Chapter 3: Research Method

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*Write an introduction and chapter outcomes here.*

## Statement of the Problem

The problem to be addressed in this study is implementing a quality assurance process for an autonomous assistant to elderly and special needs care. Multiple industry-wide trends create the need for this technology. First, the number of practicing nurses has declined for several years (Kim & Kim, 2021). This labor shortage increases hiring and employee retention costs that the patients and welfare programs must cover. The funding gap is a global problem that does not impact all communities equally. For instance, in South Africa, rural special needs communities have 57% fewer nursing visits than their urban neighbors (Besada, 2020). Newly industrialized economies like Taiwan, South Korea, Thailand, and Malaysia are experiencing challenges maintaining their long-term care programs due to growing costs (Phua, 2021). Domestic programs like Veterans Health Administration (V.H.A.) and Medicare are not immune to these economic limits (Lei et al., 2021). Businesses and governments need to control these costs and replace human labor with less expensive automation processes.

Implementing and verifying those processes comes with a high barrier to entry, precisely due to personal privacy concerns, logistical complexity, ethical & cultural considerations, and procurement & configuration overhead. For example, a recent study shows that 95% of Pakistani versus 50% of New Zealand patients refuse to share a severe medical concern outside their primary care physician (Shirazi & Shekhani, 2021). Researchers create frameworks to mitigate these privacy concerns (e.g., redaction), though these procedures are challenging in practice (Blackhurn, 2021). Beyond human and process issues are technical complexities in configuring prototype autonomous assistants. It requires multiple domain specializations like computer networking, embedded technologies, AI/ML, and distributed computing (Tun, Madanian, & Mirza, 2021). Each cross-cutting concern adds complexity and reduces the probability that small teams can successfully provision their test environment. Furthermore, those difficulties limit other researchers from reproducing the results. These factors slow down innovation and restrict the value researchers can contribute to the body of knowledge.

## Purpose of the Study

This constructive research design study aims to propose a research process that divorces privacy and safety concerns from investigating autonomous assistants in elderly and special needs care. It aims to deliver this capability by utilizing humanoid constructs within a realistic physics simulation process like PhysX or Gazebo (Bipin, 2018; Unreal, 2021). These engines support replaying specific MoCAP human behaviors under varying character properties such as weight, flexibility, and dexterity. Next, positioning virtual cameras, instruments, and devices within the virtual world enables researchers to collect their experimentation data. Lastly, the automation can modify the environment using programmable interfaces such as raising the alarm or applying other mitigations.

Hemodialysis (H.D.) patients have a high risk of falling and becoming injured (Shirai et al., 2021). This situation negatively impacts their quality of life by either remaining in bed or requiring more medical resources. The study explores this use case by virtualizing the H.D. patients and monitoring them with an AI/ML CV process to collect metadata and predict a fall in advance. Human trials prioritize safety, creating challenges to study metadata properties like floor slickness and character overexertion (Aihara et al., 2021). In contrast, humanoids are well-suited for these experiments. Furthermore, the lack of privacy concerns simplifies the video collection in bathrooms and showers.

Robot operating systems (R.O.S.) and similar toolchains support generating dozens of floor plans and filling them with furniture (Bipin, 2018; A.W.S. RoboMaker, 2021). These services streamline experimentation, allowing the research to focus on the patient requirements versus simulation infrastructure. The study will use these capabilities to verify the AI/ML CV process across a reproducible gradient of character properties (e.g., weight from 80 to 500 lbs and age between 30 to 120 years).

## Research Methodology and Design

Design science is a research methodology that creates purposeful artifacts and applies them to study a phenomenon (Hevner et al., 2004). Both academic and business communities employ this method as a standard approach to Information Technology and Communication (IT&C) problems (Peffers et al., 2007; Bryar & Carr, 2021). It comes with well-defined guidelines to implement a three-phased procedure. First, the researcher(s) must identify a domain-specific challenge. Next, that researcher creates artifacts that study this phenomenon. Third, those artifacts assess the topic and communicate answers to the research questions.

### Study appropriateness

This methodology is appropriate *because…*

### Alternative methodologies

Quality research begins with a well-defined set of questions, such as ‘can an autonomous vehicle safely navigate city streets?’ Next, the researcher needs a plan to answer the question by collecting evidence and observations. Executing that plan requires a collection of quantitive and qualitative methods. Each of these methods is a tool with its inherent strengths and weaknesses (Jason & Glenwick, 2016). These attributes necessitate researchers to understand when a hammer is more appropriate than a screwdriver (see Table 1). Many people erroneously believe that quantitative methods are superior to qualitative alternatives (McCusker & Gunaydin, 2015; Creswell, 2014; Jason & Glenwick, 2016). This naïve perspective incorrectly assumes that a hammer is always the right tool. When researchers treat screws like nails, it results in erroneous publication claims.

Table 1: Research Approaches

|  |  |  |
| --- | --- | --- |
| Approach | Description | Example Use Case |
| Quantitative | Statistical modeling of a scenario | * Estimate the probability of an event * Stating a broad generalization * Cause and effect analysis |
| Qualitative | Non-numerical representation of a scenario | * Open-ended surveys * Exploration of needs * Investigating a local issue |
| Mixed Method | Combination of both quantitative and qualitative | * Examining the breadth and depth of a topic * Examining a scientific idea and then mapping it to use cases |

Consider the difference when the vehicle study’s objective is (a) to identify safety requirements versus (b) modeling the limitations of the braking system. Under (a), qualitative methods best support the open exploratory nature of the problem. With (b), the answer needs a quantitative method that describes the relationship of multiple variables, such as the car’s speed and the number of objects on the road. However, a more comprehensive study could answer both (a) and (b) by first uncovering the importance of braking enhancements, then describing the limitations in greater detail.

*Now let’s take that analogy back to the original problem statement. There should also be a page(?) that describes how each of these studies could look before saying that these are ultimately different problems than the goal here… and that goal is to study neural networks in a quasi realistic use-case.*

## Population and Sample

For an experiment to be successful, it needs to have sufficient *power* to measure the *effect* in question. Several knobs feed into the power of an experiment, such as relaxing the confidence interval, using parametric statistics, converting to a one-tail model, increasing the samples, or adjusting the sensitivity (Donovan, 2016). Choosing which value to tweak and optimize is scenario-specific and can be somewhat of an art form.

### Determining Power

*Insert data about choosing the power level here*. Given the relatively small sample count, adjusting the confidence intervals to meet acceptable power requirements might be necessary. Another option might be to reduce the number of racial categories, from nationalities to three groups. These data tweaks might detect high-level trends that future research could tease further.

### Determining Effect

Effect size measures the strength of a phenomenon (Donovan, 2016). While calculating the difference between the two distributions is relatively straightforward, it can be difficult to predict ahead of time. This bittersweet relationship introduces challenges when determining the appropriate sample size. One potential solution is to use an iterative sequential sampling policy instead of a fixed size upfront (García-Pérez, 2012). In this situation, *insert data about what this means for this situation* and variable selection. While this small group would have a reasonably low confidence interval, it could qualitatively hint at the overall sample size needing to be minor, medium, or large. There are potential risks that the random-initial sample produces an invalid seed in the study.

### Potential Sample Sizes

Despite the effect size being unknown potential, it is possible to determine the range of sample sizes for the experiment (see Table 2). G\*Power version 3.1.9.7 projects that t-tests of the “difference between two independent means (two groups)” for a one-tail model will need somewhere to *insert actual values*. Since *insert available values* examples, there should be sufficient coverage assuming the specific measurements are kept simple.

Table 2: Sample Sizes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Power | Effect Size | Confidence – 50% | Confidence – 80% | Confidence – 95% | Confidence – 99% |
| 70% Adequate | 0.20 – Small | 28 | 188 | 472 | 816 |
| 0.50 – Medium | 6 | 32 | 78 | 134 |
| 0.80 – Large | 4 | 14 | 32 | 54 |
| 95% Excellent | 0.20 – Small | 272 | 620 | 1084 | 1580 |
| 0.50 – Medium | 44 | 100 | 176 | 256 |
| 0.80 – Large | 18 | 40 | 70 | 102 |

### Acquiring the required sample

This study aims to demonstrate a research methodology for using humanoids in simulation processes to assess machine learning models. It presents an example scenario of employing computer vision (C.V.) to detect patients falling. The research project will generate different humanoid configurations and have them perform MoCAP sequences. For instance, one experiment would provide a thirty-year-old actor that’s one hundred pounds (forty-five kilograms). Another one could have a sixty-year-old actor that weighs three hundred pounds. The simulation software will use these variables to influence movement speed and flexibility.

Using this approach is appropriate for the dissertation proposal methodology and design. It has several core strengths, such as avoiding a cumbersome human recruiting process and concerns that the selection procedure is unfair. This method examines the generalization and usefulness of the research technique. Furthermore, the experiments automated nature makes reproducing the results straightforward and economical. This design choice means that future researchers have sufficient information to replicate the study.

## Instrumentation

In a physics simulation process, humanoid actors perform behaviors in a highly controlled environment. This feature allows the study always to know the current world state and quickly assess any C.V. model prediction’s accuracy.

*There should be another 2-paragraphs with examples of this idea here.*

*Checklist:*

*Describe the instruments (e.g., tests, questionnaires, observation protocols) that will be (proposal) or were (manuscript) used, including information on their origin and evidence of their reliability and validity. OR as applicable, describe the materials to be used (e.g., lesson plans for interventions, webinars, or archived data, etc.).*

*Describe in detail any field testing or pilot testing of instruments to include their results and any subsequent modifications.*

*If instruments or materials are used that were developed by another researcher, include evidence in the appendix that permission was granted to use the instrument(s) and/or material(s) and refer to that fact and the appendix in this section.*

## Operational Definitions of Variables

*The instructions do not specify if this section exists in constructive research. Assuming it does, I can talk about the humanoid configuration and how these influence the simulation. Additionally, there can be an expansion to discuss feature selection and D.N.N. consideration.*

### ~~XXX~~

*~~Text…~~*

*~~Checklist:~~*

*~~For quantitative and mixed methods studies, identify how each variable will be (proposal) or was (manuscript) used in the study. Use terminology appropriate for the selected statistical test (e.g., independent/dependent, predictor/criterion, mediator, moderator).~~*

*~~Base the operational definitions on published research and valid and reliable instruments.~~*

*~~Identify the specific instrument that will be (proposal) or was (manuscript) used to measure each variable.~~*

*~~Describe the level of measurement of each variable (e.g., nominal, ordinal, interval, ratio), potential scores for each variable (e.g., the range [0–100] or levels [low, medium, high]), and data sources. If appropriate, identify what specific scores (e.g., subscale scores, total scores) will be (proposal) or were (manuscript) included in the analysis and how they will be (proposal) or were (manuscript) derived (e.g., calculating the sum, difference, average).~~*

## Study Procedures

The research project aims to build a C.V. model that can accurately predict human activity recognition (H.A.R.). Model training will initialize a random experiment configuration and perform an appropriate MoCAP sequence. During the performance, a virtual camera will collect changes in joint positionings. This delta stream will serve as input feature parameters to the classification process (e.g., sitting versus falling).

A distributed training service can horizontally scale and assess these different humanoid permutations in isolation. Amazon SageMaker offers these capabilities through its “bring your own container” design. Researchers essentially bundle custom automation and open-source tooling into a virtualized process. SageMaker uses public cloud resources like compute and storage to execute the experiment hundreds or thousands of times. It also integrates into TensorFlow 2 for collecting accuracy and performance metrics. These features reduce the complexity of building boilerplate instruments for many standard requirements.

Future researchers can replicate this experiment by deploying the same container images into their Amazon SageMaker and TensorFlow 2 environments. The humanoid automation will be versioned using GitHub. GitHub simplifies sharing open-source code and identifying specific point-in-time versions (called a commit S.H.A.). Since those researchers can synchronize the repository to a particular commit and rerun the automation using industry-standard tooling, they have sufficient capabilities to reproduce the experiment.

## Data Analysis

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Checklist:

Describe the strategies that will be (proposal) or were (manuscript) used to code and/or analyze the data, and any software that will be (proposal) or was (manuscript) used.

Ensure the data that will be (proposal) or were (manuscript) analyzed can be used to answer the research questions and/or test the hypotheses with the ultimate goal of addressing the identified problem.

Use proper terminology in association with each design/analysis (e.g., independent variable and dependent variable for an experimental design, predictor and criterion variables for regression).

For quantitative studies, describe the analysis that will be (proposal) or was (manuscript) used to test each hypothesis. Provide evidence the statistical test chosen is appropriate to test the hypotheses and the data meet the assumptions of the statistical tests.

For qualitative studies, describe how the data will be (proposal) or were (manuscript) processed and analyzed, including any triangulation efforts. Explain the role of the researcher.

For mixed methods studies, include all of the above.

## Assumptions

Begin writing here…

Checklist:

Discuss the assumptions along with the corresponding rationale underlying them.

## Limitations

Begin writing here…

Checklist:

Describe the study limitations.

Discuss the measures taken to mitigate these limitations.

## Delimitations

Begin writing here…

Checklist:

Describe the study delimitations along with the corresponding rationale underlying them. An example of delimitations are the conditions and parameters set intentionally by the researcher or by selection of the population and sample.

Explain how these research decisions relate to the existing literature and theoretical/conceptual framework, problem statement, purpose statement, and research questions.

## Ethical Assurances

Begin writing here…

Checklist:

Confirm in a statement the study will (proposal) or did (manuscript) receive approval from Northcentral University’s Institutional Review Board (I.R.B.) before data collection.

If the risk to participants is greater than minimal, discuss the relevant ethical issues and how they will be (proposal) or were (manuscript) addressed.

Describe how confidentiality or anonymity will be (proposal) or was (manuscript) achieved.

Identify how the data will be (proposal) or were (manuscript) securely stored in accordance with I.R.B. requirements.

Describe the role of the researcher in the study. Discuss relevant issues, including biases as well as personal and professional experiences with the topic, problem, or context. Present the strategies that will be (proposal) or were (manuscript) used to prevent these biases and experiences from influencing the analysis or findings.

In the dissertation manuscript only, include the I.R.B. approval letter in an appendix.

## Summary

Begin writing here…

Checklist:

Summarize the key points presented in the chapter.

Logically lead the reader to the next chapter on the findings of the study.

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