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A concept for acquiring clinical expert motion data for digital twins and humanoid robots

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Abstract: This work presents a novel concept for capturing and curating expert clinical motion intelligence ("kinesthetics") to enhance nursing education and training. By recording optimal movement sequences using motion capture suits and wireless body area sensor networks with synchronized IMUs, essential tacit knowledge is preserved. These data are condensed into digital motion twins, creating virtual models that simulate expert actions and support dynamic, person-specific training. Humanoid robots can then use these motion twins to provide realistic, responsive practice environments. The approach emphasizes the importance of relational, context-aware movements and aims to make education more accessible and effective. Ensuring data protection, ethical standards, and solutions for individual variability is crucial. Ultimately, this concept supports the responsible integration of technology into nursing, strengthening bodily relational practice rather than replacing it.

I. Introduction

Besides factual and procedural clinical knowledge about certain domains such as, e.g., nursing, endoscopy or surgery, also comprehension and knowledge about optimal movements of the experts and specialist is important for the education and training of tomorrows clinical staff. With an upcoming lack of clinical experts, the acquisition and preservation of knowledge about optimal and energy efficient movement sequences ("kinesthetics") is essential.

Within the field of nursing, typical such movements relate to the patient's mobilization (measures for activation and promoting movement) or transfers (e.g. from bed to wheelchair), while in the sphere of endoscopy (gastroscopy and colonoscopy) movement sequences describe the complex control techniques used by endoscopists to navigate a long flexible instruments through natural orifices in the body by precisely coordinating angulation wheels, pushing, pulling and rotating the endoscope shaft to obtain an optimal view of organs. This list of "movement intelligence ("kinesthetics") could easily be continued through the compete medial field.

II. Material and methods

To capture, curate, preserve and make use of expert motion intelligence for education and, training, the concept of a novel approach will be provided, see Fig. 1. Based on typical movements within nursing (A), provided by expert intelligence (Fig. 1.B) [1], the various motion sequences can be captured with a motion capture suit (Fig. 1.C) as reference [2]. As such suits are expensive, an application-optimized light-weight wireless body-area sensor-network (WBAN) can be used (Fig. 1.D) [3] to capture these motion sequences with an array of closely synchronized *inertial measurement units* (IMUs) (Fig. 1.E) [4]. All nursing motion sequences captured either by the suit or the WBAN by various experts are condensed and curated into to a *digital motion twin*, being the entity, where all motion intelligence is stored and preserved (Fig. 1.F). This digital motion twin can finally be used to emulate various stored motion sequences on physical AI systems such as humanoid robots (Fig. 1.G).

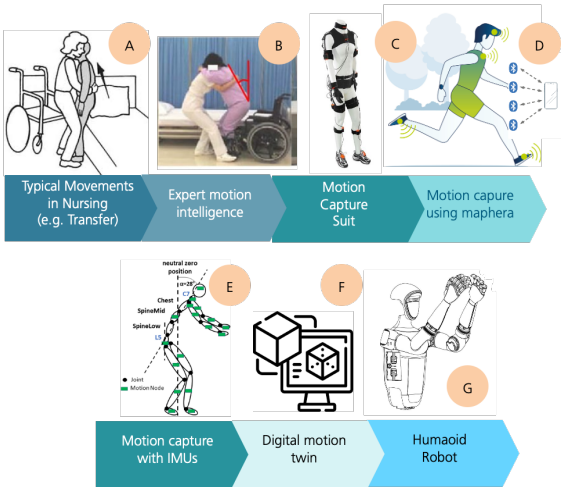

Fig. 1: Concept of various interacting components for the acquisition and preservation of "motion intelligence", see text.

II.I. Motion capture suits

Motion capture ("mocap") suits have already been used in different types of healthcare scenarios, such as patient assessment, rehabilitation, or clinical trials. Such suits allow

to capture detailed body movements for diagnosing disorders (e.g. muscular dystrophies), creating personalized therapy, measuring worker strain (ergonomics), or making trials more efficient by tracking subtle changes in gait and posture [5]. One of the most prominent mocap-suits is the XSense Suit (*movella corp*., Fig. 1.C) which in our case shall be used as high-end reference system for the WBAN.

II.II. Wireless Body Area Sensor Network

As mocap suits are quite costly and challenging to use in most clinical settings, a WBAN shall be applied. *maphera*© (Fig. 1.D) is such a WBAN for the recording and synchronizing physiological data. Commercially available mobile sensors such as smartwatches, sensor-integrated shirts, arm and chest straps, finger clips, VR glasses, and smart glasses can potentially be integrated or combined with the system to record vital signs (pulse and respiratory rate, ECG, EDA, EMG) or eye changes (pupil size, gaze direction, blinking). In addition, proprietary sensor nodes can be integrated. In addition, IMUs can also be integrated into the WBAN to record macro and micro movements of the wearer (Fig. 1.E). The data from all freely configurable sensor nodes can be collected on a smartphone and synchronized using Bluetooth Low Energy. The system focuses on data quality and consistency, as well as close synchronization of the sensors.

II.III. Digital motion Twins

Digital twins are an emerging technology in healthcare and are gradually demonstrating significant potential for application in nursing. The concept of a digital twin originates from the mapping between physical entities and virtual models, enabling the monitoring and analysis of the patients' — or care-givers — health status, thus providing accurate support for nursing as well as safety. — *Digital motion twins* refer to the application of digital twin technology in form of virtual replicas of nurses, patients, as well as physiological systems to model, preserve, possibly predict physical needs, and optimize care, especially for complex tasks such as elderly sit-to-stand transitions or guiding physical therapy, moving beyond just static data to simulate dynamic actions and improve patient outcomes. It combines the acquisition of motion data (from wearables or mocap-suits) with biophysiological models to create dynamic, person-specific simulations, thus helping nurses and clinicians anticipate needs and reduce risks. Digital motion twins can also be used to provide “motion intelligence” for training and education of nursing staff

II.IV Humanoid Robots

Humanoid robots are increasingly used in nursing education. They help students practice communication, motion intelligence and bedside manners in a safe environment. Such robots can mimic various medical conditions, allowing trainees to respond to realistic clinical situations. By providing immediate feedback, they can support the development of critical thinking, decision-making skills as well as nursing motion. Their application could reduce the need for human experts in training, making simulations more flexible and accessible [7].

III. Results and discussion

In our concept we highlight the importance of capturing expert movement knowledge, or "kinesthetics," in the field of nursing to enhance education and training. Traditional motion capture suits can record these expert movements but are costly and cumbersome, leading to the use of more practical WBANs. Such collected motion data must then be curated into digital motion twins, which act as virtual models for simulating expert actions. These digital twins can then be used to program humanoid robots, enabling realistic and dynamic training for clinical staff. This approach aims to preserve valuable expert motion knowledge and make clinical education more effective, accessible, and efficient.

IV. Conclusions

The proposed concept for capturing clinical motion intelligence is most meaningful when aligned with Hülsken Giesler’s view of nursing as a bodily relational practice, emphasizing co-movement with patients [8]. Digital methods must capture not only kinematic data but also the context and interactive meanings of movement, requiring expert annotation and contextual metadata. Professional nursing actions involve tacit knowledge (timing, pressure, contact, gaze, and voice) which should be recorded with synchronized sensors and embedded in digital twins, so learners develop real co-movement, not just mimicry. Motion twins and robotics should facilitate dialogical learning and be validated by clinical outcomes and patient experience, with real care relationships as the standard. Technology must support co-agency, while ensuring data protection, consent, and transparency. As expert movements are not universally transferable, adaptive, person-specific solutions are needed. Future work addresses co-design with practitioners and patients, evaluate effectiveness, and create curricula combing relational and technical skills. In summary, digital preservation of motion intelligence is valuable if it respects and reinforces the bodily relational core of nursing, making technology a responsible medium for patient interaction.

AUTHOR’S STATEMENT

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REFERENCES

[1] Z. Huang et al.: Self-help training system for nursing students to learn patient transfer skills. *IEEE* Proc’s *Learning Tech* 7(4), pp. 319-332, 2014.

[2] N. Govardhanan et al.: Real-Time Activity Classification Using Wearable Sensors: A DL Approach for Gait Analysis, Proc‘s INCIP 2025, pp. 576-581.

[3] D. Weber, N. Pfeiffer, 2025. Methods for microsecond accuracy synchronization of Wireless Body Area Networks for biosignal acquisition using Bluetooth Low Energy. Measurement 253, 117635.

[4] S. Hellmers et al. Posture and Mechanical Load Assessment During Patient Transfers. SN COMPUT. SCI. **3**, 375 (2022).

[5] S. Salisu, et al. Motion Capture Technologies for Ergonomics: A Systematic Literature Review. *Diagnostics* **2023**, *13*, 2593.

[6] D. Gu et al. Digital Twins in the Field of Nursing: A Literature Review. Nurs Adm Q. 2025 Oct 1;43(10):e01338.

[7] A.W. Kushniruk et al. The NAO Robot in Healthcare and Education: A Scoping Review. Stud Health Technol Inform. 2025 Apr 8;323:374-378.

[8] M. Hülsken-Giesler: Mimesis in Nursing Practice: The Hermeneutical Potential of the Body to Understand Patients’ Lived Experiences. In: Foth et al (eds.): Critical Approaches in Nursing Theory and Nursing Research. Implications for Nursing Practice. Göttingen: V&Runipress, p. 151-168, 2017