Medical Core · Radiotherapy Research

Surface-guided Respiratory Tracking (SGRT)

Build the optical part of surface-guided radiotherapy - patient-surface setup registration and respiratory gating - on a domestic 3D sensor stack.

Period 2026.06 - present | Evidence state Ongoing · Research | Portfolio tier Medical Core

An early-stage research assignment contracted to DIGITRACK within the K-LINAC programme (led by KERI, imaging sub-project led by ETRI): far-field surface reconstruction and near-field real-time breathing tracking with commercial 3D sensors. Commercial systems do not publish the reasoning behind their sensor and algorithm choices, so a domestic stack has to build that evidence itself.

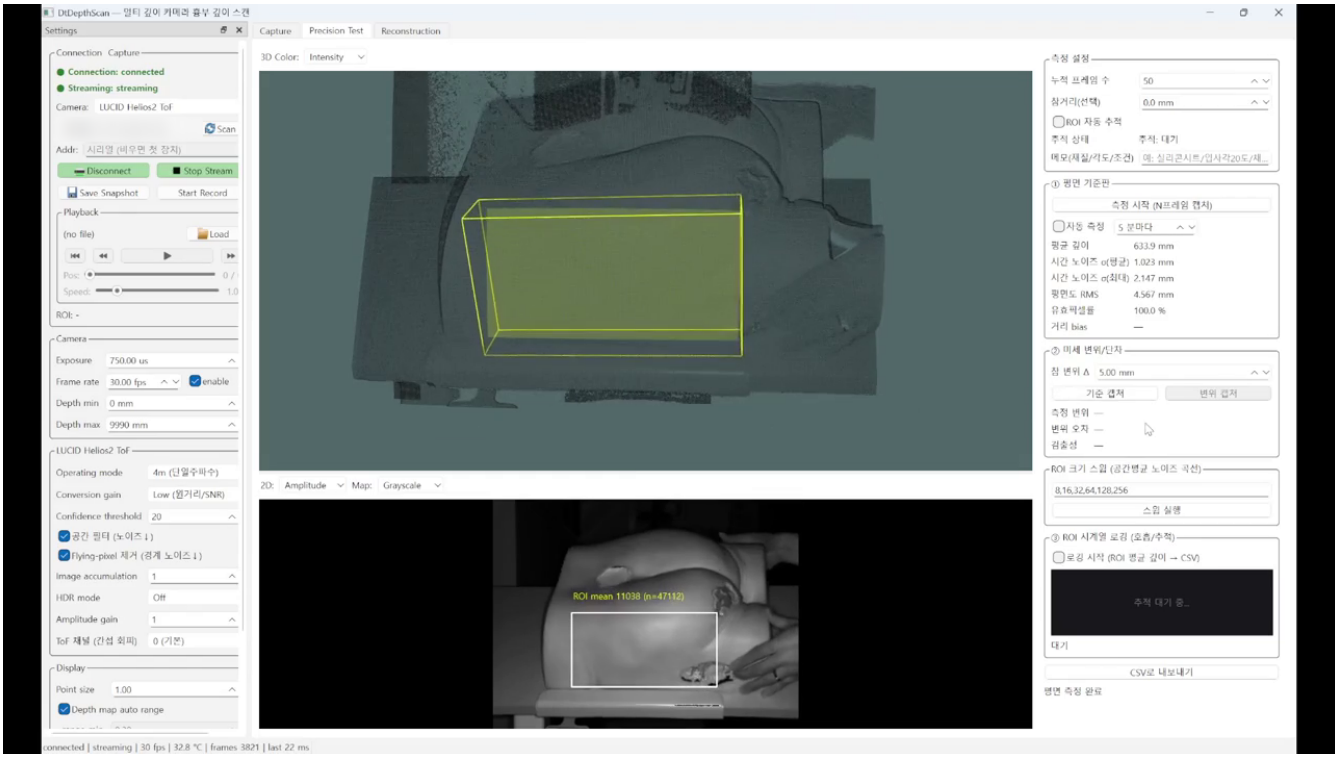


Figure 1. The in-house validation tool DtDepthScan measuring a silicone body phantom: mean depth and temporal noise σ are computed live from the ROI on the point cloud. Device serial and address are masked.

Problem and system boundary

Patient position and breathing must be known during treatment without extra imaging or skin marks.

Owned decisions and implementation

My role

Lead the sensor validation campaign, which first required building the in-house tool DtDepthScan (Qt, VTK, OpenCV): raw continuous recording with acquisition timestamps, ROI depth time series, automatic σ, delivered fps and fill rate, and PLY/CSV export for cross-checking elsewhere. Then design and implement the breathing-tracking algorithm from ROI depth to respiratory waveform and gating signal, define the sensor interface and transport protocol, and run day-to-day project work.

Two optical tracks

Far-field sensors merge point clouds into a surface and register it to the planning CT; near-field sensors turn chest and abdomen ROI depth into a respiratory waveform and gating signal.

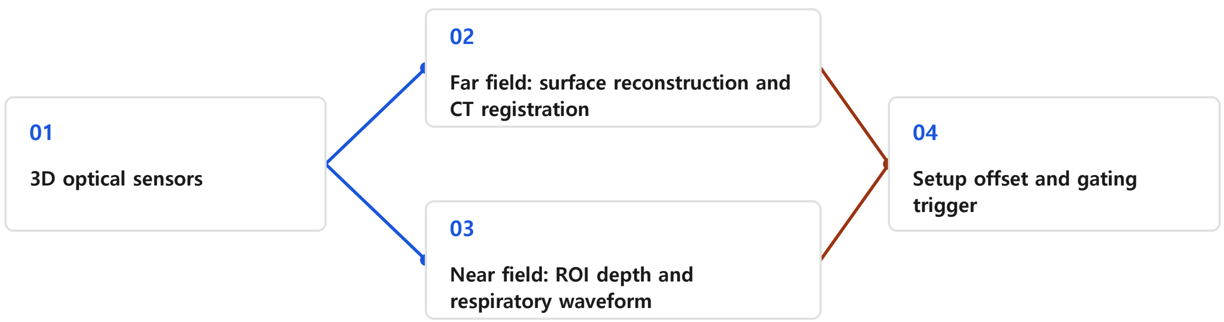
The tool came first

Abstracting the camera layer lets any sensor run the same procedure. Timestamped raw recording gives delivered fps, ROI depth time series yield σ and fill rate automatically, and PLY and CSV export allow cross-checking elsewhere.

One procedure, five sensors

- Silicone body phantom, five distances 0.5-3.0 m
- Five sensors and condition sweeps, 55 runs
- 500 frames per run
- Repeatability ±0.05 mm, σ settles by 50 frames

Two optical tracks converging on one output



Explanatory system relationship diagram; it is not photographic or experimental evidence.

Verification and evidence ledger

A silicone body phantom measured at five distances from 0.5 to 3.0 m with five commercial 3D sensors, 55 runs of 500 frames each, gave precision σ, delivered fps, and fill rate; repeats agreed to within ±0.05 mm. That table and the DtDepthScan captures are my own measurements.

The conditions outlived the numbers

The operating conditions will outlast the σ table. At 0.5 m the default exposure saturates the IR return and no depth is produced, and from a cold start σ is up to 1.7 times worse than at thermal steady state. Both became design inputs for the real-time module.

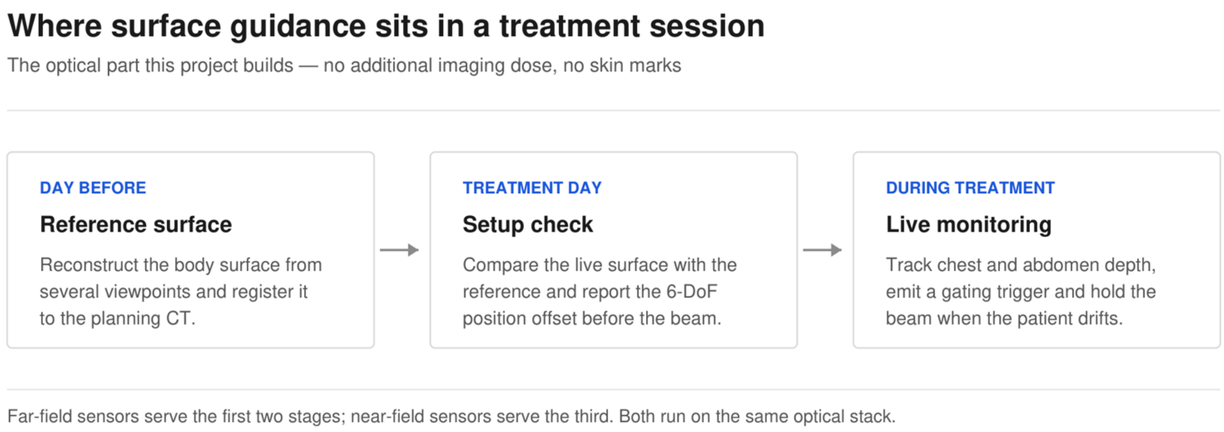


Figure 2. Where surface guidance sits in a session: reference surface the day before, setup check on the day, live monitoring during treatment

Figure 3. The five commercial 3D sensors put through validation: three ToF, one structured-light, one active-stereo

Precision σ of five commercial 3D sensors vs. distance

Author-measured with the in-house validation tool DtDepthScan · silicone body phantom · 500 frames per run
σ [mm] = temporal standard deviation of the mean ROI depth (lower is better)

Sensor	0.5 m	1 m	1.5 m	2 m	3 m	Measured fps	Fill rate
LUCID Helios2+	0.18*	0.07	0.10	0.20	0.45	24–29	≥91%
Helios2+ Narrow	0.09*	0.05	0.10	0.10	0.18	18–25	≥93%
Orbbec Astra 2	N/A	0.06	0.19	0.48	2.04	16–17	100%
Basler Blaze-102	0.07	0.07	0.15	0.13	0.28	~20	100%
Intel RealSense D455	0.15	0.41	1.90	2.99	9.93	~19	≥91%

* 0.5 m values taken with reduced exposure (250 μs) to avoid IR saturation; Astra 2 at 0.5 m is outside its minimum range (N/A). Repeatability ±0.05 mm between repeated runs; σ converges within ~50 frames (about 2 s). ToF sensors need a 15 min warm-up (cold-start σ up to 1.7× higher). Units: σ in mm, fps = frames per second actually delivered, fill rate = valid-depth pixels in the ROI.

Measurements by Jinmin Kim, DIGITRACK, June–July 2026 — sensor validation for surface-guided respiratory tracking (SGRT)

Figure 4. Measured precision σ, delivered fps, and fill rate for the five sensors by distance (author-measured)

Operating conditions found during sensor validation

Author-measured, silicone body phantom, June–July 2026 — each finding changed how the tool is used or built

Near-field exposure

At 0.5 m the default 1000 μs saturates the IR return and no depth is produced. 250 μs restores it, so exposure has to follow distance instead of staying on one preset.

Warm-up

Straight from a cold start, σ is up to 1.7× worse than at thermal steady state (3 m: 0.77 mm cold vs 0.45 mm warm). Fifteen minutes of settling precedes every run.

Repeatability

Repeated runs under the same conditions agree to within ±0.05 mm, and σ converges after about 50 frames (~2 s), which makes a short screening run trustworthy.

Mismatched exposure units

One sensor takes depth exposure in μs but colour exposure in 100 μs steps; setting it by hand silently ruins the run. Auto-exposure control was added to the validation tool.

These conditions are the design input for the real-time tracking module: distance-linked exposure, warm-up interlock, sensor-state monitoring.

Figure 5. Four operating conditions the measurements produced: near-field exposure, warm-up, repeatability, mismatched exposure units

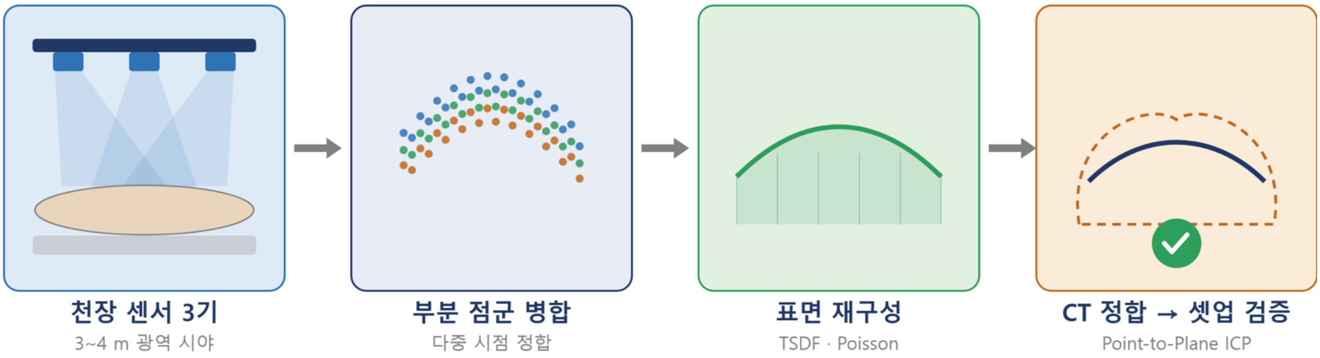


Figure 6. Far-field track: merge point clouds from several viewpoints, reconstruct the surface, register it to the planning CT

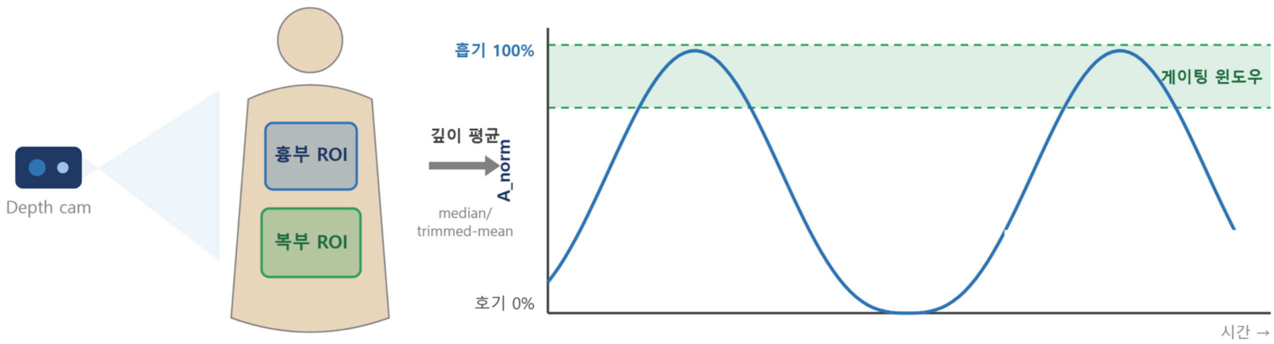


Figure 7. Near-field track: chest and abdomen ROI depth becomes a respiratory waveform, and the gating window is judged on it

Role, team result, and limits

Team result

Consortium partners own 4DCT reconstruction, the image-guidance framework, and clinical advice. Programme-level results are not attributed to me.

Limitations

First-year sensor validation only; no clinical performance or programme-target achievement is claimed, and programme targets, budgets, and metrics of other institutions are not published here.

Research boundary

First-year sensor and algorithm groundwork; no clinical performance or programme-target achievement is claimed.

Collaboration boundary

The clinical partner is the radiation oncology department of Seoul St. Mary's Hospital; interfaces are agreed with 4DCT reconstruction, image guidance, and integrated-control partners.

Implementation technologies

ToF camera · Structured light · Qt · VTK · OpenCV · Python · 4DCT

Primary capability

3D Geometry & Registration · Sensor Fusion & Localization · Medical Navigation & Visualization

Registered public evidence

No external public link is currently registered.

What to bring

Share the problem, data or sensors, target validation, and schedule. We can define coordinate and evidence boundaries together.

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