



A Real-time Pose Estimation Application for Simple Dances

A Capstone Project on Operational Technologies
Presented to the Faculty of the
Department of Electronics and Computer Engineering
Gokongwei College of Engineering
De La Salle University

In Partial Fulfillment of the
Operational Technologies

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20 **ABSTRACT**

21 Keep your abstract short by giving the gist/nutshell of your capstone project on operational
22 technologies. Use the following checklist questions to help you in crafting your abstract.

23 ☐ Did you briefly state what you intend to do?

24 ☐ Did you concisely discuss the problem statement?

25 ☐ Did you tersely mention the objectives in general terms?

26 ☐ Did you succinctly describe the methodology for the target audience?

27 ☐ Did you strongly describe your significant results and your conclusions?

28 *Index Terms*—Dance, Pose Estimation, Real-time, OpenPose .

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ABBREVIATIONS

143	AC	Alternating Current.....	73
144	CSS	Cascading Style Sheet.....	73
145	HTML	Hyper-text Markup Language.....	73
146	XML	eXtensible Markup Language.....	73

NOTATION

148	$ \mathcal{S} $	the number of elements in the set \mathcal{S} 75
149	\emptyset	the set with no elements 75
150	$h(t)$	impulse response 65
151	\mathcal{S}	a collection of distinct objects 75
152	\mathcal{U}	the set containing everything 75
153	$x(t)$	input signal represented in the time domain 65
154	$y(t)$	output signal represented in the time domain 65

155 Throughout this capstone project on operational technologies, mathematical notations
 156 conform to ISO 80000-2 standard, e.g., variable names are printed in italics, the only
 157 exception being acronyms like, e.g., SNR, which are printed in regular font. Constants are
 158 also set in regular font like j . Standard functions and operators are also set in regular font,
 159 e.g., in $\sin(\cdot)$, $\max\{\cdot\}$. Commonly used notations are t , f , $j = \sqrt{-1}$, n and $\exp(\cdot)$, which
 160 refer to the time variable, frequency variable, imaginary unit, n th variable, and exponential
 161 function, respectively.

GLOSSARY

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180 **Chapter 1**

181 **INTRODUCTION**

1.1 Background of the Study

Classical CV approaches used skin color segmentation, contour analysis, optical flow, and handcrafted descriptors (HOG, motion history images) to detect and classify gestures. Despite being simple and interpretable, those methods struggle with background variation and scale. The deep-learning era replaced handcrafted features with CNNs that learn hierarchical visual features directly from image data, yielding much higher accuracy for static hand pose and short-sequence recognition tasks. Many recent capstone and journal implementations pair OpenCV (for capture/preprocessing) with CNNs built and trained in TensorFlow/PyTorch to recognize a fixed vocabulary of gestures in real time. These hybrid pipelines are practical for capstone projects because OpenCV handles efficient frame processing while CNNs provide generalization across users and backgrounds. (<https://pmc.ncbi.nlm.nih.gov/articles/PMC8321080/>)

Instead of classifying raw images, several high-performance systems first extract skeletal landmarks (e.g., MediaPipe's 21-point hand model) and feed those coordinates to a classifier (small CNN, MLP, or temporal model like LSTM). Landmark-based pipelines reduce sensitivity to background and scale and make models smaller and faster, which is ideal for mobile or AR deployment. Markerless commercial devices such as the Leap Motion Controller and Ultraleap cameras provide very accurate 3D joint data using IR illumination and multi-camera setups; those give superior fidelity but add hardware cost and integration work. For a capstone aiming at broad deployability, a practical approach is to prototype with MediaPipe + OpenCV + CNN (or lightweight temporal model) and consider Ultraleap integration later for high-precision installations. (<https://arxiv.org/abs/2006.10214>)

204 **1.2 Prior Studies**

205 MediaPipe Hands (Zhang et al., Google / arXiv; MediaPipe docs). MediaPipe Hands
 206 presents a two-stage on-device pipeline (palm detector + hand-landmark regressor) that
 207 extracts 21 hand landmarks from a single RGB frame and runs in real time on mobile
 208 GPUs; the architecture and open implementation are widely used as a practical basis for
 209 gesture recognition because they offer compact, robust landmark outputs that are easier
 210 to classify than raw images. This work is especially relevant to mobile or cross-platform
 211 deployment without extra hardware. (<https://arxiv.org/abs/2006.10214>) Ultraleap / Leap
 212 Motion surveys and reviews. Reviews and vendor docs show that Ultraleap’s IR stereo
 213 cameras and LED illumination give very precise 3D joint tracking and low latency, making
 214 them popular for VR/installation work; academic comparisons find Leap/Ultraleap and
 215 MediaPipe are both capable, with trade-offs in precision versus hardware requirements.
 216 Ultraleap or similar IR camera hardware is a practical choice for professional installa-
 217 tion quality (amusement park kiosk, VR attraction). (docs.ultraleap.com) Sign-language
 218 gesture recognition studies (landmark + CNN/LSTM). ASL and other sign recognition
 219 papers demonstrate that combining landmark features (from MediaPipe or depth sensors)
 220 with temporal models (LSTM/CNN temporal stacks) yields state-of-the-art results for
 221 complex hand sequences. These studies emphasize the importance of considering variable
 222 visibility conditions as spellcasting often requires temporal tracing (drawing shapes), and
 223 not just static poses. This also provides insight into dataset design and labeling strategies.
 224 (<https://arxiv.org/html/2406.03729v1>) A comparative study of advanced technologies and
 225 methods in hand gesture analysis and recognition systems (Rahman et.al, 2025) Hand
 226 gesture recognition is advancing as a key technology for human–machine interaction. This

227 study reviews both non-vision (e.g., sensor-based) and vision-based approaches, examining
228 tools such as hidden Markov models, finite state machines, color modeling, naive Bayes,
229 deep networks, histogram features, and fuzzy clustering. Methods are categorized into
230 detection, tracking, and recognition phases, with comparisons across static and dynamic
231 gestures. The review highlights current technologies, their advantages and limitations, and
232 identifies directions for future research. Hand Gesture Recognition Based on Computer
233 Vision: A Review of Techniques (Oudah, Al-Naji, Chahl, 2020) Hand gestures, as a
234 form of nonverbal communication, are applied in fields such as HCI, assistive commu-
235 nication, robotics, home automation, and healthcare. Research spans sensor-based and
236 vision-based methods, with gestures categorized as static, dynamic, or hybrid. This paper
237 reviews literature on gesture recognition, comparing techniques in terms of segmentation,
238 classification, datasets, gesture types, camera use, detection range, and performance. It
239 provides a comprehensive overview of methods, their merits and limitations, and potential
240 applications.

241 **1.3 Problem Statement**

242 Immersive interactive systems in gaming, AR, amusement parks, and accessibility still
243 rely heavily on handheld controllers, touchscreens, or specialized hardware that break
244 immersion, add cost, or exclude users with differing motor abilities. Markerless, camera-
245 based hand-gesture recognition promises touchless, expressive input suitable for “magical”
246 metaphors (casting spells, tracing runes) that are intuitive and socially engaging. However,
247 real-world deployment is challenged by variable lighting, occlusion, noisy backgrounds, and
248 latency. These problems make accuracy and robustness the central obstacles for any spell-

249 casting CV system. Modern solutions that combine real-time hand-landmark extraction and
250 convolutional neural networks (CNNs) have narrowed the gap, but careful design is required
251 to meet the high level competency goals for responsiveness, cross-platform deployment, and
252 accessibility. (<https://pmc.ncbi.nlm.nih.gov/articles/PMC8321080/>)A persuasive problem
253 statement from a contextualized and intended-audience-awareness perspective consists of:

254 1. PS1: description of the ideal scenario for your intended audience

- 255 • Describe the goals, desired state, or the values that your audience considers
256 important and that are relevant to the problem.

257 2. PS2: reality of the situation

- 258 • Describe a condition that prevents the goal, state, or value discussed in PS1
259 from being achieved or realized at the present time.
- 260 • It is imperative to make the audience feel the pain point.

261 3. PS3: consequences for the audience

- 262 • Using specific details, show how the situation contains a little promise of
263 improvement unless something is done.

264 After the above-mentioned items, succinctly describe your solution. Please avoid describing
265 your entire solution here since you will articulate and elucidate it by showing what you want
266 to achieve through your objectives, and how you will make it through your methodology.

267 A well-constructed problem statement will convince your audience that the problem is real
268 and worth having you solve it.

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274 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
275 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
276 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
277 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

278 1.4 Objectives and Deliverables

279 Your objectives are the states that you desire to achieve in solving the problem. The general
280 objective is the main state to be achieved whereas the specific ones are sub-states to be
281 achieved.

282 1.4.1 General Objective (GO)

283 GO: To Morbi quis dolor. ;

284 1.4.2 Specific Objectives (SOs)

- 285 • SO1: To implement a real-time pipeline that captures camera frames, extracts ro-
286 bust hand features (landmarks or processed images), and classifies gestures into a
287 configurable spell vocabulary with low latency (30 fps target) and high accuracy;;

- SO2: To make the model robust to lighting, background clutter, and user variation through data augmentation and landmark-based representations ;
- SO3: To design the system to be deployable across desktop, mobile, and simple AR setups using cross-platform libraries (OpenCV, MediaPipe, TensorFlow/TensorFlow Lite) ;
- SO4: To make the interaction ergonomically accessible by supporting alternative gestures and calibration for users with different ranges of motion ;
- SO5: On UX side, to make spells feel immediately meaningful (clear mapping between motion and effect), provide instant feedback when a spell is recognized, and allow easy extension of the spell set. ;

1.4.3 Expected Deliverables

Table 1.1 shows the outputs, products, results, achievements, gains, realizations, and/or yields of the Capstone Project on Operational Technologies.

TABLE 1.1 EXPECTED DELIVERABLES PER OBJECTIVE

Objectives	Expected Deliverables
GO: To Morbi quis dolor.	⋮

1.5 Significance of the Study

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306 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
307 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
308 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
309 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
310 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

311 1.5.1 Technical Benefit

312

- 313 1. First itemtext
- 314 2. Second itemtext
- 315 3. Last itemtext
- 316 4. First itemtext
- 317 5. Second itemtext

318 1.5.2 Social Impact

319

- 320 1. First itemtext
- 321 2. Second itemtext

322 3. Last itemtext

323 4. First itemtext

324 5. Second itemtext

325 **1.5.3 Environmental Welfare**

326

327 1. First itemtext

328 2. Second itemtext

329 3. Last itemtext

330 4. First itemtext

331 5. Second itemtext

332 **1.6 Assumptions, Scope, and Delimitations**

333 **1.6.1 Assumptions**

334 1. ...;

335 2. ...;

336 3. ...;

337 **1.6.2 Scope**

338 1. ...;

339 2. ...;

340 3. ...;

341 **1.6.3 Delimitations**

342 1. ...;

343 2. ...;

344 3. ...;

345 **1.7 Description and Methodology of the Capstone**
346 **Project on Operational Technologies**

347 1. Phase 1: Model Development serves a precursor for Phase 2 wherein the specifics
348 of the model, libraries, and environment to use are defined. In total, Phase 1 would
349 last 4 weeks spanning from week 4 to 7. The bulk of the research for the project
350 would be carried out during this phase. The dataset to be used for training would be
351 collected during this phase as well.

352 2. Phase 2: Model Training consists of training the model using the dataset collected
353 in the previous phase. This phase will largely consist of testing and improving the
354 resulting model. Tests would be conducted using the group members as dancers.

355 This phase also includes the optimization of the model for real-time detection simul-
356 taneously with the music. In total, this phase would last 4 weeks spanning from week
357 8 to 11.

358 3. Phase 3: UI/EX Development consists of the integration of the trained model with
359 a user interface. Once integrated final testing and refinement of the final program
360 would be carried out. The final output would be presented as well during this phase
361 along with the finalization of the documentation. This phase would last for 3 weeks
362 spanning from week 11 to 13

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367 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
368 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
369 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
370 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
371 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Real-time Pose Estimation App for Dancing

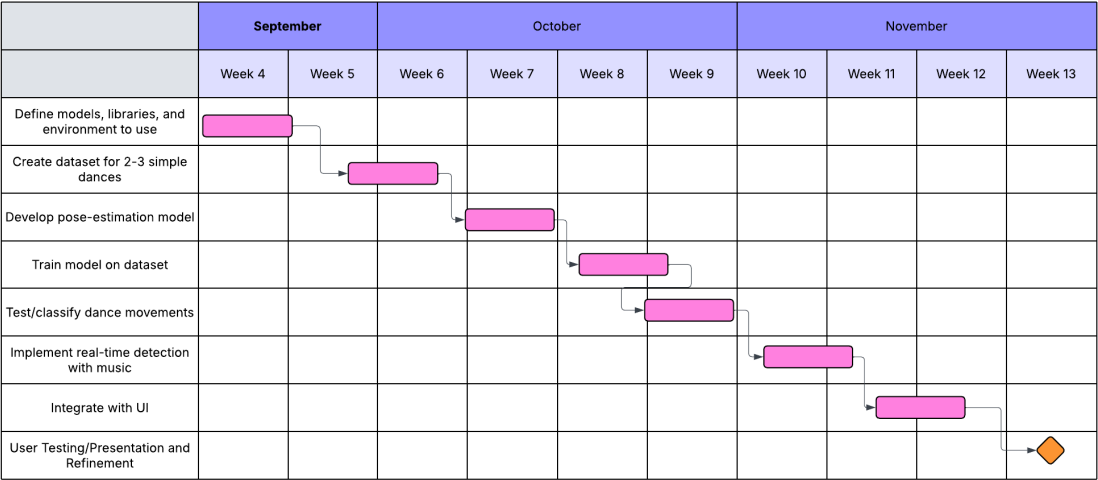


Fig. 1.1 Milestone Gantt Chart for Real-time Pose Estimation Dance Software

372 1.8 Estimated Work Schedule and Budget

373 1.8.1 Milestones and Gantt Chart

374 1.8.2 Budget

375 Given that the capstone project largely consists of software, apart from the use of a laptop
376 for both programming, as well as actual implementation and usage of the dance program,
377 the only expense to consider would be for that of a Webcam, which is already owned.

TABLE 1.2 OPERATIONAL FINANCIAL PLAN

Item	Price
Webcam	P1,850
Total	P1,850

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384 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
385 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
386 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

387 **1.9 Overview of the Capstone Project on Operational** 388 **Technologies**

389 **Chapter 2**

390 **LITERATURE REVIEW**

391 It is to be noted that each subsection in this chapter should discuss in narrative form
392 each table that is presented in order to point out to the reader what the author(s) intend to
393 convey.

394 **2.1 Existing Work**

395 Cite and summarize here relevant and significant literature (dissertations, theses, journals,
396 patents, notable conference papers) through a table and descriptions to prove that no one
397 has done your work yet and/or that your work is not a duplication of existing ones. Your
398 focus here is what has *been done*.

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412 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla

2. Literature Review

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414 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
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424 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
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444 2.2 Lacking in the Approaches

445 You can summarize the weaknesses of existing approaches by a tabular comparison of the
446 literature. Your focus here is what has *not been done*, i.e. what features were missed, what
447 solutions were not considered, what the demerits are, etc. Through these items, you then
448 can introduce the necessity for doing your proposed solution.

449 It is to be noted that the degree of novelty for undergraduate thesis is lower than those
450 for graduate school. If a Ph.D. dissertation/thesis has a high degree of novelty and that for
451 an undergraduate is low, then a master's thesis is somewhere between the two.

452 Briefly include here the following in order to remind the reader why you are highlighting
453 the weaknesses of the solutions of existing literature.

- 454 • mentioning the problem
- 455 • showing how your solution is better (can be better (for proposals))

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2. Literature Review

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501 **2.3 Summary**

502 Provide the gist of this chapter such that it reflects the contents and the message.

503 **Chapter 3**

504 **THEORETICAL CONSIDERATIONS**

3. Theoretical Considerations

505 Before starting the first section, provide an overview of the purpose of this chapter and
506 its contents, and how they are relevant to your methodology. Discuss in this chapter the
507 relevant theories and concepts that should support your proposed solutions.

508 This chapter is for providing the context to your panelist/reader. It is actually an
509 expanded form of the Background of the Study that you have put in Chapter 1.

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3. Theoretical Considerations

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3. Theoretical Considerations

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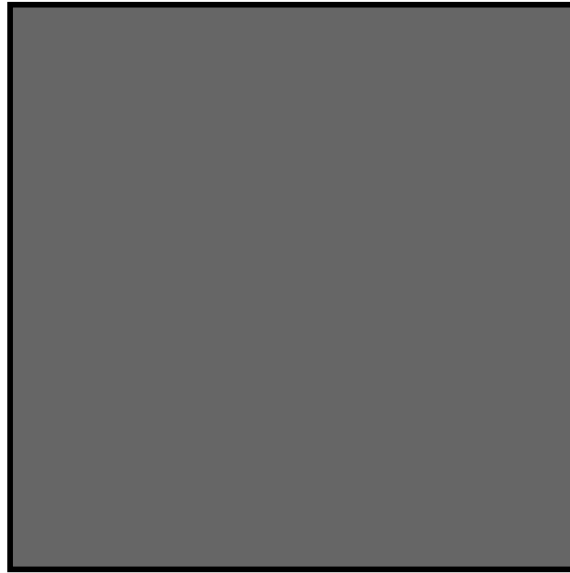


Fig. 3.1 A quadrilateral image example.

555 3.1 Summary

556 Provide the gist of this chapter such that it reflects the contents and the message.

557 **Chapter 4**

558 **DESIGN CONSIDERATIONS**

559 Before starting the first section, provide an overview of the purpose of this chapter and
560 its contents, and how they are relevant to your methodology.

561 Your primary goal in the Design Considerations chapter is to describe to your pan-
562 elist/readers the key topics that fall further under Theoretical Considerations, but should
563 be placed here instead since they are geared towards your Methodology. These key topics
564 are those that you have directly adopted in making your solution/methodology. You can
565 think of the connection of the Design Considerations chapter to the Theoretical Considera-
566 tions chapter in this way: if your Theoretical Considerations chapter serves as the main
567 foundation of a building, then the Design Considerations chapter functions as the columns.

568 The Design Considerations chapter is an avenue for explaining why you considered
569 the topics here for your proposed methodology. This chapter is different from your
570 methodology, because topics you discuss here are already accepted as part of the body of
571 knowledge, and may have not been developed by you.

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4. Design Considerations

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4.1 Standards

Standards are essential for successful projects and impactful research. They provide a common framework and ensure consistency, quality, and safety across various disciplines. By adhering to established standards, your work becomes more reliable, interoperable, and valuable in real-world applications. Standards also demonstrate your understanding of industry best practices and enhance the credibility of your research.

 To effectively integrate standards into your project, begin by identifying relevant standards related to your specific field. Thoroughly research and understand the requirements and guidelines outlined within these standards. Align your project objectives and methodologies to meet or exceed these standards. Document your use of standards in this section, including how and why specific standards were chosen. Finally, evaluate your results against the established standards, justifying any deviations from the norm with sound

629 reasoning and evidence.

630 **4.2 Summary**

631 Provide the gist of this chapter such that it reflects the contents and message.

632 **Chapter 5**

633 **METHODOLOGY**

Put an overview of the contents of chapter. Mention here your methodology flow through a figure and provide an overview of it and how your methodology achieves your objectives. How your methodology achieves each of your specific objectives is what your panelists/examiners will be looking for. Specify how your methodology achieves your general objective and specific objectives. A point-by-point comparison how your methodology achieves each of your specific objectives is expected in the final Capstone Project on Operational Technologies.

Also make sure that you refer clearly to the chapters on the Literature Review, Theoretical Considerations, and Design Considerations showing how your methodology ties with those that you have discussed in those chapters.

Make an overview of the contents of the chapter. Put here your methodology flow through a figure and provide an overview of it.

In summative form, Table 5.1 indicates the approaches, designs, modes, processes, programs, techniques, and/or ways that the Capstone Project on Operational Technologies-reaches the objectives.

TABLE 5.1 SUMMARY OF METHODS FOR REACHING THE OBJECTIVES

Objectives	Methods	Locations
GO: To Morbi quis dolor.	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32

Continued on next page

Continued from previous page

Objectives	Methods	Locations
SO1: To implement a real-time pipeline that captures camera frames, extracts robust hand features (landmarks or processed images), and classifies gestures into a configurable spell vocabulary with low latency (30 fps target) and high accuracy;	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32
SO2: To make the model robust to lighting, background clutter, and user variation through data augmentation and landmark-based representations	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32
SO3: To design the system to be deployable across desktop, mobile, and simple AR setups using cross-platform libraries (OpenCV, MediaPipe, TensorFlow/TensorFlow Lite)	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32

Continued on next page

Continued from previous page

Objectives	Methods	Locations
SO4: To make the interaction ergonomically accessible by supporting alternative gestures and calibration for users with different ranges of motion	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32
SO5: On UX side, to make spells feel immediately meaningful (clear mapping between motion and effect), provide instant feedback when a spell is recognized, and allow easy extension of the spell set.	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32

649 5.1 Implementation

650 Summarize the process used to create/set-up the work with an explanation of such process,
 651 instruments, and materials that you used if any. If the description is lengthy, use condensed
 652 bullet points.

653 *Rule of thumb:* Implementation is how you made your work; (keywords: implemented,
 654 created, made, soldered, programmed, etc.).

655 If you wrote a program or made a simulation, you must state how the program or
 656 simulation functions in this section. An algorithm or a pseudocode as shown in Table L.2
 657 is a good example.

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703 5.2 Evaluation

704 Describe the procedures for evaluating the correct behavior and outcome of your work,
705 including what information you need to gather and how you will obtain or measure it.

706 *Rule of thumb:* Evaluation is how you tested your work; (keywords: measured, tested,
707 compared, simulated, etc.).

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753 **5.3 Summary**

754 Provide the gist of this chapter such that it reflects the contents and the message.

755 **Chapter 6**

756 **RESULTS AND DISCUSSIONS**

757 Show in this chapter proofs why your proposed solution works. However, presenting
 758 results ("It worked") without an appropriate explanation does not show thorough under-
 759 standing. Aside from the data and results that you have obtained, and their explanation,
 760 the discussion includes why components of your proposed solution work did or did not
 761 work in accordance to what you described in the evaluation process, and how the proposed
 762 solution performed and faired. Interpret the results and the reasons why they were obtained.
 763 If your results are incorrect, apparent discrepancies from theory should be pointed out and
 764 explained. In essence, what do the results mean? Citing existing publication can help you
 765 compare your results and your explanations.

766 The next items below is not related to the description of this results and discussions
 767 chapter, but serves as an opener for the \LaTeX portion of this template.

768 Here is an example of a citation for ISO 80000-2 standard [?]. Another one is [?]
 769 and [?].

770 In using this template, the user is expected to have a working knowledge of \LaTeX . A
 771 good introduction is in [?]. Its latest version can be accessed at <http://www.ctan.org/tex-archive/info/lshort>. See the Appendix of `document_guide.pdf` for examples.

773 In aggregate form, Table 6.1 shows the outcomes and completions in applying the
 774 methodology of the Capstone Project on Operational Technologiesper objective.

TABLE 6.1 SUMMARY OF RESULTS FOR ACHIEVING THE OBJECTIVES

Objectives	Results	Locations
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Continued on next page

6. Results and Discussions

Continued from previous page

Objectives	Results	Locations
GO: To Morbi quis dolor.	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32
SO1: To implement a real-time pipeline that captures camera frames, extracts robust hand features (landmarks or processed images), and classifies gestures into a configurable spell vocabulary with low latency (30 fps target) and high accuracy;	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32
SO2: To make the model robust to lighting, background clutter, and user variation through data augmentation and landmark-based representations	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	Sec. 5.1 on p. 32

Continued on next page

Continued from previous page

Objectives	Results	Locations
SO3: To design the system to be deployable across desktop, mobile, and simple AR setups using cross-platform libraries (OpenCV, MediaPipe, TensorFlow/TensorFlow Lite)	<div>1. First itemtext</div> <div>2. Second itemtext</div> <div>3. Last itemtext</div> <div>4. First itemtext</div> <div>5. Second itemtext</div>	Sec. 5.1 on p. 32
SO4: To make the interaction ergonomically accessible by supporting alternative gestures and calibration for users with different ranges of motion	<div>1. First itemtext</div> <div>2. Second itemtext</div> <div>3. Last itemtext</div> <div>4. First itemtext</div> <div>5. Second itemtext</div>	Sec. 5.1 on p. 32
SO5: On UX side, to make spells feel immediately meaningful (clear mapping between motion and effect), provide instant feedback when a spell is recognized, and allow easy extension of the spell set.	<div>1. First itemtext</div> <div>2. Second itemtext</div> <div>3. Last itemtext</div> <div>4. First itemtext</div> <div>5. Second itemtext</div>	Sec. 5.1 on p. 32

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820 **6.1 Summary**

821 Provide the gist of this chapter such that it reflects the contents and the message.

822 **Chapter 7**

823 **CONCLUSIONS, RECOMMENDATIONS, AND**

824 **FUTURE DIRECTIVES**

825 **7.1 Concluding Remarks**

826 In this Capstone Project on Operational Technologies, . . .

827 Put here the main points that should be known and learned about the work topic.

828 Summarize or give the gist of the essential principles and inferences drawn from your
829 results.

830 **7.2 Contributions**

831 The interrelated contributions and supplements that have been developed by the author(s)
832 in this Capstone Project on Operational Technologies are listed as follows. Only those that
833 are unique to the authors' work are included.

834 • the ;

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837 **7.3 Recommendations**

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7. Conclusions, Recommendations, and Future Directives

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7. Conclusions, Recommendations, and Future Directives

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883 **7.4 Future Prospects**

884 There are several prospects that may be extended for further studies. . . . So the suggested
885 topics are listed in the following.

886 1. the

887 2. the

888 3. the

7. Conclusions, Recommendations, and Future Directives

889 Note that for ECE undergraduate theses, as per the directions of the thesis adviser,
890 Recommendations and Future Directives will be removed for the hardbound copy but will
891 be retained for database storage.

7. Conclusions, Recommendations, and Future Directives

892 \LaTeX -comment this and the following texts after you have implemented them. See the
893 following references for helpful guides for the bibliography and script editing in general.
894 Note that the links might be unavailable, but the names can be searched in the Web.

- 895 1. IEEE Citation Reference: www.ieee.org/documents/ieeecitationref.pdf
- 896 2. IEEE Editorial Style manual: www.ieee.org/documents/style_manual.pdf
- 897 3. IEEE Abbreviations for Transactions, Journals, Letters, and Magazines: www.ieee.org/documents/trans_journal_names.pdf

899 Also in your BibTeX file, enclose letters or words that should all be in uppercase in curly
900 brackets. Example: IBM, Philippines, eXtensible Markup Language.

902

Chapter H

903

MEMBER SKILLSET IDENTIFICATION

TABLE H.1 TEAM MEMBERS' PROGRAMMING SKILLS

Member	Programming: Model Development	Programming: User Interface Design	Programming: Source Control (GitHub)	Programming: Problem Solving & Optimization	Programming: Python Language Knowledge
Hans	Intermediate	Novice	Expert	Intermediate	Intermediate
Gerald	Intermediate	Basic	Novice	Intermediate	Intermediate
Nathan	Intermediate	Novice	Novice	Intermediate	Intermediate

904 **Chapter I**
905 **WORK BREAKDOWN**
906 **STRUCTURECAPSTONE PROJECT ON**
907 **OPERATIONAL TECHNOLOGIES**

I. Work Breakdown StructureCapstone Project on Operational Technologies

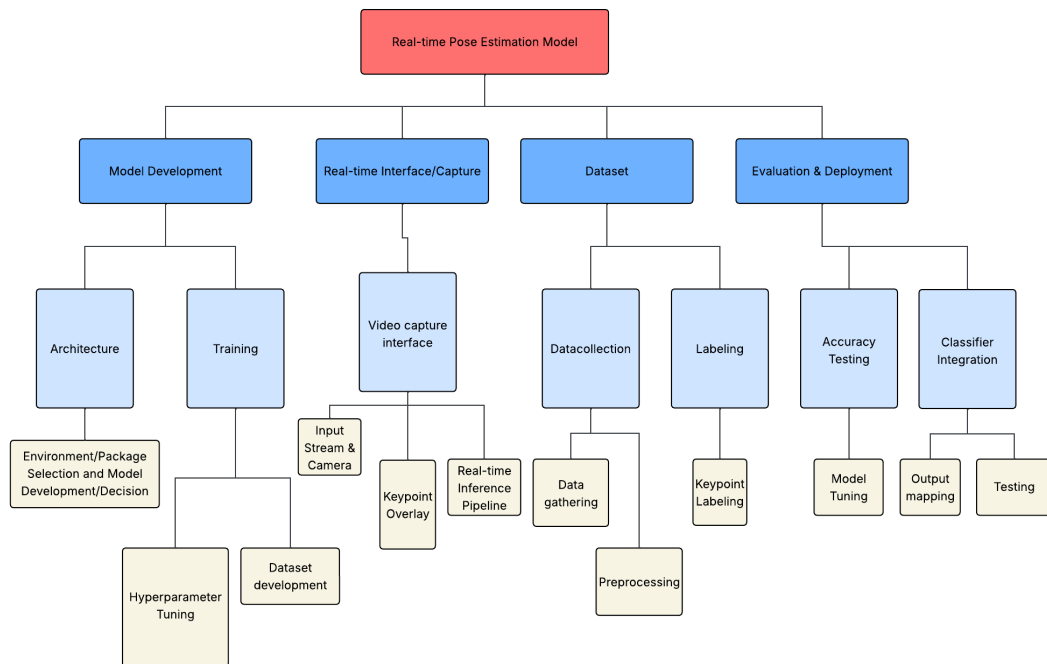


Fig. I.1 Work Breakdown Structure for Hans Capstone Project on Operational Technologies

I. Work Breakdown StructureCapstone Project on Operational Technologies

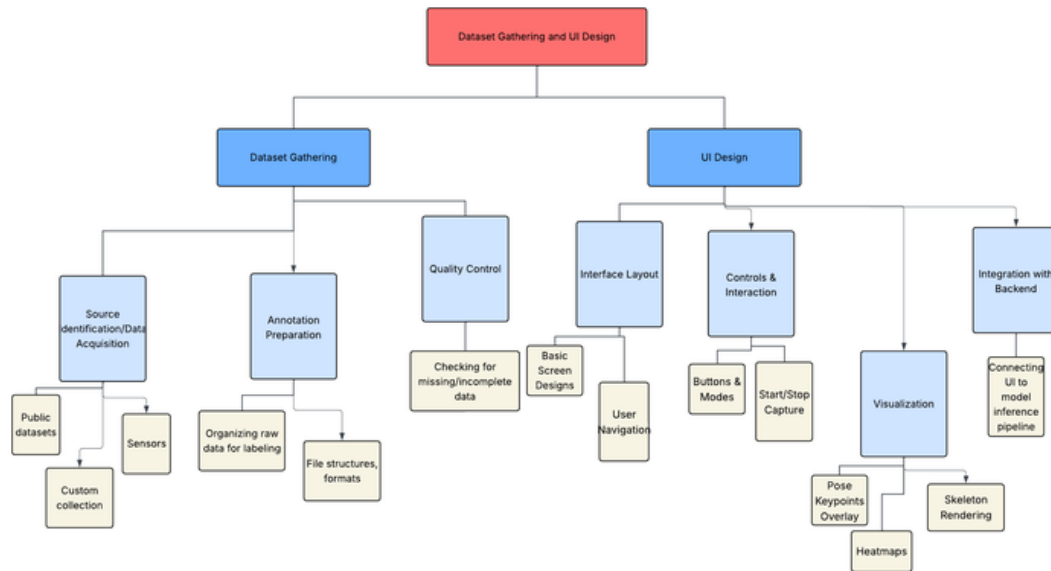


Fig. I.2 Work Breakdown Structure for Nathan Capstone Project on Operational Technologies

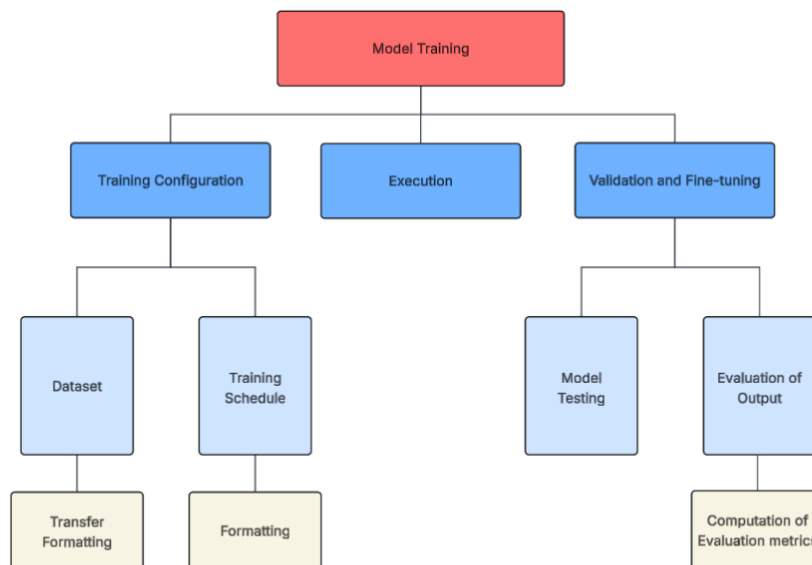


Fig. I.3 Work Breakdown Structure for Gerald Capstone Project on Operational Technologies

908 **Chapter J**
909 **REVISIONS TO THE PROPOSAL**

910 Make a table with the following columns for showing the summary of revisions to the
 911 proposal based on the comments of the panel of examiners.

912 1. Examiner

913 2. Comment

914 3. Summary of how the comment was addressed

915 4. Locations in the document where the changes have been reflected

TABLE J.1 SUMMARY OF REVISIONS TO THE PROPOSAL

Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Francisco D. Baltasar	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <p>First itemtext</p> <p>Second itemtext</p> <p>Last itemtext</p> <p>First itemtext</p> <p>Second itemtext</p>	<p>Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

Continued on next page

J. Revisions to the Proposal

Continued from previous page

Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Amado Z. Hernandez	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <p>First itemtext</p> <p>Second itemtext</p> <p>Last itemtext</p> <p>First itemtext</p> <p>Second itemtext</p>	<p>Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

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J. Revisions to the Proposal

Continued from previous page

Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Jose Y. Alonzo	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ul style="list-style-type: none"> • First itemtext • Second itemtext • Last itemtext • First itemtext • Second itemtext 	<p>Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

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J. Revisions to the Proposal

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Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Mariana X. Mercado	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p> <ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	<p>Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

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J. Revisions to the Proposal

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Examiner	Comment	Summary of how the comment was addressed	Locations
Dr. Rafael W. Sison	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.</p>	<p>Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23</p>

916 **Chapter K**
917 **REVISIONS TO THE FINAL**

- 918 Make a table with the following columns for showing the summary of revisions to the
919 proposal based on the comments of the panel of examiners.
- 920 1. Examiner
- 921 2. Comment
- 922 3. Summary of how the comment has been addressed
- 923 4. Locations in the document where the changes have been reflected

TABLE K.1 SUMMARY OF REVISIONS TO THE CAPSTONE PROJECT ON
 OPERATIONAL TECHNOLOGIES

Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Francisco D. Baltasar	1. First itemtext	1. First itemtext	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23
	2. Second itemtext	2. Second itemtext	
	3. Last itemtext	3. Last itemtext	
	4. First itemtext	4. First itemtext	
	5. Second itemtext	5. Second itemtext	
		First itemtext Second itemtext Last itemtext First itemtext Second itemtext	

Continued on next page

K. Revisions to the Final

Continued from previous page

Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Amado Z. Hernandez	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext <p>First itemtext</p> <p>Second itemtext</p> <p>Last itemtext</p> <p>First itemtext</p> <p>Second itemtext</p>	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23
Dr. Jose Y. Alonzo	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext 	<ol style="list-style-type: none"> 1. First itemtext 2. Second itemtext 3. Last itemtext 4. First itemtext 5. Second itemtext <ul style="list-style-type: none"> • First itemtext • Second itemtext • Last itemtext • First itemtext • Second itemtext 	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23

Continued on next page

K. Revisions to the Final

Continued from previous page

Examiner	Comment	Summary of how the comment has been addressed	Locations
Dr. Mariana X. Mercado	1. First itemtext	1. First itemtext	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23
	2. Second itemtext	2. Second itemtext	
	3. Last itemtext	3. Last itemtext	
	4. First itemtext	4. First itemtext	
	5. Second itemtext	5. Second itemtext	
Dr. Rafael W. Sison	1. First itemtext	1. First itemtext	Sec. 5.1 on p. 32, Sec. 5.2 on p. 35, Fig. 3.1 on p. 23
	2. Second itemtext	2. Second itemtext	
	3. Last itemtext	3. Last itemtext	
	4. First itemtext	4. First itemtext	
	5. Second itemtext	5. Second itemtext	

924 **Chapter L**
925 **USAGE EXAMPLES**

926 The user is expected to have a working knowledge of \LaTeX . A good introduction is
 927 in [?]. Its latest version can be accessed at <http://www.ctan.org/tex-archive/info/lshort>.

928 L1 Equations

929 The following examples show how to typeset equations in \LaTeX . This section also shows
 930 examples of the use of `\gls{ }` commands in conjunction with the items that are in
 931 the `notation.tex` file. **Please make sure that the entries in `notation.tex` are**
 932 **those that are referenced in the \LaTeX document files used by this Capstone Project on**
 933 **Operational Technologies. Please comment out unused notations and be careful with**
 934 **the commas and brackets in `notation.tex` .**

935 In (L.1), the output signal $y(t)$ is the result of the convolution of the input signal $x(t)$
 936 and the impulse response $h(t)$.

$$y(t) = h(t) * x(t) = \int_{-\infty}^{+\infty} h(t - \tau) x(\tau) d\tau \quad (\text{L.1})$$

937 Other example equations are as follows.

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix} \quad (\text{L.2})$$

$$\frac{1}{2} < \left\lfloor \text{mod} \left(\left\lfloor \frac{y}{17} \right\rfloor 2^{-17\lfloor x \rfloor - \text{mod}(\lfloor y \rfloor, 17)}, 2 \right) \right\rfloor, \quad (\text{L.3})$$

$$|\zeta(x)^3 \zeta(x + iy)^4 \zeta(x + 2iy)| = \exp \sum_{n,p} \frac{3 + 4 \cos(ny \log p) + \cos(2ny \log p)}{np^{nx}} \geq 1 \quad (\text{L.4})$$

The verbatim \LaTeX code of Sec. L1 is in List. L.1.

Listing L.1: Sample \LaTeX code for equations and notations usage

```

1 The following examples show how to typeset equations in \LaTeX. This
  section also shows examples of the use of \verb| \gls{ } | commands
  in conjunction with the items that are in the \verb| notation.tex |
  file. \textbf{Please make sure that the entries in} \verb| notation.
  tex | \textbf{ are those that are referenced in the \LaTeX \
  document files used by this \documentType. Please comment out
  unused notations and be careful with the commas and brackets in} \
  \verb| notation.tex |.

2
3 In~\eqref{eq:conv}, the output signal \gls{not:output_sigt} is the
  result of the convolution of the input signal \gls{not:input_sigt}
  and the impulse response \gls{not:ir}.

4
5 \begin{eqnarray}
6   y\left( t \right) = h\left( t \right) * x\left( t \right)=\int_{-\infty}^{+\infty}h\left( t-\tau \right)x\left( \tau \right) \mathrm{d}\tau
7   \label{eq:conv}
8 \end{eqnarray}
9
10 Other example equations are as follows.
11
12 \begin{eqnarray}
13   \left[ \dfrac{V_{1}}{I_{1}} \right] =
14   \begin{bmatrix}
15     A & B \\
16     C & D
17   \end{bmatrix}
18   \left[ \dfrac{V_{2}}{I_{2}} \right]
19   \label{eq:ABCD}
20 \end{eqnarray}
21
22 \begin{eqnarray}
23   \dfrac{1}{2} < \left\lfloor \mathrm{mod} \left( \left\lfloor \dfrac{y}{17} \right\rfloor \right. \right. \right.
24   \left. \left. \left. \right\rfloor 2^{-17} \left\lfloor x \right\rfloor - \mathrm{mod} \left( \left\lfloor y \right\rfloor \right. \right. \right.
25   \left. \left. \left. \right\rfloor, 17) \right), 2 \right) \right\rfloor,
26 \end{eqnarray}
27
28 \begin{eqnarray}
29   \left| \zeta(x)^3 \zeta(x + iy)^4 \zeta(x + 2iy) \right| =
  \exp \sum_{n,p} \frac{3 + 4 \cos( ny \log p) + \cos( 2ny \log p)}{n^p}
  \geq 1
  \end{eqnarray}

```

939 L2 Notations

940 In order to use the standardized notation, the user is highly suggested to see the ISO 80000-2
941 standard [?].

942 See https://en.wikipedia.org/wiki/Help:Displaying_a_formula and https://en.wikipedia.org/wiki/List_of_mathematical_symbols for L^AT_EX maths and other notations, respectively.

944 The following were taken from `isomath-test.tex`.

945 L2.1 Math alphabets

946 If there are other symbols in place of Greek letters in a math alphabet, it uses T1 or OT1
947 font encoding instead of OML.

<code>mathnormal</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathit</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \mathfrak{f}, \mathfrak{f}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathrm</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \mathfrak{f}, \mathfrak{f}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathbf</code>	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \mathbf{f}, \mathbf{f}, \mathbf{\beta}, \circ, !, v, w, 0, 1, 9$
<code>mathsf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \mathfrak{f}, \mathfrak{f}, \beta, \circ, !, v, w, 0, 1, 9$
<code>mathtt</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \uparrow, \downarrow, \beta, \circ, !, v, w, 0, 1, 9$

948 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

<code>mathbfit</code>	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
<code>mathsfbit</code>	$\mathbf{A}, \mathbf{B}, \mathbf{\Gamma}, \mathbf{\Delta}, \mathbf{\Theta}, \mathbf{\Lambda}, \mathbf{\Xi}, \mathbf{\Pi}, \mathbf{\Sigma}, \mathbf{\Phi}, \mathbf{\Psi}, \mathbf{\Omega}, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$

949 Do the math alphabets match?

950 $\alpha x \alpha \omega \mathbf{a} x \alpha \omega \mathbf{a} x \alpha \omega \quad T C \Theta \Gamma T C \Theta \Gamma T C \Theta \Gamma$

951 L2.2 Vector symbols

952 Alphabetic symbols for vectors are boldface italic, $\lambda = e_1 \cdot \mathbf{a}$, while numeric ones (e.g.
953 the zero vector) are bold upright, $\mathbf{a} + \mathbf{0} = \mathbf{a}$.

954 L2.3 Matrix symbols

955 Symbols for matrices are boldface italic, too:¹ $\mathbf{A} = \mathbf{E} \cdot \mathbf{A}$.

¹However, matrix symbols are usually capital letters whereas vectors are small ones. Exceptions are physical quantities like the force vector \mathbf{F} or the electrical field \mathbf{E} .

956 **L2.4 Tensor symbols**

957 Symbols for tensors are sans-serif bold italic,

$$\boldsymbol{\alpha} = \boldsymbol{e} \cdot \boldsymbol{a} \quad \Longleftrightarrow \quad \alpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

958 The permittivity tensor describes the coupling of electric field and displacement:

$$\boldsymbol{D} = \epsilon_0 \boldsymbol{\epsilon}_r \boldsymbol{E}$$

959 **L2.5 Bold math version**

960 The “bold” math version is selected with the commands `\boldmath` or `\mathversion{bold}`

mathnormal	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, 0, 1, 9$
mathit	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \textit{ff}, \textit{fi}, \textit{\beta}, \textit{^}, \textit{!}, v, w, 0, 1, 9$
mathrm	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \text{\beta}, \text{^}, \text{!}, \text{v}, \text{w}, 0, 1, 9$
mathbf	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \text{\beta}, \text{^}, \text{!}, \text{v}, \text{w}, 0, 1, 9$
mathsf	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \text{ff}, \text{fi}, \text{\beta}, \text{^}, \text{!}, \text{v}, \text{w}, 0, 1, 9$
mathtt	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \uparrow, \downarrow, \text{\beta}, \text{^}, \text{!}, \text{v}, \text{w}, 0, 1, 9$

961 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-italic.

<code>mathbfit</code>	$\boldsymbol{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, o, 1, 9}$
<code>mathsf</code>	$A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, o, 1, 9$
<code>mathsfbfit</code>	$\boldsymbol{A, B, \Gamma, \Delta, \Theta, \Lambda, \Xi, \Pi, \Sigma, \Phi, \Psi, \Omega, \alpha, \beta, \pi, \nu, \omega, v, w, o, 1, 9}$

962 Do the math alphabets match?

963 *αξαωαξαωαξαω* *TCΘΓTCΘΓTCΘΓ*

964 **L2.5.1 Vector symbols**

Alphabetic symbols for vectors are boldface italic, $\lambda = e_1 \cdot \mathbf{a}$, while numeric ones (e.g. the zero vector) are bold upright, $\mathbf{a} + \mathbf{0} = \mathbf{a}$.

967 **L2.5.2 Matrix symbols**

968 Symbols for matrices are boldface italic, too:² $\Lambda = E \cdot A$.

969 L2.5.3 Tensor symbols

970 Symbols for tensors are sans-serif bold italic,

$$\alpha = e \cdot a \quad \Longleftrightarrow \quad \alpha_{ijl} = e_{ijk} \cdot a_{kl}.$$

971 The permittivity tensor describes the coupling of electric field and displacement:

$$D = \epsilon_0 \epsilon_r E$$

²However, matrix symbols are usually capital letters whereas vectors are small ones. Exceptions are physical quantities like the force vector \mathbf{F} or the electrical field \mathbf{E} .

972 The verbatim \LaTeX code of Sec. L2 is in List. L.2.

Listing L.2: Sample \LaTeX code for notations usage

```

973 1 % A teststring with Latin and Greek letters::
974 2 \newcommand{\teststring}{%
975 3 % capital Latin letters
976 4 % A,B,C,
977 5 A,B,
978 6 % capital Greek letters
979 7 %\Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Upsilon,\Phi,\Psi,
980 8 \Gamma,\Delta,\Theta,\Lambda,\Xi,\Pi,\Sigma,\Phi,\Psi,\Omega,
981 9 % small Greek letters
982 10 \alpha,\beta,\pi,\nu,\omega,
983 11 % small Latin letters:
984 12 % compare \nu, \omega, v, and w
985 13 v,w,
986 14 % digits
987 15 0,1,9
988 16 }
989 17
990 18
991 19 \subsection{Math alphabets}
992 20
993 21 If there are other symbols in place of Greek letters in a math
994 22 alphabet, it uses T1 or OT1 font encoding instead of OML.
995 23
996 24 \begin{eqnarray*}
997 25 \mbox{\mathnormal} & & \mbox{\teststring} \\
998 26 \mbox{\mathit} & & \mbox{\mathit{\teststring}} \\
999 27 \mbox{\mathrm} & & \mbox{\mathrm{\teststring}} \\
1000 28 \mbox{\mathbf} & & \mbox{\mathbf{\teststring}} \\
1001 29 \mbox{\mathsf} & & \mbox{\mathsf{\teststring}} \\
1002 30 \mbox{\mathtt} & & \mbox{\mathtt{\teststring}} \\
1003 31 \end{eqnarray*}
1004 32 New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-
1005 33 italic.
1006 34 \begin{eqnarray*}
1007 35 \mbox{\mathbfit} & & \mbox{\mathbfit{\teststring}} \\
1008 36 \mbox{\mathsf fit} & & \mbox{\mathsf fit{\teststring}} \\
1009 37 \mbox{\mathsf bfit} & & \mbox{\mathsf bfit{\teststring}} \\
1010 38 \end{eqnarray*}
1011 39 %
1012 40 Do the math alphabets match?
1013 41 $
1014 42 \mathnormal {a x \alpha \omega}
1015 43 \mathbfit {a x \alpha \omega}
1016 44 \mathsf bfit {a x \alpha \omega}
1017 45 \quad
1018 46 \mathsf bfit {T C \Theta \Gamma}
1019 47 \mathbfit {T C \Theta \Gamma}
1020 48 \mathnormal {T C \Theta \Gamma}
1021 49 $
1022 50
1023 51 \subsection{Vector symbols}
1024 52

```

```

1027 53 Alphabetic symbols for vectors are boldface italic,
1028 54  $\vec{\lambda} = \vec{e}_1 \cdot \vec{a}$ ,
1029 55 while numeric ones (e.g. the zero vector) are bold upright,
1030 56  $\vec{a} + \vec{0} = \vec{a}$ .
1031 57
1032 58 \subsection{Matrix symbols}
1033 59
1034 60 Symbols for matrices are boldface italic, too:%
1035 61 \footnote{However, matrix symbols are usually capital letters whereas
1036 62 vectors
1037 62 are small ones. Exceptions are physical quantities like the force
1038 63 vector  $\vec{F}$  or the electrical field  $\vec{E}$ .%
1039 64 }
1040 65  $\Lambda = E \cdot A$ .
1041 66
1042 67
1043 68 \subsection{Tensor symbols}
1044 69
1045 70 Symbols for tensors are sans-serif bold italic,
1046 71
1047 72 \[
1048 73 \quad \text{\textit{\textbf{tensorsym{\alpha}}}} = \text{\textit{\textbf{tensorsym{e}}}} \cdot \text{\textit{\textbf{tensorsym{a}}}}
1049 74 \quad \Longleftrightarrow
1050 75 \quad \alpha_{ijl} = e_{ijk} \cdot a_{kl}.
1051 76 \]
1052 77
1053 78
1054 79 The permittivity tensor describes the coupling of electric field and
1055 80 displacement: \[
1056 81 \vec{D} = \epsilon_0 \text{\textit{\textbf{tensorsym{\epsilon}}}}_{\text{\textit{\textbf{r}}}} \vec{E} \]
1057 82
1058 83
1059 84
1060 85 \newpage
1061 86 \subsection{Bold math version}
1062 87
1063 88 The ‘‘bold’’ math version is selected with the commands
1064 89 \verb+\boldmath+ or \verb+\mathversion{bold}+
1065 90
1066 91 {\boldmath
1067 92 \begin{eqnarray*}
1068 93 \quad \text{\textnormal} & & \text{\teststring} \\
1069 94 \quad \text{\mathit} & & \text{\mathit{\teststring}} \\
1070 95 \quad \text{\mathrm} & & \text{\mathrm{\teststring}} \\
1071 96 \quad \text{\mathbf} & & \text{\mathbf{\teststring}} \\
1072 97 \quad \text{\mathsf} & & \text{\mathsf{\teststring}} \\
1073 98 \quad \text{\mathtt} & & \text{\mathtt{\teststring}} \\
1074 99 \end{eqnarray*}
1075 100 \quad \text{New alphabets bold-italic, sans-serif-italic, and sans-serif-bold-}
1076 101 \quad \text{italic.}
1077 102 \begin{eqnarray*}
1078 103 \quad \text{\mathbfit} & & \text{\mathbfit{\teststring}} \\
1079 104 \quad \text{\mathsfit} & & \text{\mathsfit{\teststring}} \\
1080 105 \quad \text{\mathsfbfit} & & \text{\mathsfbfit{\teststring}} \\
1081 106 \end{eqnarray*}
1082 107 \%
1083 107 Do the math alphabets match?

```

```

1084 108
1085 109 $
1086 110 \mathnormal {a x \alpha \omega}
1087 111 \mathbfit {a x \alpha \omega}
1088 112 \mathsfbfit{a x \alpha \omega}
1089 113 \quad
1090 114 \mathsfbfit{T C \Theta \Gamma}
1091 115 \mathbfit {T C \Theta \Gamma}
1092 116 \mathnormal {T C \Theta \Gamma}
1093 117 $
1094 118
1095 119 \subsection{Vector symbols}
1096 120
1097 121 Alphabetic symbols for vectors are boldface italic,
1098 122 $\vec{\lambda}=\vec{e}_{1}\cdot\vec{a}$,
1099 123 while numeric ones (e.g. the zero vector) are bold upright,
1100 124 $\vec{a} + \vec{0} = \vec{a}$.
1101 125
1102 126
1103 127
1104 128
1105 129 \subsection{Matrix symbols}
1106 130
1107 131 Symbols for matrices are boldface italic, too:%
1108 132 \footnote{However, matrix symbols are usually capital letters whereas
1109 133 vectors
1110 134 are small ones. Exceptions are physical quantities like the force
1111 135 vector $\vec{F}$ or the electrical field $\vec{E}$.%
1112 136 }
1113 137 $\matrixsym{\Lambda}=\matrixsym{E}\cdot\matrixsym{A}$.
1114 138
1115 139 \subsection{Tensor symbols}
1116 140
1117 141 Symbols for tensors are sans-serif bold italic,
1118 142
1119 143 \[
1120 144 \quad \matrixsym{\alpha} = \matrixsym{e}\cdot\matrixsym{a}
1121 145 \quad \Longleftrightarrow \quad
1122 146 \quad \alpha_{ijl} = e_{ijk}\cdot a_{kl}.
1123 147 \]
1124 148
1125 149 The permittivity tensor describes the coupling of electric field and
1126 150 displacement: \[
1127 151 \quad \vec{D}=\epsilon_{0}\matrixsym{\epsilon}_{\mathrm{r}}\vec{E}\]
1128 152 }

```

1131 L3 Abbreviation

1132 This section shows examples of the use of \LaTeX commands in conjunction with the
 1133 items that are in the `abbreviation.tex` and in the `glossary.tex` files. Please see
 1134 List. L.3. **To lessen the \LaTeX parsing time, it is suggested that you use `\acr{ }` only**
 1135 **for the first occurrence of the word to be abbreviated.**

1136 Again please see List. L.3. Here is an example of first use: alternating current (ac).
 1137 Next use: ac. Full: alternating current (ac). Here's an acronym referenced using `\acr` :
 1138 hyper-text markup language (html). And here it is again: html. If you are used to the
 1139 glossaries package, note the difference in using `\gls` : hyper-text markup language
 1140 (html). And again (no difference): hyper-text markup language (html). For plural use
 1141 `\glspl` . Here are some more entries:

- 1143 • extensible markup language (xml) and cascading style sheet (css).
- 1144 • Next use: xml and css.
- 1145 • Full form: extensible markup language (xml) and cascading style sheet (css).
- 1146 • Reset again.
- 1147 • Start with a capital. Hyper-text markup language (html).
- 1148 • Next: Html. Full: Hyper-text markup language (html).
- 1149 • Prefer capitals? Extensible markup language (XML). Next: XML. Full: extensible
 1150 markup language (XML).
- 1151 • Prefer small-caps? Cascading style sheet (CSS). Next: CSS. Full: cascading style
 1152 sheet (CSS).
- 1153 • Resetting all acronyms.
- 1154 • Here are the acronyms again:
- 1155 • Hyper-text markup language (HTML), extensible markup language (XML) and cas-
 1156 cading style sheet (CSS).
- 1157 • Next use: HTML, XML and CSS.
- 1158 • Full form: Hyper-text markup language (HTML), extensible markup language (XML)
 1159 and cascading style sheet (CSS).

- Provide your own link text: style sheet.

The verbatim \LaTeX code of Sec. L3 is in List. L.3.

Listing L.3: Sample \LaTeX code for abbreviations usage

```

1 Again please see List.~\ref{lst:abbrv}. Here is an example of first use:
   \acr{ac}. Next use: \acr{ac}. Full: \gls{ac}. Here's an acronym
   referenced using \verb| \acr |: \acr{html}. And here it is again: \
   acr{html}. If you are used to the \texttt{glossaries} package, note
   the difference in using \verb| \gls |: \gls{html}. And again (no
   difference): \gls{html}. Here are some more entries:
2
3 \begin{itemize}
4
5   \item \acr{xml} and \acr{css}.
6
7   \item Next use: \acr{xml} and \acr{css}.
8
9   \item Full form: \gls{xml} and \gls{css}.
10
11  \item Reset again. \glsresetall{abbreviation}
12
13  \item Start with a capital. \Acr{html}.
14
15  \item Next: \Acr{html}. Full: \Gls{html}.
16
17  \item Prefer capitals? \renewcommand{\acronymfont}[1]{\
   MakeTextUppercase{#1}} \Acr{xml}. Next: \acr{xml}. Full: \gls{xml}
   }.
18
19  \item Prefer small-caps? \renewcommand{\acronymfont}[1]{\textsc{#1}}
   \Acr{css}. Next: \acr{css}. Full: \gls{css}.
20
21  \item Resetting all acronyms.\glsresetall{abbreviation}
22
23  \item Here are the acronyms again:
24
25  \item \Acr{html}, \acr{xml} and \acr{css}.
26
27  \item Next use: \Acr{html}, \acr{xml} and \acr{css}.
28
29  \item Full form: \Gls{html}, \gls{xml} and \gls{css}.
30
31  \item Provide your own link text: \glslink{[textbf]css}{style}
32
33 \end{itemize}

```

1162 L4 Glossary

1163 This section shows examples of the use of `\gls{ }` commands in conjunction with the
 1164 items that are in the `glossary.tex` and `notation.tex` files. Note that entries in
 1165 `notation.tex` are prefixed with “ not: ” label (see List. L.4).

1166 **Please make sure that the entries in `notation.tex` are those that are referenced**
 1167 **in the \LaTeX document files used by this Capstone Project on Operational Technologies.**
 1168 **Please comment out unused notations and be careful with the commas and brackets**
 1169 **in `notation.tex` .**

- 1170 • are usually denoted by a bold capital letter, such as \mathbf{A} . The ’s (i, j) th element is
 1171 usually denoted a_{ij} . \mathbf{I} is the identity .
- 1172 • A set, denoted as \mathcal{S} , is a collection of objects.
- 1173 • The universal set, denoted as \mathcal{U} , is the set of everything.
- 1174 • The empty set, denoted as \emptyset , contains no elements.
- 1175 • is seen as the study of complete normed vector spaces, i.e., Banach spaces.
- 1176 • The cardinality of a set, denoted as $|\mathcal{S}|$, is the number of elements in the set.

1177 The verbatim \LaTeX code for the part of Sec. L4 is in List. L.4.

Listing L.4: Sample \LaTeX code for glossary and notations usage

```

1 \begin{itemize}
2
3   \item \Glspl{matrix} are usually denoted by a bold capital letter,
      such as  $\mathbf{A}$ . The  $\text{\gls{matrix}}$ 's  $(i,j)$ th element is
      usually denoted  $a_{ij}$ .  $\text{\Gls{matrix}}$   $\mathbf{I}$  is the
      identity  $\text{\gls{matrix}}$ .
4
5   \item A set, denoted as  $\text{\gls{not:set}}$ , is a collection of objects.
6
7   \item The universal set, denoted as  $\text{\gls{not:universalSet}}$ , is the
      set of everything.
8
9   \item The empty set, denoted as  $\text{\gls{not:emptySet}}$ , contains no
      elements.
10
11   \item  $\text{\Gls{Functional Analysis}}$  is seen as the study of complete
      normed vector spaces, i.e., Banach spaces.
12
13   \item The cardinality of a set, denoted as  $\text{\gls{not:cardinality}}$ , is
      the number of elements in the set.
14
15 \end{itemize}

```

L5 Figure

1178

1179 This section shows several ways of placing figures. PDF_LTEX compatible files are PDF,
1180 PNG, and JPG. Please see the `figure` subdirectory.



Fig. L.1 A quadrilateral image example.

1181 Fig. L.1 is a gray box enclosed by a dark border. List. L.5 shows the corresponding
1182 \LaTeX code.

Listing L.5: Sample \LaTeX code for a single figure

```
1 \begin{figure}[!htbp]
2   \centering
3   \includegraphics[width=0.5\textwidth]{example}
4   \caption{A quadrilateral image example.}
5   \label{fig:example}
6 \end{figure}
7 \cleardoublepage
8
9 Fig.~\ref{fig:example} is a gray box enclosed by a dark border. List.~\ref{lst:onefig} shows the corresponding  $\text{\LaTeX}$  \ code.
10 \end{figure}
```



(a) A sub-figure in the top row.



(b) A sub-figure in the middle row.

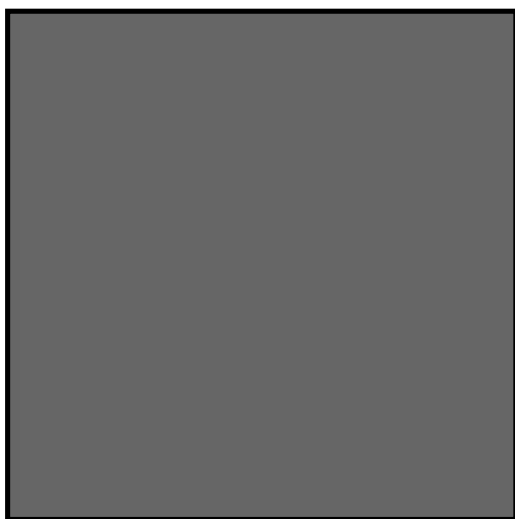


(c) A sub-figure in the bottom row.

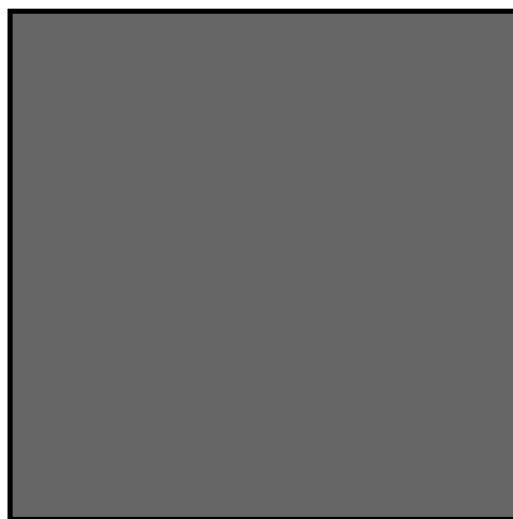
Fig. L.2 Figures on top of each other. See List. L.6 for the corresponding \LaTeX code.

Listing L.6: Sample L^AT_EX code for three figures on top of each other

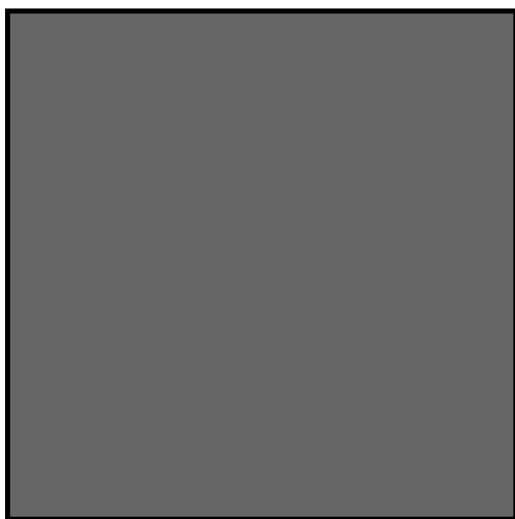
```
1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the top row.]{
4 \includegraphics[width=0.35\textwidth]{example_gray_box}
5 \label{fig:top}
6 }
7 \vfill
8 \subbottom[A sub-figure in the middle row.]{
9 \includegraphics[width=0.35\textwidth]{example_gray_box}
10 \label{fig:mid}
11 }
12 \vfill
13 \subbottom[A sub-figure in the bottom row.]{
14 \includegraphics[width=0.35\textwidth]{example_gray_box}
15 \label{fig:botm}
16 }
17 \caption{Figures on top of each other}
18 \label{fig:tmb}
19 \end{figure}
```



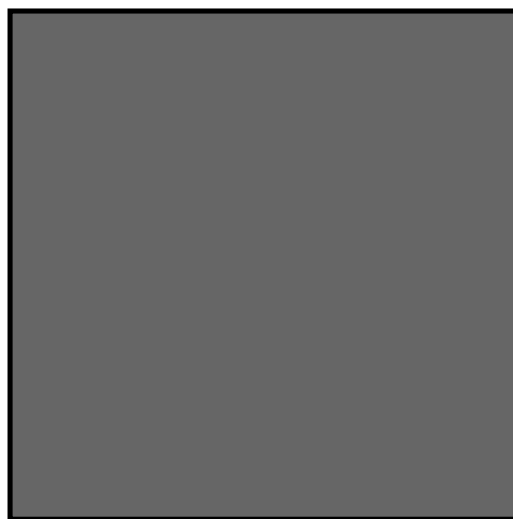
(a) A sub-figure in the upper-left corner.



(b) A sub-figure in the upper-right corner.



(c) A sub-figure in the lower-left corner.



(d) A sub-figure in the lower-right corner.

Fig. L.3 Four figures in each corner. See List. L.7 for the corresponding \LaTeX code.

Listing L.7: Sample \LaTeX code for the four figures

```

1 \begin{figure}[!htbp]
2 \centering
3 \subbottom[A sub-figure in the upper-left corner.]{
4 \includegraphics[width=0.45\textwidth]{example_gray_box}
5 \label{fig:upprleft}
6 }
7 \hfill
8 \subbottom[A sub-figure in the upper-right corner.]{
9 \includegraphics[width=0.45\textwidth]{example_gray_box}
10 \label{fig:uppright}
11 }
12 \vfill
13 \subbottom[A sub-figure in the lower-left corner.]{
14 \includegraphics[width=0.45\textwidth]{example_gray_box}
15 \label{fig:lowerleft}
16 }
17 \hfill
18 \subbottom[A sub-figure in the lower-right corner]{
19 \includegraphics[width=0.45\textwidth]{example_gray_box}
20 \label{fig:lowright}
21 }
22 \caption{Four figures in each corner. See List.\ref{lst:fourfigs} for
23 the corresponding \LaTeX \ code.}
24 \label{fig:fourfig}
25 \end{figure}

```

L6 Table

This section shows an example of placing a table (a long one). Table L.1 are the triples.

TABLE L.1 FEASIBLE TRIPLES FOR HIGHLY VARIABLE GRID

Time (s)	Triple chosen	Other feasible triples
0	(1, 11, 13725)	(1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0)
2745	(1, 12, 10980)	(1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0)
5490	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
8235	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
10980	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
13725	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
16470	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
19215	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
21960	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
24705	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
27450	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
30195	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
32940	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
35685	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
38430	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
41175	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
43920	(1, 13, 10980)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
46665	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
49410	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
52155	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
54900	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
57645	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
60390	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
63135	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
65880	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
68625	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
71370	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
74115	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
76860	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
79605	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
82350	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
85095	(1, 12, 13725)	(1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
87840	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
90585	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
93330	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
96075	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
98820	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
101565	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
104310	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
107055	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
109800	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
112545	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
115290	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
118035	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
120780	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
123525	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)

Continued on next page

Continued from previous page

Time (s)	Triple chosen	Other feasible triples
126270	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
129015	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
131760	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
134505	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
137250	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
139995	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
142740	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
145485	(1, 12, 16470)	(1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0)
148230	(2, 2, 2745)	(2, 3, 0), (3, 1, 0)
150975	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
153720	(1, 12, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
156465	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
159210	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
161955	(1, 13, 16470)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)
164700	(1, 13, 13725)	(2, 2, 2745), (2, 3, 0), (3, 1, 0)

1186 List. L.8 shows the corresponding \LaTeX code.

Listing L.8: Sample \LaTeX code for making typical table environment

```

1187 1 \begin{center}
1188 2 {\scriptsize
1189 3 \begin{tabularx}{\textwidth}{p{0.1\textwidth}|p{0.2\textwidth}|p{0.5\textwidth}}
1190 4 \caption{Feasible triples for highly variable grid} \label{tab:triple_
1191 5 grid} \\
1192 6 \hline
1193 7 \textbf{Time (s)} &
1194 8 \textbf{Triple chosen} &
1195 9 \textbf{Other feasible triples} \\
1196 10 \hline
1197 11 \endfirsthead
1198 12 \multicolumn{3}{c}{\textit{Continued from previous page}} \\
1199 13 \hline
1200 14 \hline
1201 15 \textbf{Time (s)} &
1202 16 \textbf{Triple chosen} &
1203 17 \textbf{Other feasible triples} \\
1204 18 \hline
1205 19 \endhead
1206 20 \hline
1207 21 \multicolumn{3}{r}{\textit{Continued on next page}} \\
1208 22 \endfoot
1209 23 \hline
1210 24 \endlastfoot
1211 25 \hline
1212 26
1213 27
1214 28 0 & (1, 11, 13725) & (1, 12, 10980), (1, 13, 8235), (2, 2, 0), (3, 1, 0) \\
1215 29 & \\
1216 30 2745 & (1, 12, 10980) & (1, 13, 8235), (2, 2, 0), (2, 3, 0), (3, 1, 0) \\
1217 31 & \\
1218 32 5490 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1219 33 8235 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1220 34 10980 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1221 35 13725 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1222 36 16470 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1223 37 19215 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1224 38 21960 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1225 39 24705 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1226 40 27450 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1227 41 30195 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1228 42 32940 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1229 43 35685 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1230 44 38430 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0)

```



```

1241 43 41175 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1242      0) \\
1243 44 43920 & (1, 13, 10980) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1244 45 46665 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1245 46 49410 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1246 47 52155 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3, 1,
1247      0) \\
1248 48 54900 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1249 49 57645 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1250 50 60390 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1251 51 63135 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1252 52 65880 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1253 53 68625 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1254 54 71370 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1255 55 74115 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1256 56 76860 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1257 57 79605 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1258 58 82350 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1259 59 85095 & (1, 12, 13725) & (1, 13, 10980), (2, 2, 2745), (2, 3, 0), (3, 1,
1260      0) \\
1261 60 87840 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1262 61 90585 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1263 62 93330 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1264 63 96075 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1265 64 98820 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1266 65 101565 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1267 66 104310 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1268 67 107055 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1269 68 109800 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1270 69 112545 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1271      1, 0) \\
1272 70 115290 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1273 71 118035 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1274 72 120780 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1275 73 123525 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1276 74 126270 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1277      1, 0) \\
1278 75 129015 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1279 76 131760 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1280 77 134505 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1281 78 137250 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1282 79 139995 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1283 80 142740 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1284 81 145485 & (1, 12, 16470) & (1, 13, 13725), (2, 2, 2745), (2, 3, 0), (3,
1285      1, 0) \\
1286 82 148230 & (2, 2, 2745) & (2, 3, 0), (3, 1, 0) \\
1287 83 150975 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1288 84 153720 & (1, 12, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1289 85 156465 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1290 86 159210 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1291 87 161955 & (1, 13, 16470) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1292 88 164700 & (1, 13, 13725) & (2, 2, 2745), (2, 3, 0), (3, 1, 0) \\
1293 89 \end{tabularx}
1294 90 }
1295 91 \end{center}

```

L7 Algorithm or Pseudocode Listing

Table L.2 shows an example pseudocode. Note that if the pseudocode exceeds one page, it can mean that its implementation is not modular. List. L.9 shows the corresponding L^AT_EX code.

TABLE L.2 CALCULATION OF $y = x^n$

Input(s):	
n	: n th power; $n \in \mathbb{Z}^+$
x	: base value; $x \in \mathbb{R}^+$
Output(s):	
y	: result; $y \in \mathbb{R}^+$

Require: $n \geq 0 \vee x \neq 0$

Ensure: $y = x^n$

```

1:  $y \leftarrow 1$ 
2: if  $n < 0$  then
3:    $X \leftarrow 1/x$ 
4:    $N \leftarrow -n$ 
5: else
6:    $X \leftarrow x$ 
7:    $N \leftarrow n$ 
8: end if
9: while  $N \neq 0$  do
10:  if  $N$  is even then
11:     $X \leftarrow X \times X$ 
12:     $N \leftarrow N/2$ 
13:  else { $N$  is odd}
14:     $y \leftarrow y \times X$ 
15:     $N \leftarrow N - 1$ 
16:  end if
17: end while
```

Listing L.9: Sample L^AT_EX code for algorithm or pseudocode listing usage

```

1 \begin{table}[!htbp]
2   \caption{Calculation of  $y = x^n$ }
3   \label{tab:calcxn}
4   {\footnotesize
5     \begin{tabular}{lll}
6       \hline
7       \hline
8       {\bfseries Input(s):} & & \\
9       $n$ & : & $n$th power; $n$ \in \mathbb{Z}^{+}$ \\
10      $x$ & : & base value; $x$ \in \mathbb{R}^{+}$ \\
11      \hline
12      {\bfseries Output(s):} & & \\
13      $y$ & : & result; $y$ \in \mathbb{R}^{+}$ \\
14      \hline
15      \hline
16      \\
17    \end{tabular}
18  }
19  \begin{algorithmic}[1]
20    {\footnotesize
21      \REQUIRE $n \geq 0$ \vee $x \neq 0$
22      \ENSURE $y = x^n$
23      \STATE $y \leftarrow 1$
24      \IF{$n < 0$}
25        \STATE $X \leftarrow 1 / x$
26        \STATE $N \leftarrow -n$
27      \ELSE
28        \STATE $X \leftarrow x$
29        \STATE $N \leftarrow n$
30      \ENDIF
31      \WHILE{$N \neq 0$}
32        \IF{$N$ is even}
33          \STATE $X \leftarrow X \times X$
34          \STATE $N \leftarrow N / 2$
35        \ELSE[$N$ is odd]
36          \STATE $y \leftarrow y \times X$
37          \STATE $N \leftarrow N - 1$
38        \ENDIF
39      \ENDWHILE
40    }
41  \end{algorithmic}
42 \end{table}

```

L8 Program/Code Listing

List. L.10 is a program listing of a C code for computing Fibonacci numbers by calling the actual code. Please see the `code` subdirectory.

Listing L.10: Computing Fibonacci numbers in C (`./code/fibo.c`)

```

1  /* fibo.c -- It prints out the first N Fibonacci
2  *              numbers.
3  */
4
5  #include <stdio.h>
6
7  int main(void) {
8      int n;          /* Number of fibonacci numbers we will print */
9      int i;          /* Index of fibonacci number to be printed next */
10     int current;     /* Value of the (i)th fibonacci number */
11     int next;        /* Value of the (i+1)th fibonacci number */
12     int twoaway;     /* Value of the (i+2)th fibonacci number */
13
14     printf("How many Fibonacci numbers do you want to compute? ");
15     scanf("%d", &n);
16     if (n<=0)
17         printf("The number should be positive.\n");
18     else {
19         printf("\n\n\tI\t\t\tFibonacci(I)\t\t\t\n\n\t===== \n");
20         next = current = 1;
21         for (i=1; i<=n; i++) {
22             printf("\t%d\t\t\t\t%d\n", i, current);
23             twoaway = current+next;
24             current = next;
25             next = twoaway;
26         }
27     }
28 }
29
30 /* The output from a run of this program was:
31
32 How many Fibonacci numbers do you want to compute? 9
33
34      I      Fibonacci(I)
35      =====
36      1      1
37      2      1
38      3      2
39      4      3
40      5      5
41      6      8
42      7      13
43      8      21
44      9      34
45
46  */

```

1304 List. L.11 shows the corresponding \LaTeX code.

Listing L.11: Sample \LaTeX code for program listing

```
1 List.\ref{lst:fib_c} is a program listing of a C code for computing  
   Fibonacci numbers by calling the actual code. Please see the \verb|  
   code | subdirectory.
```

1305 L9 Referencing

1306 Referencing chapters: This appendix is in Appendix L, which is about examples in using
 1307 various \LaTeX commands.

1308 Referencing sections: This section is Sec. L9, which shows how to refer to the locations
 1309 of various labels that have been placed in the \LaTeX files. List. L.12 shows the corresponding
 1310 \LaTeX code.

Listing L.12: Sample \LaTeX code for referencing sections

```
1 Referencing sections: This section is Sec.~\ref{sec:ref}, which shows
  how to refer to the locations of various labels that have been
  placed in the \LaTeX \ files. List.~\ref{lst:refsec} shows the
  corresponding \LaTeX \ code.
```

1311 Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem.
 1312 Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec
 1313 ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus
 1314 placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor.
 1315 Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla
 1316 tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue
 1317 a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris.
 1318 Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit
 1319 amet ipsum. Nunc quis urna dictum turpis accumsan semper.

L9.1 A subsection

Referencing subsections: This section is Sec. L9.1, which shows how to refer to a subsection. List. L.13 shows the corresponding \LaTeX code.

Listing L.13: Sample \LaTeX code for referencing subsections

```
1 Referencing subsections: This section is Sec.~\ref{sec:subsec}, which
  shows how to refer to a subsection. List.~\ref{lst:refsub} shows the
  corresponding \LaTeX \ code.
```

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

L9.1.1 A sub-subsection

Referencing sub-subsections: This section is Sec. L9.1.1, which shows how to refer to a sub-subsection. List. L.14 shows the corresponding \LaTeX code.

Listing L.14: Sample \LaTeX code for referencing sub-subsections

```
1 Referencing sub-subsections: This section is Sec.\ref{sec:subsubsec},
   which shows how to refer to a sub-subsection. List.\ref{lst:
   refsubsub} shows the corresponding \LaTeX \ code.
```

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1344 L10 Citing

1345 Citing bibliography content is done using BibTeX. It requires the creation of a BibTeX
 1346 file (.bib extension name), and then added in the argument of `\bibliography{ }`. For
 1347 each .bib file, separate them by a comma in the argument of `\bibliography{ }` without
 1348 the extension name. Building your BibTeX file (references.bib) can be done easily with a
 1349 tool called JabRef (www.jabref.org).

1350 The following subsections are examples of citations.

1351 L10.1 Books

1352 • [?]

1353 • [?]

1354 • [?]

1355 • [?]

1356 • [?]

1357 • [?]

1358 • [?]

1359 • [?]

1360 • [?]

1361 • [?]

1362 • [?]

1363 • [?]

1364 • [?]

1365 • [?]

1366 • [?]

1367 • [?]

1368 • [?]

1369 • [?]

- 1370 • [?]
- 1371 • [?]
- 1372 • [?]
- 1373 • [?]
- 1374 • [?]
- 1375 • [?]
- 1376 • [?]
- 1377 • [?]
- 1378 • [?]
- 1379 • [?]
- 1380 • [?]
- 1381 • [?]
- 1382 • [?]
- 1383 • [?]
- 1384 • [?]
- 1385 • [?]
- 1386 • [?]
- 1387 • [?]
- 1388 • [?]
- 1389 • [?]
- 1390 • [?]
- 1391 • [?]
- 1392 • [?]
- 1393 • [?]
- 1394 • [?]
- 1395 • [?]

1396 **L10.2 Booklets**

- 1397 • [?]

1398 **L10.3 Proceedings**

- 1399 • [?]

1400 **L10.4 In books**

- 1401 • [?]

- 1402 • [?]

- 1403 • [?]

- 1404 • [?]

- 1405 • [?]

- 1406 • [?]

- 1407 • [?]

- 1408 • [?]

- 1409 • [?]

- 1410 • [?]

- 1411 • [?]

- 1412 • [?]

- 1413 • [?]

- 1414 • [?]

- 1415 • [?]

- 1416 • [?]

- 1417 • [?]

- 1418 • [?]

1419 • [?]

1420 • [?]

1421 • [?]

1422 • [?]

1423 • [?]

1424 • [?]

1425 • [?]

1426 • [?]

1427 **L10.5 In proceedings**

1428 • [?]

1429 • [?]

1430 • [?]

1431 • [?]

1432 • [?]

1433 • [?]

1434 • [?]

1435 **L10.6 Journals**

1436 • [?]

1437 • [?]

1438 • [?]

1439 • [?]

1440 • [?]

1441 • [?]

- 1442 • [?]
- 1443 • [?]
- 1444 • [?]
- 1445 • [?]
- 1446 • [?]
- 1447 • [?]
- 1448 • [?]
- 1449 • [?]
- 1450 • [?]
- 1451 • [?]
- 1452 • [?]
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- 1454 • [?]
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- 1458 • [?]
- 1459 • [?]
- 1460 • [?]
- 1461 • [?]
- 1462 • [?]
- 1463 • [?]
- 1464 • [?]
- 1465 • [?]

1466 • [?]

1467 • [?]

1468 • [?]

1469 • [?]

1470 • [?]

1471 **L10.7 Theses/dissertations**

1472 • [?]

1473 • [?]

1474 • [?]

1475 • [?]

1476 • [?]

1477 • [?]

1478 • [?]

1479 **L10.8 Technical Reports and Others**

1480 • [?]

1481 • [?]

1482 • [?]

1483 • [?]

1484 • [?]

1485 • [?]

1486 • [?]

1487 • [?]

1488 • [?]

1489 • [?]

1490 • [?]

1491 • [?]

1492 • [?]

1493 • [?]

1494 • [?]

1495 **L10.9 Miscellaneous**

1496 • [?]

1497 • [?]

1498 • [?]

1499 • [?]

1500 • [?]

1501 • [?]

1502 • [?]

1503 • [?]

1504 • [?]

1505 • [?]

1506 • [?]

1507 • [?]

1508 • [?]

1509 L11 Index

1510 For key words or topics that are expected (or the user would like) to appear in the Index, use
 1511 `\index{key}` , where `key` is an example keyword to appear in the Index. For example,
 1512 Fredholm integral and Fourier operator of the following paragraph are in the Index.

1513 If we make a very large matrix with complex exponentials in the rows (i.e., cosine real
 1514 parts and sine imaginary parts), and increase the resolution without bound, we approach
 1515 the kernel of the Fredholm integral equation of the 2nd kind, namely the Fourier operator
 1516 that defines the continuous Fourier transform.

1517 List. L.15 is a program listing of the above-mentioned paragraph.

Listing L.15: Sample \LaTeX code for Index usage

```
1 If we make a very large matrix with complex exponentials in the rows (i.
  e., cosine real parts and sine imaginary parts), and increase the
  resolution without bound, we approach the kernel of the \index{
  Fredholm integral} Fredholm integral equation of the 2nd kind,
  namely the \index{Fourier} Fourier operator that defines the
  continuous Fourier transform.
```


L12 Adding Relevant PDF Pages

Examples of such PDF pages are Standards, Datasheets, Specification Sheets, Application Notes, etc. Selected PDF pages can be added (see List. L.16), but note that the options must be tweaked. See the manual of `pdfpages` for other options.

Listing L.16: Sample \LaTeX code for including PDF pages

```
1 \includepdf[pages={8-10},%  
2 offset=3.5mm -10mm,%  
3 scale=0.73,%  
4 frame,%  
5 pagecommand={},]  
6 {./reference/Xilinx2015-UltraScale-Architecture-Overview.pdf}
```

Virtex UltraScale FPGA Feature Summary

Table 6: Virtex UltraScale FPGA Feature Summary

	VU065	VU080	VU095	VU125	VU160	VU190	VU440
Logic Cells	626,640	780,000	940,800	1,253,280	1,621,200	1,879,920	4,432,680
CLB Flip-Flops	716,160	891,424	1,075,200	1,432,320	1,852,800	2,148,480	5,065,920
CLB LUTs	358,080	445,712	537,600	716,160	926,400	1,074,240	2,532,960
Maximum Distributed RAM (Mb)	4.8	3.9	4.8	9.7	12.7	14.5	28.7
Block RAM/FIFO w/ECC (36Kb each)	1,260	1,421	1,728	2,520	3,276	3,780	2,520
Total Block RAM (Mb)	44.3	50.0	60.8	88.6	115.2	132.9	88.6
CMT (1 MMCM, 2 PLLs)	10	16	16	20	30	30	30
I/O DLLs	40	64	64	80	120	120	120
Fractional PLLs	5	8	8	10	15	15	0
Maximum HP I/Os ⁽¹⁾	468	780	780	780	650	650	1,404
Maximum HR I/Os ⁽²⁾	52	52	52	104	52	52	52
DSP Slices	600	672	768	1,200	1,560	1,800	2,880
System Monitor	1	1	1	2	3	3	3
PCIe Gen3 x8	2	4	4	4	5	6	6
150G Interlaken	3	6	6	6	8	9	0
100G Ethernet	3	4	4	6	9	9	3
GTH 16.3Gb/s Transceivers	20	32	32	40	52	60	48
GTY 30.5Gb/s Transceivers	20	32	32	40	52	60	0

Notes:

1. HP = High-performance I/O with support for I/O voltage from 1.0V to 1.8V.
2. HR = High-range I/O with support for I/O voltage from 1.2V to 3.3V.



Virtex UltraScale Device-Package Combinations and Maximum I/Os

Table 7: Virtex UltraScale Device-Package Combinations and Maximum I/Os

Package ⁽¹⁾⁽²⁾⁽³⁾	Package Dimensions (mm)	VU065	VU080	VU095	VU125	VU160	VU190	VU440
		HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY	HR, HP GTH, GTY
FFVC1517	40x40	52, 468 20, 20	52, 468 20, 20	52, 468 20, 20				
FFVD1517	40x40		52, 286 32, 32	52, 286 32, 32				
FLVD1517	40x40				52, 286 40, 32			
FFVB1760	42.5x42.5		52, 650 32, 16	52, 650 32, 16				
FLVB1760	42.5x42.5				52, 650 36, 16			
FFVA2104	47.5x47.5		52, 780 28, 24	52, 780 28, 24				
FLVA2104	47.5x47.5				52, 780 28, 24			
FFVB2104	47.5x47.5		52, 650 32, 32	52, 650 32, 32				
FLVB2104	47.5x47.5				52, 650 40, 36			
FLGB2104	47.5x47.5					52, 650 40, 36	52, 650 40, 36	
FFVC2104	47.5x47.5			52, 364 32, 32				
FLVC2104	47.5x47.5				52, 364 40, 40			
FLGC2104	47.5x47.5					52, 364 52, 52	52, 364 52, 52	
FLGB2377	50x50							52, 1248 36, 0
FLGA2577	52.5x52.5						0, 448 60, 60	
FLGA2892	55x55							52, 1404 48, 0

Notes:

1. Go to [Ordering Information](#) for package designation details.
2. All packages have 1.0mm ball pitch.
3. Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale architecture-based devices with the same sequence. The footprint compatible devices within this family are outlined. See the [UltraScale Architecture Product Selection Guide](#) for details on inter-family migration.

Virtex UltraScale+ FPGA Feature Summary

Table 8: Virtex UltraScale+ FPGA Feature Summary

	VU3P	VU5P	VU7P	VU9P	VU11P	VU13P
Logic Cells	689,640	1,051,010	1,379,280	2,068,920	2,147,040	2,862,720
CLB Flip-Flops	788,160	1,201,154	1,576,320	2,364,480	2,453,760	3,271,680
CLB LUTs	394,080	600,577	788,160	1,182,240	1,226,880	1,635,840
Max. Distributed RAM (Mb)	12.0	18.3	24.1	36.1	34.8	46.4
Block RAM/FIFO w/ECC (36Kb each)	720	1,024	1,440	2,160	2,016	2,688
Block RAM (Mb)	25.3	36.0	50.6	75.9	70.9	94.5
UltraRAM Blocks	320	470	640	960	1,152	1,536
UltraRAM (Mb)	90.0	132.2	180.0	270.0	324.0	432.0
CMTs (1 MMCM and 2 PLLs)	10	20	20	30	12	16
Max. HP I/O ⁽¹⁾	520	832	832	832	624	832
DSP Slices	2,280	3,474	4,560	6,840	8,928	11,904
System Monitor	1	2	2	3	3	4
GTY Transceivers 32.75Gb/s	40	80	80	120	96	128
PCIe Gen3 x16 and Gen4 x8	2	4	4	6	3	4
150G Interlaken	3	4	6	9	9	12
100G Ethernet w/RS-FEC	3	4	6	9	6	8

Notes:

1. HP = High-performance I/O with support for I/O voltage from 1.0V to 1.8V.

Virtex UltraScale+ Device-Package Combinations and Maximum I/Os

Table 9: Virtex UltraScale+ Device-Package Combinations and Maximum I/Os

Package (1)(2)(3)	Package Dimensions (mm)	VU3P	VU5P	VU7P	VU9P	VU11P	VU13P
		HP, GTY	HP, GTY	HP, GTY	HP, GTY	HP, GTY	HP, GTY
FFVC1517	40x40	520, 40					
FLVF1924	45x45					624, 64	
FLVA2104	47.5x47.5		832, 52	832, 52	832, 52		
FHVA2104	52.5x52.5 ⁽⁴⁾						832, 52
FLVB2104	47.5x47.5		702, 76	702, 76	702, 76	624, 76	
FHVB2104	52.5x52.5 ⁽⁴⁾						702, 76
FLVC2104	47.5x47.5		416, 80	416, 80	416, 104	416, 96	
FHVC2104	52.5x52.5 ⁽⁴⁾						416, 104
FLVA2577	52.5x52.5				448, 120	448, 96	448, 128

Notes:

- Go to [Ordering Information](#) for package designation details.
- All packages have 1.0mm ball pitch.
- Packages with the same last letter and number sequence, e.g., A2104, are footprint compatible with all other UltraScale devices with the same sequence. The footprint compatible devices within this family are outlined.
- These 52.5x52.5mm overhang packages have the same PCB ball footprint as the corresponding 47.5x47.5mm packages (i.e., the same last letter and number sequence) and are footprint compatible.

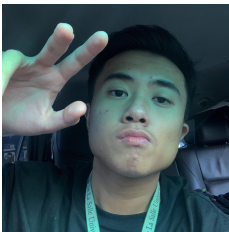
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1533 **Chapter N**
1534 **ARTICLE PAPER(S)**