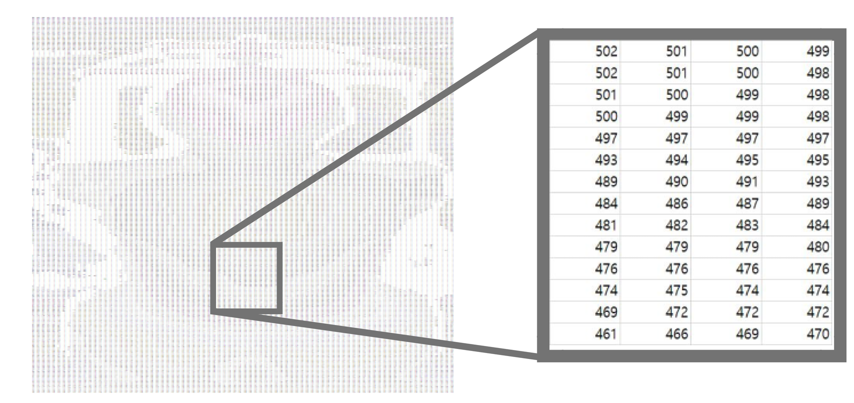

Fig 1. Depth camera buffer data (mm)

Fig 2. Atom phantom (CIRS, US)

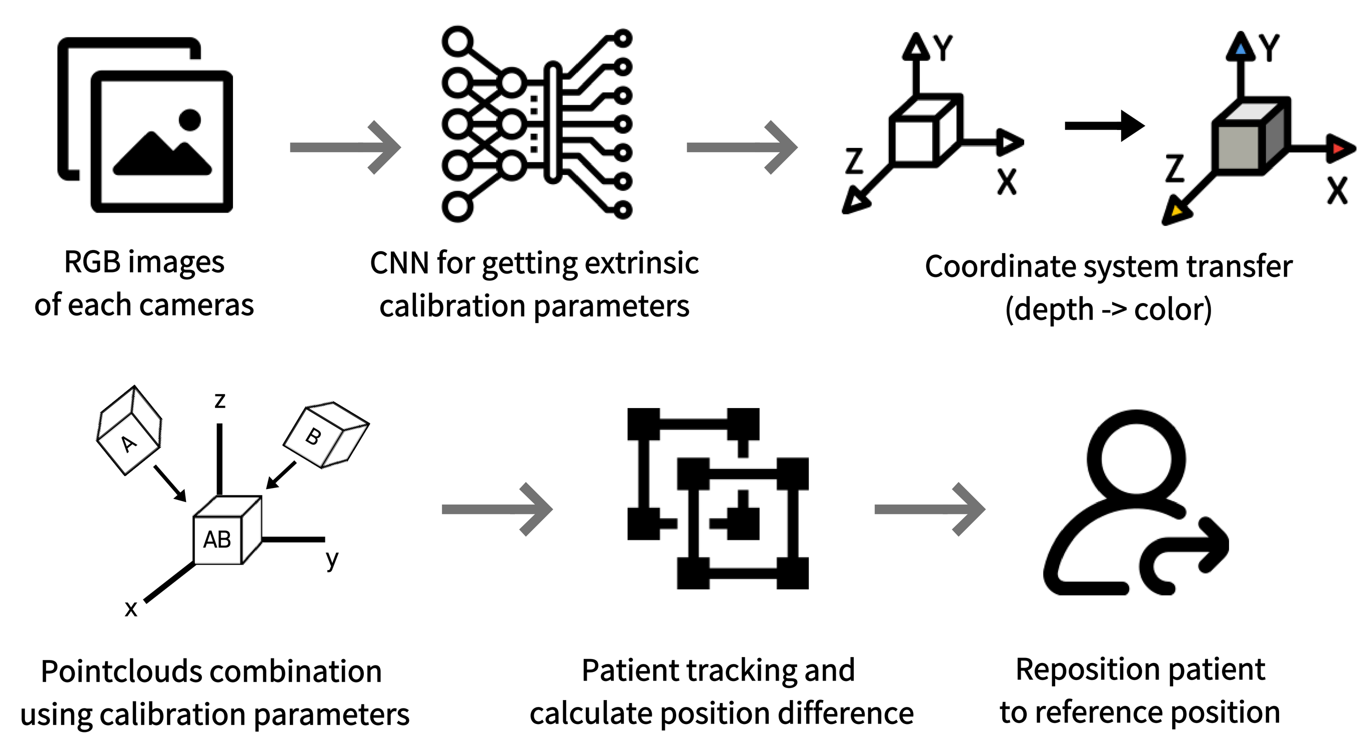

Fig 3. Overall process of patient tracking

Results

- The visualization was successfully constructed, and the phantom movements were easily recognizable. (Fig 4) Translation experiment result with patient couch and phantom is presented below. (Table 1) Patient couch has ± 1 mm error.

- A series of processes described above were successfully performed. (Fig 3)

- Position discrepancies from depth camera at several body points were calculated by laser measuring equipment and the difference from depth camera was under 3 mm.

- Comparison results of laser equipment and CT data will be presented.

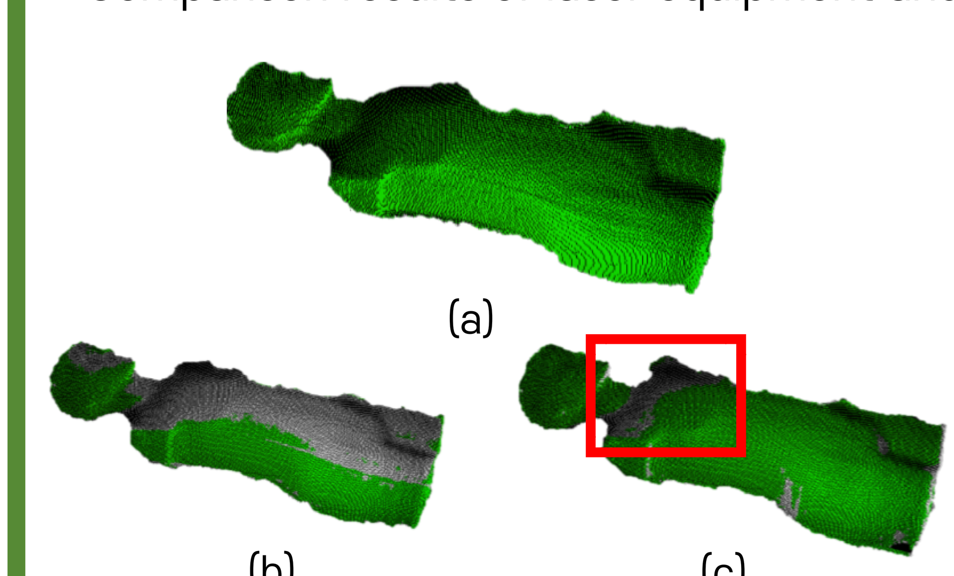

Fig 4. Pointcloud visualization of phantomusing one Azure Kinect
(a) Visualization of reference position
(b) Visualization of 5mm down translation
(c) Visualization of 5mm right translation

measured value / translation (5mm)	mean	std
origin	767.479	20.196
up	764.483	19.135
down	771.542	21.431
left	767.553	20.820
right	768.680	19.666

Table 1. Depth buffer value in abdomen ROI with one Azure Kinect (mm, 53x55 matrix)

Conclusion & Discussion

- With proposed method, accurate realtime patient tracking and position correction during beam irradiation can be acheived.

- As translation experiment implies, some direction of translation with short distance cannot be measured correctly due to object shape.

- If patients wear clothes, it is diffucult to detect patient's movement deliberately.

- Repositioning a patient to reference position is difficult due to three-dimensional characteristics of movement to reference position.

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