**Cancer Patient Movement Tracking System During Radiotherapy Treatment Using Artificial Intelligence**

## **System Architecture**

The tracking system comprises the following key components:

### ****1. Cameras:****

* High-resolution RGB or depth cameras for capturing patient movements.
* Strategically positioned for optimal coverage of the treatment area.

### ****2. Pose Estimation Model:****

* Pre-trained AI models to estimate patient posture and movement, including:
  + **OpenPose** – Multi-person keypoint detection.
  + **MediaPipe Pose** – Lightweight, real-time tracking.
  + **DeepLabCut** – High-accuracy pose estimation.
  + **Custom Models** – Trained on medical datasets.

### ****3. Processing Unit:****

* High-performance GPUs or CPUs for real-time pose estimation and motion tracking.

### ****4. Software Pipeline:****

* Frameworks for pose detection, data processing, and movement visualization.
* Uses **OpenCV, TensorFlow, PyTorch** for AI-driven analysis.

### ****5. Output Interface:****

* Tracks patient posture and detects excessive movement.
* Integrates movement data with imaging systems for real-time treatment adjustments.
* **Automatically stops the radiation machine if excessive motion is detected.**

## **Machines Used in Radiotherapy**

### ****1. Radiation Source Machines:****

* **Cobalt-60 (Co-60) Machine** – Used in external beam radiotherapy.
* **Iridium-192 (Ir-192) Brachytherapy System** – Internal radiation therapy.

### ****2. Radiation Generation Machines:****

* **Medical Linear Accelerator (LINAC)** – Provides high-energy X-rays/electrons for precise targeting (**±3mm along the central axis**).

## **Hardware Setup**

* **Cameras** – High-resolution RGB/depth cameras.
* **Lighting** – Ensures consistent illumination for accurate tracking.
* **Processing Units** – High-performance GPUs/CPUs.

## **Software and Algorithm Implementation**

### ****1. Pose Estimation Model Selection:****

* Selection of an open-source or pre-trained model:
  + **OpenPose** – Multi-person keypoint detection.
  + **MediaPipe Pose** – Efficient real-time tracking.
  + **DeepLabCut** – High-accuracy tracking.

### ****2. Model Integration:****

* Deploying the model in a machine learning framework (e.g., TensorFlow, PyTorch).

### ****3. Data Preprocessing:****

* Capturing and resizing video frames.
* Normalizing pixel values for consistency.

### ****4. Pose Estimation Pipeline:****

* Detecting key points (e.g., head, shoulders, joints) per frame.
* Analyzing movement patterns.

### ****5. Movement Tracking:****

* Comparing key point positions across frames to detect motion.

### ****6. Output and Integration:****

* Visualizing detected poses.
* Sending movement data to the imaging system.
* **Automatically stopping the machine if excessive motion is detected.**

## **Workflow for Tracking**

### ****1. System Setup:****

* Mounting and calibrating cameras for optimal coverage.

### ****2. Patient Preparation:****

* Ensuring minimal movement during treatment.
* Capturing initial pose for motion detection baseline.

### ****3. Tracking Activation:****

* Capturing and processing video frames.

### ****4. Motion Detection:****

* Analyzing deviations in key points (e.g., head tilt, chest movement).
* **Triggering an automatic stop if movement exceeds predefined thresholds.**

### ****5. Post-Processing:****

* Using motion data to correct imaging artifacts.

## **Key Considerations**

### ****1. Accuracy:****

* Fine-tuned models improve precision in clinical environments.
* High-resolution input enhances subtle movement detection.

### ****2. Latency:****

* Optimized pipeline for real-time processing (<50ms latency).

### ****3. Patient Safety and Comfort:****

* Non-intrusive setup to minimize anxiety.

### ****4. Environmental Adaptability:****

* Handling occlusions and varying lighting conditions.

### ****5. Privacy:****

* Anonymized, locally processed video data ensures confidentiality.

## **Tools and Resources**

### ****1. Hardware:****

* **Cameras** – High-resolution RGB/depth cameras.
* **Processing Units** – High-performance GPUs/CPUs.

### ****2. Software:****

* **Pose Estimation Frameworks:**
  + OpenPose
  + MediaPipe Pose
  + DeepLabCut
* **Libraries:** OpenCV, TensorFlow, PyTorch.

## **Advantages of AI-based Tracking**

* **Non-invasive** – No physical markers required.
* **Reduces setup time** – Quick deployment.
* **Improved patient comfort** – No wearables needed.
* **Enhances safety** – **Automatically stops the radiation machine upon excessive motion detection.**

This AI-powered system ensures accurate treatment, minimizes imaging artifacts, and improves patient safety during radiotherapy.

| **Feature** | **Traditional Gated Systems (e.g., RPM, VisionRT)** | **Your AI-Based System** |
| --- | --- | --- |
| **Motion detection method** | Infrared markers, chest bands, reflective dots | **Camera + AI-based pose estimation** |
| **Hardware required** | Specialized sensors, calibration markers | **Standard RGB/depth cameras** |
| **Setup time** | Longer (attach sensors, calibrate) | Faster (camera placement + software) |
| **Intrusiveness** | Can be uncomfortable or anxiety-inducing | **Non-contact, non-intrusive** |
| **Cost** | High (proprietary hardware + maintenance) | **Lower (uses existing hardware + open-source AI models)** |
| **Scalability** | Limited to clinics with advanced infrastructure | **Scalable to smaller clinics or mobile setups** |
| **Real-time processing** | Yes (hardware-accelerated) | **Yes (with GPU or optimized model)** |

## 🧠 How Your AI System Works Conceptually:

1. **Camera** records patient in treatment position
2. **AI model (e.g., MediaPipe Pose, OpenPose)** estimates body keypoints (head, shoulders, chest, etc.)
3. **Initial keypoints** saved as baseline (i.e., “correct position”)
4. In real time:
   * Keypoints are compared to baseline
   * If deviation > threshold (e.g., head moved 5 mm), trigger **automatic pause**
   * Resume when keypoints return to acceptable position

✅ This is a **vision-based gating system**, without requiring markers or hardware sensors.