Week 5: Annotated Bibliography

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# Annotated Bibliography

Examining the Northcentral University (NCU) Library with search terms such as elderly care, IoT, and video health monitoring uncovers several industry-wide trends.

## Just Walk-Out (2018)

Amazon Go enables customers to purchase goods from physical stores without requiring cashiers (Amazon, 2021). Their solution uses Deep Neural Network (DNN) algorithms that process real-time video streams. Wankdhede et al. (2018) assessed the system’s sophistication through a series of shoplifting test cases. Their malicious attempts to steal items failed, which provides evidence that real-time video monitoring is an effective real-world tool. However, before engineers can transpose the solution directly into a person’s home, several critical changes are necessary.

## Consumer RGB-D Cameras and Applications (2012)

Action tracking systems require sophisticated machine learning algorithms that classify spatiotemporal movements. They typically follow a process that collects RGB+D (Color and Depth) camera frames and decodes them into 3-D space (Litomisky, 2012). Next, a series of filters must crop, resize, and align the principal subject. These steps are necessary because people can freely move around the room. Third, a feature extract process outputs matrices representing the body’s location, pose, and orientation. Finally, those tensors flow into Long-Term Short-Term (LTSM) algorithms that classify the movement into gestures.

## Toyota Smarthome (2019)

Many general-purpose gesture detection libraries already exist for behaviors such as sporting events and other high-energy actions. However, daily indoor activity tends to be more subtle and nuanced (Das et al., 2019). This discrepancy limits reusability and creates the need for purpose-built training sets that sufficiently cover patient-specific actions. Furthermore, these custom datasets necessitate vast quantities of examples with accurate labels, or the machine learning model will produce unreliable results. As a general rule of thumb, each model parameter needs at least ten examples to avoid overfitting (Snee, 2015). Gesture models can quickly explode into hundreds or thousands of parameters which represents the 3-D space plus time. Mechanisms exist for accelerating the process of building custom datasets (e.g., transfer learning). However, this is still an open research topic.

## Integration of SmartHome (2020)

After the system decodes the subject’s actions, it needs to act upon that information. While some responses are relatively trivial (e.g., dispatch an ambulance), other reactions must utilize Cyber-Physical Systems (CPS) to cross the digital boundary. Building these integrations is challenging as it draws upon knowledge spanning networking, sensors, embedded systems, and related concepts. Furthermore, CPS devices lack standardization which impacts component reusability.

Elloumi et al. (2020) propose a Smarthouse Operating System (SOS) that provides core services such as identity management, system state, and message routing. Their blueprint also outlines several automation application profiles (e.g., heat management and fire detection). These capabilities enable developers to focus on their integrations value differentiation versus writing tedious generic code. Finally, the authors demonstrate the effectiveness of this approach using a CNC (Computer Numerical Control) machine to print a replica house (2 cubic feet).

## Privacy Enhanced Cloud-Based Facial Recognition (2021)

It can be helpful to think of identity within IoT as a profile of historical choices, stated preferences, user roles, and known associations (Wachter, 2018). When the device understands the user’s profile, the experience can be customized and produce more accurate predictions. However, the payment for access to these inferences and decision processes comes from personal information, such as calendars, contacts, and routines (Mickens, 2018). This trade creates privacy concerns that can be subtle and can go unnoticed for some time.

The monitoring system will collect intimate knowledge of its assigned patients and even capture private communications. Therefore, mechanisms must exist for protecting this information as it flows between different compute domains (e.g., local versus cloud providers). Yang et al. (2021) propose a Secure MultiParty Computation (SMC) model that locally encrypts sensitive images (e.g., faces). Afterward, they use Cheon-Kim-Kim-Song Homomorphic Encryption (CKKS HE) to remotely make predictions on the encrypted payload (e.g., that is Bob’s face). Ideally, the system minimizes the information that leaves the patient’s private network. However, when sensitive images must upload into the cloud, the system can leverage encryption strategies like CKKS HE.

## Healthcare Monitoring using IoT (2020)

Software that takes advantage of cloud resources gains agility, elasticity, instantaneous provisioning, and cost management constructs. However, some businesses are reluctant to trust these environments entirely due to security concerns (Ali et al., 2015). Alternatively, systems engineers can deploy hardware appliances that bring cloud aspects into the home or medical facility. For example, Abdulameer et al. (2020) propose implementing a small replica house similar to Elloumi. Their solution uses various wearable device sensors, Arduino micro-controllers, and one Raspberry-PI. In addition, users can check their vitals and other health KPIs (Key Performance Indicators) through a web portal. Therefore, provisioning small on-premise appliances makes sense and handles scenarios such as failures at the ISP (Internet Service Provider). In addition, other benefits come from standardizing the control plane versus assuming the patient’s personal computer is compatible and Always-On Always Connected (AoAC).

## Two-Way Video Healthcare System Design (2021)

Recently, Yi & Feng (2021) proposed a complete video-based injury rehabilitation solution that includes support for CPS and wearables. The authors leverage Carnegie Mellon University’s Open Pose library to map skeletal structures within images. Then, they publish this information and various sensor readings (e.g., smoke detectors) into a secure private cloud. Unlike Toyota (2019), the authors use Dynamic Time Warping (DTW) to compare and categorize the patient’s movements. Researchers use DTW to normalize time series and avoid discrepancies from action speeds (e.g., raising one’s hand within two versus four seconds).

## Nonintrusive Home Care Monitoring (2020)

Chen, Saiki & Nakamura (2020) state that monitoring low-insensitive slow physical movements is challenging. These issues arise because training data is not broadly available due to researchers focusing on fast-paced sporting video by default. Their study uses PoseNet to track skeletal movements and predict activities. Additionally, they compare the resources necessary for Raspberry PI and a desktop computer to make those predictions. The researchers assess the model’s accuracy in terms of delta changes in the bounding box. This approach is unique and comes with several limitations. For instance, a person laying on the couch versus standing will have different dimensions. While this methodology is not directly usable, it provides another measurement strategy.

## Component-Based Intelligent Home-Care System (2011)

Chaing et al. (2011) propose a Uniform Markup Language (UML) model for collecting health care metadata from video sources. Their solution focuses on physiological information, such as the patient’s movements. The model also describes a storage structure for persisting the recordings. There are specific aspects from this study that are reusable. For instance, the authors propose service interfaces to several patient monitoring components (e.g., heart rate and oxygen levels). However, the video monitoring system is critically dependent on wearable technologies. This requirement makes the solution loosely relevant to the ESHOS project.

## Pain Detection (2018)

Nugroho, Harmanto & Hassan (2018) propose a deep learning model to assess a patient’s pain level. Their solution uses facial expressions from fourteen people that train both OpenFace and FaceNet topologies. The researchers claim that they can predict with 93% accuracy if a person is currently experiencing pain. This capability is helpful within home monitoring systems as a mechanism to assess medication levels. The ESHOS solution could introduce similar capabilities to improve patient care. For instance, the system could emit a pain frequency Key Performance Indicator (KPI) as part of the patient’s scorecard. The scorecard would then grant reassurance to family members that sufficient attention is available.

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