CS4110 - Project Assignment

Design and Implementation of a Insertion Algorihim

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*Abstract* — The scope of this document discusses the consideration of design and implementation of an insertion sorting algorithm in both hardware and software. We will go into greater detail with our insight and present the four implementations for our selected algorithm that consists of an ASIP, a FSMD, a single-thread C program in Zynq/Vitis IDE, and an IP generated with Vitis HLS and used in Zynq/Vitis IDE.

Keywords—Hardware, Software, Basys-3, Zybq, RTL, HLS, C, VHDL, FSMD, ASIP ISA, Vivado, Vitis

# Introduction

This assignment is written as a technical paper that goes through our process regarding our design and implementation of an insertion sorting algorithm for four tasks in mind: 1) expanding our basic ASIP ISA, 2) creating an FSMD in VHDL, 3) coding it in Vitis IDE / Zynq and 4) creating a user IP block in Vitis HLS.

The AMD's Vitis Core Development Kit with the recommended version of 2023.2 was needed for this assignment as it includes applications like Vivado and Vitis HLS for our hardware and software implementation respectively.

Two development boards were used to carry out our testing and implementation of our insertion sorting algorithm. This includes the Digilent Basys-3 [2] and the Digilent Zybq-7000 (or Zybo-Z7) [3]. The Basys-3 was utilized for our first and second task because it was equipped with a Field Programmable Gate Array (FPGA) [2]. The ZYBO board was used for the third and last task as ZYBO development board has a Zynq 7000 System on Chip (SoC), which includes an FPGA, an ARM Cortex-A9 CPU, and connectivity peripherals [3].

# Insertion Sorting Algorihim

An insertion sorting algorithm is a very simple, straightforward method for sorting entries in a list or array in an ascending and descending order. The algorithm constructs a sorted segment of the array of one element at a time, placing each element into its proper position relative to the already-sorted area [1].

Initially, the algorithm treats the first member of the list as a sorted sublist with only that one entry. It then considers the next element in the list and compares it to those in the sorted sublist. If the new element is smaller than any of the elements in the sorted sublist, it is relocated until it reaches its proper position. This procedure repeats for each successive entry in the list, with the algorithm ensuring that the sorted sublist expands one element at a time while keeping its order.

(MAYBE SHOW PSEUDO CODE)

In the case of a list of numbers such as [4, 3, 5, 1, 2], for instance, insertion sort would begin at the first element of the array by considering element (4) as a sorted sublist. After comparing element 3 with element 4, it determines that element 3 should come before element 4. 3 is inserted in front of it, while 4 is moved to the right. The third element (5) is then considered by the algorithm. The two sorted elements (3 and 4) are already less than 5, thus nothing is changed. After the other elements in the sorted sublist (3, 4, and 5) have been shifted, the fourth element (1) is inserted at the front after being compared with every other element. The fifth element (2) is finally added between 1 and 3, resulting in the fully sorted list [1, 2, 3, 4, 5].

(SHOW FIGURE)

Insertion sort has the advantage of sorting the list in place, which eliminates the need for additional memory for a second list. This increases efficiency in terms of space complexity. However, it has a somewhat high time complexity for big lists, as it must constantly compare and shift entries, resulting in a worst-case time complexity of O(n²), where "n" is the number of elements in the list.

(SHOW GRAPH OF TIME-COMPLEXITY)

Identify applicable funding agency here. If none, delete this text box.

# …

# Prepare Your Paper Before Styling

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## Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

## Units

* Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
* Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.
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* Use a zero before decimal points: “0.25”, not “.25”. Use “cm3”, not “cc”. (*bullet list*)

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The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please no other font). To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

Number equations consecutively. Equation numbers, within parentheses, are to position flush right, as in (1), using a right tab stop. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

*a**b* 

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## Some Common Mistakes

* The word “data” is plural, not singular.
* The subscript for the permeability of vacuum **0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
* In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
* A graph within a graph is an “inset”, not an “insert”. The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).
* Do not use the word “essentially” to mean “approximately” or “effectively”.
* In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.
* Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
* Do not confuse “imply” and “infer”.
* The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
* There is no period after the “et” in the Latin abbreviation “et al.”.
* The abbreviation “i.e.” means “that is”, and the abbreviation “e.g.” means “for example”.

An excellent style manual for science writers is [7].

# Using the Template

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## Authors and Affiliations

**The template is designed for, but not limited to, six authors.** A minimum of one author is required for all conference articles. Author names should be listed starting from left to right and then moving down to the next line. This is the author sequence that will be used in future citations and by indexing services. Names should not be listed in columns nor group by affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization).

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Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is “Heading 5”. Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract”, will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced. Styles named “Heading 1”, “Heading 2”, “Heading 3”, and “Heading 4” are prescribed.

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1. Table Type Styles

| Table Head | Table Column Head | | |
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| copy | More table copya |  |  |

1. Sample of a Table footnote. (*Table footnote*)
2. Example of a figure caption. (*figure caption*)

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity “Magnetization”, or “Magnetization, M”, not just “M”. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write “Magnetization (A/m)” or “Magnetization {A[m(1)]}”, not just “A/m”. Do not label axes with a ratio of quantities and units. For example, write “Temperature (K)”, not “Temperature/K”.

##### Acknowledgment *(Heading 5)*

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

##### References

1. Wikipedia Contributors, “Insertion sort,” Wikipedia, Sep. 07, 2024. https://en.wikipedia.org/wiki/Insertion\_sort# (accessed Oct. 20, 2024).
2. Digilent, “Basys 3 FPGA Board Reference Manual”, April 2016.
3. Digilent, “ZYBO FPGA Board Reference Manual”, February 2017.