



UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO

FACULTAD DE CIENCIAS

CNN PARA LA DISTINCIÓN DE GAMMAS Y HADRONES CON  
HAWC'S EYE

T E S I S

Que para obtener el título de:

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Presenta:

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TUTOR:

Dr. José Rubén Alfaro Molina LOCATION:

Ciudad de México, México

*Ohana* means family.  
Family means nobody gets left behind, or forgotten.  
— Lilo & Stitch

Dedicated to the loving memory of Rudolf Miede.  
1939 – 2005





## Resumen

Short summary of the contents in English...a great guide by Kent Beck how to write good abstracts can be found here:

<https://plg.uwaterloo.ca/~migod/research/beck00PSLA.html>



## Abstract

Kurze Zusammenfassung des Inhaltes in deutscher Sprache...



*We have seen that computer programming is an art,  
because it applies accumulated knowledge to the world,  
because it requires skill and ingenuity, and especially  
because it produces objects of beauty.*

— Donald E. Knuth [14]



## Agradecimientos

Put your acknowledgments here.

Many thanks to everybody who already sent me a postcard!

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<sup>1</sup> Members of GuIT (Gruppo Italiano Utilizzatori di T<sub>E</sub>X e L<sup>A</sup>T<sub>E</sub>X)







## Índice general

### I PRÓLOGO

|     |   |   |
|-----|---|---|
| 1   | INTRODUCCIÓN                                    | 3 |
| 1.1 | Planteamiento del problema y objetivo . . . . . | 3 |
| 1.2 | Estructura de la tesis . . . . .                | 3 |

### II DETECTECCTORES DE RAYOS GAMMA Y HADRONES

|       |  |   |
|-------|--|---|
| 2     | MARCO HISTÓRICO                                | 7 |
| 2.1   | Primeros telescopios y observatorios . . . . . | 7 |
| 2.2   | Resultados importantes . . . . .               | 7 |
| 3     | HAWC'S EYE                                     | 9 |
| 3.1   | Marco histórico . . . . .                      | 9 |
| 3.1.1 | Comienzo del proyecto HAWC's Eye . . . . .     | 9 |
| 3.1.2 | Propósitos u objetivos . . . . .               | 9 |
| 3.2   | Principios de funcionamiento . . . . .         | 9 |
| 3.3   | Campañas observacionales . . . . .             | 9 |
| 3.3.1 | Datos . . . . .                                | 9 |

### III REDES NEURONALES

|       |  |    |
|-------|--|----|
| 4     | INTELIGENCIA ARTIFICIAL                                  | 13 |
| 4.1   | Inteligencia Artificial y Aprendizaje Profundo . . . . . | 13 |
| 4.2   | Redes Neuronales . . . . .                               | 13 |
| 5     | FUNDAMENTOS TEÓRICOS                                     | 15 |
| 5.1   | Teorema del aproximador universal . . . . .              | 15 |
| 5.2   | Teoremas otros . . . . .                                 | 15 |
| 6     | IMPLEMENTACIÓN DE MODELOS                                | 17 |
| 6.1   | División de los datos . . . . .                          | 17 |
| 6.1.1 | Datos de entrenamiento (Train) . . . . .                 | 17 |
| 6.1.2 | Datos de Validación (Validation) . . . . .               | 17 |
| 6.1.3 | Datos de prueba (Test) . . . . .                         | 17 |
| 6.2   | Función de activación . . . . .                          | 17 |
| 6.3   | Funciones de pérdida y métricas . . . . .                | 17 |
| 6.4   | Optimizador . . . . .                                    | 17 |
| 7     | REDES NEURONALES CONVOLUCIONALES                         | 19 |
| 7.1   | Modelo . . . . .   | 19 |
| 7.2   | Principales aplicaciones . . . . .                       | 19 |

### IV IMPLEMENTACIÓN DE UN MODELO CNN PARA LA DISTINC- CIÓN DE GAMMAS Y HADRONES CON HAWC'S EYE

|   |                    |    |
|---|--------------------|----|
| 8 | OBTENCIÓN DE DATOS | 23 |
|---|--------------------|----|

|        |   |    |
|--------|---|----|
| 8.1    | Uso del software MARS . . . . .               | 23 |
| 8.2    | Ejemplos de datos . . . . .                   | 23 |
| 8.2.1  | Datos de entrada y salida . . . . .           | 23 |
| 8.2.2  | División de los datos . . . . .               | 23 |
| 9      | DESCRIPCIÓN DEL MODELO . . . . .              | 25 |
| 9.1    | Capas del la CNN . . . . .                    | 25 |
| 9.2    | Hiperparámetros y parámetros . . . . .        | 25 |
| 10     | ANÁLISIS DE RESULTADOS Y CONCLUSIÓN . . . . . | 27 |
| 10.1   | Inferencias . . . . .                         | 27 |
| 10.2   | Presición del modelo . . . . .                | 27 |
| 10.3   | Conclusión . . . . .                          | 27 |
| 10.3.1 | Propuestas para mejorar el modelo . . . . .   | 27 |
| V      | APÉNDICE . . . . .                            |    |
| A      | APPENDIX TEST . . . . .                       | 31 |
| A.1    | Appendix Section Test . . . . .               | 31 |
| A.2    | Another Appendix Section Test . . . . .       | 31 |
|        | BIBLIOGRAFÍA . . . . .                        | 33 |

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## Índice de figuras

---



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## Índice de cuadros

|           |                        |    |
|-----------|------------------------|----|
| Tabla A.1 | Autem usu id . . . . . | 31 |
|-----------|------------------------|----|

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## Listings

|             |  |    |
|-------------|--|----|
| Listing A.1 | A floating example (listings manual) . . . . . | 31 |
|-------------|--|----|

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## Acronyms

## Parte I

### PRÓLOGO

You can put some informational part preamble text here. Illo principalmente su nos. Non message *occidental* angloromanic da. Debitas effortio simplificate sia se, auxiliar summarios da que, se avantiate publicationes via. Pan in terra summarios, capital interlingua se que. Al via multo esser specimen, campo responder que da. Le usate medical addresses pro, europa origine sanctificate nos se.



# 1



## Introducción

- 1.1 Planteamiento del problema y objetivo
- 1.2 Estructura de la tesis



## Parte II

### DETECTORES DE RAYOS GAMMA Y HADRONES

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# 2



## Marco histórico

- 2.1 Primeros telescopios y observatorios
- 2.2 Resultados importantes



# 3



## HAWC's Eye

### 3.1 Marco histórico

#### 3.1.1 *Comienzo del proyecto HAWC's Eye*

#### 3.1.2 *Propósitos u objetivos*

### 3.2 Principios de funcionamiento

### 3.3 Campañas observacionales

#### 3.3.1 *Datos*



### Parte III

## REDES NEURONALES

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# 4



## Inteligencia Artificial

- 4.1 Inteligencia Artificial y Aprendizaje Profundo
- 4.2 Redes Neuronales





# 5



## Fundamentos teóricos

- 5.1 Teorema del aproximador universal
- 5.2 Teoremas otros



# 6



## Implementación de modelos

### 6.1 División de los datos

#### 6.1.1 *Datos de entrenamiento (Train)*

#### 6.1.2 *Datos de Validación (Validation)*

#### 6.1.3 *Datos de prueba (Test)*

### 6.2 Función de activación

### 6.3 Funciones de pérdida y métricas

### 6.4 Optimizador



# 7



## Redes Neuronales Convolucionales

7.1 Modelo

7.2 Principales aplicaciones



## Parte IV

### IMPLEMENTACIÓN DE UN MODELO CNN PARA LA DISTINCIÓN DE GAMMAS Y HADRONES CON HAWC'S EYE

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summarios, capital interlingua se que. Al via multo esser  
specimen, campo responder que da. Le usate medical ad-  
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# 8



## Obtención de datos

8.1 Uso del software MARS

8.2 Ejemplos de datos

8.2.1 *Datos de entrada y salida*

8.2.2 *División de los datos*



# 9



## Descripción del modelo

- 9.1 Capas de la CNN
- 9.2 Hiperparámetros y parámetros



# 10



## Análisis de resultados y conclusión

### 10.1 Inferencias

### 10.2 Presición del modelo

### 10.3 Conclusión

#### 10.3.1 *Propuestas para mejorar el modelo*



Parte V

## APÉNDICE





# A



## Appendix Test

Lorem ipsum at nusquam appellantur his, ut eos erant homero concludaturque. Albucius appellantur deterruisset id eam, vivendum partiendo dissentiet ei ius. Vis melius facilisis ea, sea id convenire referrentur, takimata adolescens ex duo. Ei harum argumentum per. Eam vidit exerci appetere ad, ut vel zzril intellegam interpretaris.

*More dummy text.*

### A.1 Appendix Section Test

Test: **Tablita A.1** (This reference should have a lowercase, small caps A if the option floatperchapter is activated, just as in the table itself → however, this does not work at the moment.)

| LABITUR BONORUM PRI NO | QUE VISTA | HUMAN        |
|------------------------|-----------|--------------|
| fastidii ea ius        | germano   | demonstratea |
| suscipit instructor    | titulo    | personas     |
| quaestio philosophia   | facto     | demonstrated |

Tabla A.1: Autem usu id.

### A.2 Another Appendix Section Test

Equidem detraxit cu nam, vix eu delenit periculis. Eos ut vero constituto, no vidit propriae complectitur sea. Diceret nonummy in has, no qui eligendi recteque consetetur. Mel eu dictas suscipiantur, et sed placerat oporteat. At ipsum electram mei, ad aeque atomorum mea. There is also a useless Pascal listing below: **Listing A.1**.

Listing A.1: A floating example (listings manual)

```
for i:=maxint downto 0 do
begin
{ do nothing }
end;
```





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## Declaration

Put your declaration here.

*Ciudad de México, México, 2021*

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Jessica Martínez Marcelo



## Colophon

This document was typeset using the typographical look-and-feel `classicthesis` developed by André Miede and Ivo Pletikosić. The style was inspired by Robert Bringhurst's seminal book on typography "*The Elements of Typographic Style*". `classicthesis` is available for both  $\text{\LaTeX}$  and  $\text{\LyX}$ :

<https://bitbucket.org/amiede/classicthesis/>

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