Rules Wizard

SUMMARY

These documents require Adobe® Acrobat Reader, which is a free download from the Adobe® website.

The answers you gave to questions on the previous pages of the Rules Wizard indicate that you need to download the following forms in order to adhere to the International Rules:

These three forms are required for **all** participants:

- Checklist for Adult Sponsor (1)
- Student Checklist (1A) and Research Plan
- Approval Form (1B)

- Official Abstract Form (87 kb) -- Some fairs may require the use of the Intel ISEF Official Abstract Form; others may have their own required format. Please contact your regional fair for more information. **Note:** Intel ISEF finalists do **not** fill out this abstract form - they have to fill out their abstract on-line. Please read the instructions for completion thoroughly.

- Regulated Research Institutional/Industrial Setting Form (1C) (28 kb) -- This form must be completed by the scientist supervising the student research conducted in a regulated research institution (e.g., university lab, medical center, NIH, SSTP, etc.) or industrial setting. A Research Institution Approval form may need to be supplied by the research site (i.e. IRB/IACUC/IBC).

THESE FORMS ARE NOT TO BE ELECTRONICALLY TRANSFERRED TO Society for Science & The Public. THE FORMS MUST BE COMPLETED BY THE APPROPRIATE INDIVIDUALS, SIGNED AND COPIES SUBMITTED TO your science fair for local, regional or state competition.

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Checklist for Adult Sponsor (1)

This completed form is required for ALL projects.

To be completed by the Adult Sponsor in collaboration with the student researcher(s):

Student's Name(s): Sun Xinyu.

Project Title: Prediction of Solar Power Potential in Singapore using Numerical ~~Mac~~ Weather Predic~~a~~ Models and Machine Learning.

1. ☐ I have reviewed the Intel ISEF Rules and Guidelines.

2. ☐ I have reviewed the student's completed Student Checklist (1A) and Research Plan/Project Summary.

3. ☐ I have worked with the student and we have discussed the possible risks involved in the project.

4. ☐ The project involves one or more of the following and requires prior approval by an SRC, IRB, IACUC or IBC:
   - ☐ Humans
   - ☐ Vertebrate Animals
   - Potentially Hazardous Biological Agents
     - ☐ Microorganisms ☐ rDNA ☐ Tissues

5. ☐ Items to be completed for **ALL PROJECTS**
   - ☐ Adult Sponsor Checklist (1)
   - ☐ Student Checklist (1A)
   - ☐ Research Plan/Project Summary
   - ☐ Approval Form (1B)
   - ☐ Regulated Research Institutional/Industrial Setting Form (1C) (when applicable; after completed experiment)
   - ☐ Continuation/Research Progression Form (7) (when applicable)

Additional forms required if the project includes the use of one or more of the following (check all that apply):

☐ **Humans,** including student designed inventions/prototypes. (Requires prior approval by an Institutional Review Board (IRB); see full text of the rules.)
- ☐ Human Participants Form (4) or appropriate Institutional IRB documentation
- ☐ Sample of Informed Consent Form (when applicable and/or required by the IRB)
- ☐ Qualified Scientist Form (2) (when applicable and/or required by the IRB)

☐ **Vertebrate Animals** (Requires prior approval, see full text of the rules.)
- ☐ Vertebrate Animal Form (5A) - for projects conducted in a school/home/field research site (SRC prior approval required.)
- ☐ Vertebrate Animal Form (5B) - for projects conducted at a Regulated Research Institution. (Institutional Animal Care and Use Committee (IACUC) approval required prior experimentation.)
- ☐ Qualified Scientist Form (2) (Required for all vertebrate animal projects at a regulated research site or when applicable)

☐ **Potentially Hazardous Biological Agents** (Requires prior approval by SRC, IACUC or IBC, see full text of the rules.)
- ☐ Potentially Hazardous Biological Agents Risk Assessment Form (6A)
- ☐ Human and Vertebrate Animal Tissue Form (6B) - to be completed in addition to Form 6A when project involves the use of fresh or frozen tissue, primary cell cultures, blood, blood products and body fluids.
- ☐ Qualified Scientist Form (2) (when applicable)
- ☐ The following are exempt from prior review but require a Risk Assessment Form 3: projects involving protists, archae and similar microorganisms, for projects using manure for composting, fuel production or other non-culturing experiments, projects using color change coliform water test kits, microbial fuel cells, and projects involving decomposing vertebrate organisms.

☐ **Hazardous Chemicals, Activities and Devices** (No SRC prior approval required, see full text of the rules.)
- ☐ Risk Assessment Form (3)
- ☐ Qualified Scientist Form (2) (required for projects involving DEA-controlled substances or when applicable)

Daren Ler.		12/01/18
Adult Sponsor's Printed Name	Signature	Date of Review (mm/dd/yy)
9462 8731.	daren_ler_shan_wei@moe.edu.sg	
Phone	Email	

Student Checklist (1A)

This form is required for ALL projects.

1. a. Student/Team Leader: Sun Xinyu Grade: JH4

   Email: seanxinyu2@gmail.com Phone: 8469 0102

   b. Team Member: _____ c. Team Member: _____

2. Title of Project:

   Prediction of Solar Power Potential in Singapore using Numerical Weather Prediction Models and Machine Learning

3. School: National Junior College School Phone: +65 6466 1144

   School Address: 37 Hillcrest Road, Singapore, 288913

4. Adult Sponsor: Daren Ler Phone/Email: daren_ler_shan_wei@moe.edu.sg

5. Does this project need SRC/IRB/IACUC or other pre-approval? ☐ Yes ☑ No Tentative start date: _____

6. Is this a continuation/progression from a previous year? ☐ Yes ☑ No

   If Yes:

   a. Attach the previous year's ☐ Abstract **and** ☐ Research Plan/Project Summary

   b. Explain how this project is new and different from previous years on

   ☐ Continuation/Research Progression Form (7)

7. This year's laboratory experiment/data collection:

   02/02/18 (Actual Start Date: (mm/dd/yy)) 12/31/18 (End Date: (mm/dd/yy))

8. Where will you conduct your experimentation? (check all that apply)

   ■ Research Institution ☐ School ☐ Field ■ Home ☐ Other: _____

9. List name and address of all non-home and non-school work site(s):

   Name: _____ _____

   Address: _____ _____

   _____ _____

   Phone/ email _____ _____

10. **Complete a Research Plan/Project Summary following the Research Plan/Project Summary instructions and attach to this form.**

11. **An abstract is required for all projects after experimentation.**

Approval Form (1B)

A completed form is required for each student, including all team members.

1. To Be Completed by Student and Parent

a. Student Acknowledgment:

- I understand the risks and possible dangers to me of the proposed research plan.
- I have read the Intel ISEF Rules and Guidelines and will adhere to all International Rules when conducting this research.
- I have read and will abide by the following Ethics statement

Student researchers are expected to maintain the highest standards of honesty and integrity. Scientific fraud and misconduct are not condoned at any level of research or competition. Such practices include but are not limited to plagiarism, forgery, use or presentation of other researcher's work as one's own, and fabrication of data. Fraudulent projects will fail to qualify for competition in affiliated fairs and the Intel ISEF.

Sun Xinyu		01/03/18
Student's Printed Name	Signature	Date Acknowledged (mm/dd/yy) (Must be prior to experimentation.)

b. Parent/Guardian Approval: I have read and understand the risks and possible dangers involved in the **Research Plan/Project Summary**. I consent to my child participating in this research.

Wang Muran		01/03/18
Parent/Guardian's Printed Name	Signature	Date Acknowledged (mm/dd/yy) (Must be prior to experimentation.)

2. To be completed by the local or affiliated Fair SRC

(Required for projects requiring prior SRC/IRB APPROVAL. Sign 2a or 2b as appropriate.)

a. Required for projects that need prior SRC/IRB approval BEFORE experimentation (humans, vertebrates or potentially hazardous biological agents).

The SRC/IRB has carefully studied this project's **Research Plan/ Project Summary** and all the required forms are included. My signature indicates approval of the **Research Plan/Project Summary** before the student begins experimentation.

SRC/IRB Chair's Printed Name

	01/03/18
Signature	Date of Approval (mm/dd/yy) (Must be prior to experimentation.)

OR

b. Required for research conducted at all Regulated Research Institutions with no prior fair SRC/IRB approval.

This project was conducted at a regulated research institution (**not home or high school, etc.**), was reviewed and approved by the proper institutional board before experimentation and complies with the Intel ISEF Rules. **Attach (1C) and any required institutional approvals (e.g. IACUC, IRB).**

SRC Chair's Printed Name

Signature	Date of Approval (mm/dd/yy)

3. Final Intel ISEF Affiliated Fair SRC Approval (Required for ALL Projects)

SRC Approval After Experimentation and Before Competition at Regional/State/National Fair

I certify that this project adheres to the approved **Research Plan/Project Summary** and complies with all Intel ISEF Rules.

Regional SRC Chair's Printed Name	Signature	Date of Approval (mm/dd/yy)
State/National SRC Chair's Printed Name *(where applicable)*	Signature	Date of Approval (mm/dd/yy)

Regulated Research Institutional/Industrial Setting Form (1C)

This form must be completed AFTER experimentation by the adult supervising the student research conducted in a regulated research institution, industrial setting or any work site other than home, school or field.

Student's Name(s) Sun Xinyu

Title of Project Prediction of Solar Power Potential in Singapore using Numerical Weather Prediction Models and Machine Learning

To be completed by the Supervising Adult in the Setting (NOT the Student(s)) after experimentation:
(Responses must be on the form as it is required to be displayed at student's project booth; please do not print double-sided.)

The student(s) conducted research at my work site:

1. Did you or your proxy (e.g. graduate student, postdoc, employee) mentor or provide substantial guidance to the student researcher? ☑ Yes ☐ No
   a. If no, describe your and/or your institution's role with the student researcher and his/her project (e.g. supervised use of equipment on site without ongoing mentorship and sign below.

   b. If yes, complete questions 2–5.

2. Is the student's research project a subset of your ongoing research or work? ☑ Yes ☐ No
   Use questions 3, 4 and 5 to detail how the student's project was similar and/or different from ongoing research or work at your site.

3. Describe the independence and creativity with which the student:
   a. developed the hypotheses or engineering goals for the research project

   Following consultations with his supervisors, Xinyu had a good idea of what he would be studying through the project and formulated the goals and what he had to test & study in his project

   b. designed the methodology for his/her research project

   Once the basics were explained, Xinyu grasped them well and used them to design the methodology for his work

   c. analyzed and interpreted data

   Xinyu did a fair job on interpreting and analyzing the different sets of data - what had been given to him as the input and the output from his runs.

(Continued on next page)

Regulated Research Institutional/Industrial Setting Form (1C) Continued

Student's Name(s) Sun Xinyu

4. Detail the student's role in conducting the research (e.g. data collection, specific procedures performed). Differentiate what the student observed and what the student actually did.

From discussions with his supervisors, Xinyu got an idea of what the project entailed. He picked up the relevant skills, particularly in learning & using programming languages and their libraries for machine learning. Based on big-picture discussions with his supervisors, Xinyu tried and tested out different machine learning algorithms and strategies for the project.

5. Did the student(s) work on the project as part of a group? ☐ Yes ☑ No
If yes, how many individuals were in the group and who were they (e.g. high school students, graduate students, faculty, professional researchers)?

I attest that the student has conducted the work as indicated above and that any required review and approval by institutional regulatory board (IRB/IACUC/IBC) has been obtained. Copies are attached if applicable.
I further acknowledge that the student will be presenting this work publicly in competition and I have communicated with the student research regarding any requirements for my review and/or restrictions of what is publicized.

Venugopalan Raghavan	S. Venugopalan	Research Engineer
Supervising Adult's Printed Name	Signature	Title
Institute of High Performance Computing		11/30/18
Institution		Date Signed (must be after experimentation) (mm/dd/yy)
1 Fusionopolis Way, #16-16 Connexis North, Singapore 138632		raghavanvsg@ihpc.a-star.edu.sg / 64191422
Address		Email/Phone

Project Code: 5hda EP001

Singapore Science and Engineering Fair 2019
Entry Form

Please refer to the SSEF website (http://www.science.edu.sg/ssef) for details on the application process and all the submission requirements. **All documents must be received by Wednesday, 9 January 2019, 5pm.**

PROJECT INFORMATION

**Please refer to Annex A for the list of categories and sub-categories. Selecting the appropriate category and sub-category is important to ensure that the assigned judges are familiar with your research topic.*

Type of Participation:	Project Category*:	Project Sub-Category*:
Individual / Team (Please circle)	EP: ENERGY (PHYSICAL)	EP_3: Solar.

Title of Research Project:
Prediction of Solar Power Potential in Singapore using Numerical Weather Prediction Models and Machine Learning.

DECLARATION BY PARTICIPANT(S)

I/We hereby certify that all the information provided to SSEF organisers is correct. I/We did not plagiarise material, forge or fabricate data, use or present other researcher's work as our own in my/our research project. I/We consent to the use of the information/project I/we submit to the organisers for publicity purpose. I/We understand that all the materials I/we submit will not be returned to me/us.

Individual / Team Leader (i.e. team member 1)		
Full name: Sun Xinyu	School: National Junior College.	School Level (E.g. Sec 3, IP4): IP4.
Signature:	NRIC/FIN no.: G1647712K.	Date: 12/01/18
For Team Projects:		
Team Member 2		
Full name:	School:	School Level (E.g. Sec 3, IP4):
Signature:	NRIC/FIN no.:	Date: 12/01/18
Team Member 3		
Full name:	School:	School Level (E.g. Sec 3, IP4):
Signature:	NRIC/FIN no.:	Date: 12/01/18

SCHOOL'S ENDORSEMENT
For individual project / team projects with members from the same school

Teacher-in-charge's full name:	Teacher-in-charge's email address:
Daren Ler.	daren_ler_shan_wei@moe.edu.sg.
Teacher-in-charge's signature:	**Date:**
	12/01/18

SCHOOL'S ENDORSEMENT
For team projects with members from different schools

For team member 1

Teacher-in-charge's full name:	Teacher-in-charge's email address:
Teacher-in-charge's signature:	**Date:**
	12/01/18

For team member 2

Teacher-in-charge's full name:	Teacher-in-charge's email address:
Teacher-in-charge's signature:	**Date:**
	12/01/18

For team member 3

Teacher-in-charge's full name:	Teacher-in-charge's email address:
Teacher-in-charge's signature:	**Date:**
	12/01/18

OFFICIAL ABSTRACT and CERTIFICATION

Prediction of Solar Power Potential in Singapore using Numerical Weather Prediction Models and Machine Learning

Sun Xinyu
National Junior College

Given the increasing application of solar energy, the prediction of the clean energy output is becoming more significant over the time. We can derive solar radiation forecast from Weather Research and Forecast (WRF) model and in this case, the clear-sky ratio (CSR), which reflects the ratio relationship between Diffuse Solar Radiation (SWDIF) and Direct Solar Radiation (SWDIR), is employed to classify the solar power potential into different levels. However, despite its high accuracy, WRF is highly time-consuming and requires a huge amount of prior knowledge to operate. In order to make accurate predictions with shorter periods of time, Machine Learning Algorithms are now playing an important role in the area. In this paper, based on solar radiation data generated by WRF for the period 1 Jan 2018 - 1 Jan 2019 at 62 different locations across Singapore, a few machine learning models based on various algorithms such as Support Vector Machine (SVM), Random Forest, k-nearest neighbours (KNN) together with the Time-series models are going to be built. They are going to be assessed regarding their performance in prediction, in order to find an alternative approach that can yield feasible predictions with less time taken compared with the WRF model.

Category
Pick one only—mark an "X" in box at right

Animal Sciences	☐
Behavioral & Social Sciences	☐
Biochemistry	☐
Biomedical & Health Sciences	☐
Biomedical Engineering	☐
Cellular & Molecular Biology	☐
Chemistry	☐
Computational Biology & Bioinformatics	☐
Earth & Environmental Sciences	☐
Embedded Systems	☐
Energy: Chemical	☐
Energy: Physical	■
Engineering Mechanics	☐
Environmental Engineering	☐
Materials Science	☐
Mathematics	☐
Microbiology	☐
Physics & Astronomy	☐
Plant Sciences	☐
Robotics & Intelligent Machines	☐
Systems Software	☐
Translational Medical Sciences	☐

1. As a part of this research project, the student directly handled, manipulated, or interacted with (check ALL that apply):

   ☐ human participants ☐ potentially hazardous biological agents

   ☐ vertebrate animals ☐ microorganisms ☐ rDNA ☐ tissue

2. I/we worked or used equipment in a regulated research institution or industrial setting: ☐ Yes ■ No

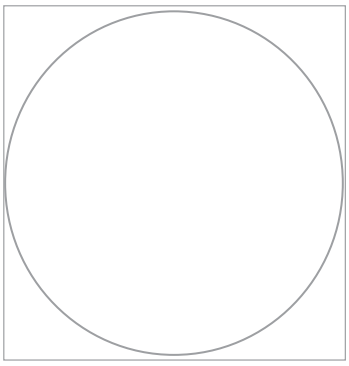
3. This project is a continuation of previous research. ☐ Yes ■ No

4. My display board includes non-published photographs/visual depictions of humans (other than myself): ☐ Yes ■ No

5. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only ■ Yes ☐ No

6. I/we hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work. ■ Yes ☐ No

This stamp or embossed seal attests that this project is in compliance with all federal and state laws and regulations and that all appropriate reviews and approvals have been obtained including the final clearance by the Scientific Review Committee.



Research Plan

Abstract

Given the increasing application of solar energy, the prediction of the clean energy output is becoming more significant over the time. We can derive solar radiation forecast from Weather Research and Forecast (WRF) model and in this case, the clear-sky ratio (CSR), which reflects the ratio relationship between Diffuse Solar Radiation (SWDIF) and Direct Solar Radiation (SWDIR), is employed to classify the solar power potential into different levels. However, despite its high accuracy, WRF is highly time-consuming and requires a huge amount of prior knowledge to operate. In order to make accurate predictions with shorter periods of time, Machine Learning Algorithms are now playing an important role in the area. In this paper, based on solar radiation data generated by WRF for the period 1 Jan 2018 - 1 Jan 2019 at 62 different locations across Singapore, a few machine learning models based on various algorithms such as Support Vector Machine (SVM), Random Forest, k-nearest neighbours (KNN) together with the Time-series models are going to be built. They are going to be assessed regarding their performance in prediction, in order to find an alternative approach that can yield feasible predictions with less time taken compared with the WRF model.

Rationale:

When it comes to energy generation, solar power remains the most promising renewable energy source in Singapore. With an average solar irradiance of 1,580 kWh/(m^2*year) and about 50% more solar radiation than temperate countries, solar photovoltaic (PV) generation has the greatest potential for wider deployment in Singapore. [1] Moreover, a report by National Renewable Energy Lab [2] has indicated that from 2010 to 2017 there has been approximately a 70% reduction in the total PV system hardware cost. Combining great potential and decreasing cost, there is a strong demand to deploy solar power widely in Singapore. Precise solar radiation prediction will be the key to successful integration of solar power.

Currently, Weather Research and Forecast (WRF) model [3] has been widely used for the weather forecast in the study [4] [5]. Additionally, the model has been proved to be successful in power output forecasting in the context of Smart Grids and Renewable Energy on [6]. However, the WRF model has its limitation of long running time [7] [8] and it took **a few weeks** in total to generate the whole dataset of solar radiation data at multiple different locations across one year used in this study.

Due to the high cost of time in applying the WRF model, there is a strong demand to develop alternative ways to make the necessary predictions. [9] Machine Learning [10] that research different algorithms, which can learn information from datasets, can be a useful tool to make predictions with much shorter time taken [11]. Essentially, various algorithms can accept a given set of training examples and derive a general trend over time. [5] There are different machine learning algorithms, such as Support Vector Machine (SVM), Random Forest, Time Series and so

on.[12][13][14][15][16][17][18][19] The focus of this study is to learn about the algorithms and apply them to this problem. With the best model evaluated by different metrics like MAE, MSE, and RMSE, we can have an alternative way to make accurate predictions of solar radiation with less time.[20]

Research question(s), hypothesis(es), engineering goal(s), expected outcome

The **Research Question** is that by building machine learning models in replace of WRF, can we find an alternative way to predict solar radiation in Singapore with less time taken?

The **hypothesis** is that through computational experiments we can build one or more machine learning models that can make solar potential predictions with faster speed.

The **engineering goal** is to develop a machine learning model to interpolate the solar radiation potential of multiple certain locations across Singapore based on the data generated by the WRF model for the past one year. This model can then be used to make predictions of the future solar potential at a certain time of interest at any given location.

The **expected outcome** is to build a machine learning model that can accurately predict the solar radiation data based on location and time with the smallest error with the much shorter time taken compared with the WRF model.

Procedures

The original data is the solar radiation data at multiple different locations across the country generated by the WRF model for the period 1 Jan 2018, 8 am - 1 Jan 2019, 8 am. It consists of four columns and processed to the format that python can accept.

In order to have a general idea about solar radiation potential in Singapore, graphs of Direct Solar Radiation (SWDIR) and Diffuse Solar Radiation (SWDIF) values at various locations between different time intervals (a day, a week and a month namely) will be plotted. As the predictions are in terms of CSR, defined as $CSR = SWDIF/(SWDIR + SWDIF)$ with its range from 0 to 1 by definition, the NaN values (not a number) of CSR with both SWDIR and SWDIF zero should be removed or converted to a usable format. The whole dataset is going to be split into training sets and test sets in the ratio of 7:3.

After preprocessing the data, we can start to work on building the model. Different inputs can help machine learning models to derive different features. In order to derive main features of the dataset, including seasonality, spatial correlation and so on[21], the training features are not only restricted with the time and corresponding CSR but also include the location features and the correlation of CSR at different places. A few models based on classification or regression (Support Vector Machine, Random Forest, Time series model and so on) [12][13][14][15][16][17][18][19] will then be built and able to accurately predict the CSR for any time during the year.

The models built are going to be tested with the test sets separated ahead and predictions made will be compared against the actual result in the test set. By using different metrics including the mean average error (MAE), mean square error (MSE) and root mean squared error (RMSE), the accuracy of each model can be quantified and compared against one another. The model with the best performance will be chosen.

Risk and Safety

As this project is purely computational, there are very few safety issues involved.

However, there are risks present as the accuracy of the data decreases. In order to obtain a general trend from the dataset, details and small variance are intentionally ignored. Moreover, machine learning models usually have the restriction of computing power. As a result, lower accuracy of machine learning models is caused compared with the WRF model. [22]

Data Analysis

In order to assess how accurate a model is, a baseline model, which creates a trend of constant straight line regardless input values, is created and compared against all the other models built to know the improvement of the model in its accuracy. To quantify the difference in comparison, different metrics are employed including Mean Average Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE). MAE can be used to measure the overall variation with the same weight for all values, while MSE will give higher weight to larger variations from the actual result. RMSE, with the same rationale behind as MSE, can be interpreted as the standard deviation from the actual trend and can be easily understood for having the same units as the corresponding variable. By combining the result of four metrics, the accuracy of a model can be completely reflected.

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