HAN_UNIVERSITY
OF APPLIED SCIENCES

## Embedded Systems Engineering

# Project 2 EN
# Reverse geocache puzzle box
## *Project guide*

**Klassen: ESE-1**
**January 2025**
**Version 1.0**

## Document history

| Version | Date | Who | Changes |
|---|---|---|---|
| 1.0 | 28-01-2025 | Hugo Arends | Initial revision for academic year 2024-2025 |
| 1.1 | 28-01-2025 | Hugo Arends | Feedback from Remko Welling processed |
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# Contents

# 1. Introduction

In the second semester, as in the first semester, you work together with fellow students on a project. Unlike the project from the first semester, in this new project not all the requirements are known.

In this project, you will apply skills that you learned in the first project. You participate in a project group of about 5 students and develop a product for a client. In addition to using one (or more) microcontrollers and programming them in the C or C++ language, you are now also expected to use multiple sensors and actuators. You are also expected to create a PC application, with a clear graphical user interface, that interacts with the microcontroller.

This project manual describes the assignment and the way in which you should work on that assignment in the second semester. The assignment is described in detail in Chapter 3. Chapter 4 describes the design process. The schedule can be found in Chapter 5. What and how it is assessed is described in Chapter 6.

# 2. Project semester 2

The semester 2 project lasts the entire semester and consists of two parts: project 2a (period 3) and project 2b (period 4).

You will not work on the project alone: you will form a project team with fellow students, you will be given the assignment by a client and you will be supervised by a tutor. Carrying out a project involves many skills, including clear communication. Also during the hours that you work independently on the project, consult with each other to make the project a success together. You can also discuss project-related problems with fellow students in the learning teams.

## 2.1 Project team

In your project team, you design and build a realistic professional product together or in subgroups based on the client's requirements. You also draw up your own requirements, which you lay down in consultation with the client.

*Company name*
In order to imitate practice as closely as possible, we assume that you work as a project team at a company. Therefore, as a team, come up with an appropriate company name that you use in your documents and communication to others.

*Meeting*
A meeting will be held during the scheduled tutor hours. During a meeting, the activities of the past week are reviewed, interim results are shared, plans are made for the coming week and agreements are recorded in an action list. The action list describes who, what and when for each activity. In addition, the overall planning is monitored.

*Alternating roles*
However, you are not only involved in technical matters: you also take turns taking on the role of project leader, chairman and minute-taker. The roles of chairman and minute-taker change every week, so that at the end of the semester everyone has been chairman once and minute-taker once. The role of project leader changes once every four weeks.

*Building together, testing individually*
Even if you work in a project team, you have to acquire all the required competencies with the corresponding knowledge and skills. You will be assessed individually. This means that every student must be able to understand, explain and justify the complete structure of the product, even if the tasks are divided among the team members and you do not work on all aspects of the assignment.

*Reviews*
When allocating tasks, it's important to be well informed by your team members and to study their parts of the product report so that you understand how the entire product is put together and works, both hardware and software. To this end, regular reviews are held in which the entire project group is present and where each other's sub-products are critically examined. As a project group, you have to plan and carry out these reviews yourself.

A lot is left to your own initiative and creativity. Everyone works on their own development, but does this together with their fellow students, especially those of their own project group. Together you can do more than alone! This is not only about the professional knowledge, but also about applying it and being able to work together, in which the project skills (also later in the business world) are of

great importance. Taking responsibility and also feeling responsible for the well-being of your teammates and for the product to be developed are highly appreciated.

*Timekeeping*
Each student is expected to keep an individual record of how much time is spent on what for the benefit of the project. After all, the costs (man-hours) spent on carrying out the project should not become too great. This is included in the process report for each project team member.

### 2.2 Tutor

Each project group is assigned a tutor who guides the project group in a process-oriented manner. To this end, the tutor is present at the weekly project meeting. If necessary, he/she will make adjustments with regard to the progress of the project. However, creativity and initiative are expected from the students. The tutor also assesses the group's documents and products.

### 2.3 IPV

Three times during the semester, a so-called IPV (individual project skills) is filled in. The IPV is a form of peer feedback, in which the project members assess each other on various aspects related to working together in a project team. These aspects are described in a separate document called *e-ESE-S2 PROJ2 2425 IPV-form.docx* which is available on #OO.

In a project meeting, the results of the IPV are discussed under the guidance of the tutor. This is a personal development-oriented session, where students learn from each other and can ask for feedback on their project skills.

The IPV also has a formal character, because during the final of the three IPVs, the aspects **Efford** and **Dealing with rules and agreements** must be scored at least with a pass in order to be able to pass the project. If this is not the case, the tutor may impose sanctions, depending on the situation. For example, a student can receive a final warning and concrete agreements can be made. Or a student can be denied further participation in the project, which means a resit the next academic year.

### 2.4 Client

One of the lecturers of the Embedded Systems Engineering team will play the role of client. Do not (simply) assume that the client has technical knowledge.

### 2.5 Learning objectives

*Project 2a (period 3)*
For a specific case study, the student will describe the following in correct English and as a member of a project team of about 5 students:

- the action plan, consisting of a description of the context, problem definition, project organisation, activities, products to be delivered and planning;
- a clear analysis of the product to be made through a field and desk study;
- a functional and technical specification based on the requirements of the customer/client;
- a functional design of the embedded part consisting of a brief description of the main functions by means of IDEs, breaking these down into relevant sub-functions and substantiating the relationships between them and the choices made with calculations and/or data from the analysis phase;

- the student actively applies themselves to the task of achieving the project objectives. This assessment criterion ensures a personalised final assessment, where peer feedback is taken into account under the guidance of a tutor (individual contribution factor).

*Project 2b (periode 4)*
For a specific case study, the student will describe the following in correct English and as a member of a project team of about 5 students:

- a technical design from the functional design, based on the chosen concept solutions (architecture) and established requirements;
- the relationship (hierarchy) between the system components such as microcontroller, sensors, actuators, PC and/or website is correctly displayed;
- a description of the realisation of the product or prototype, taking into account manufacturability and testability;
- design choices are tested against specifications and the design is verified by simulations and/or test software.;
- uses the appropriate design and development tools for the design and production of the hardware and software. As a member of a project team of about 5 students, the student demonstrates:
- the extent to which the functional and technical requirements have been achieved in the final product of the specific case study. The product was built using an ARM Cortex-M microcontroller programmed in the C language;
- the case study requires at least various sensors, various actuators and web interface (remote interface) to check the control and display data; - the student actively applies themselves to the task of achieving the project objectives. This assessment criterion ensures a personalised final assessment, where peer feedback is taken into account under the guidance of a tutor (individual contribution factor).

# 3. Assignment: Reverse geocache puzzle box

## 3.1 Assignment description

Geocaching (Wikipedia contributors, 2023) is a popular activity for many people. It is an outdoor activity with the aim of finding a 'treasure' based on a given GPS location. The 'treasure', better known as the *geocache* or cache for short, is usually a watertight container containing a logbook. With a GPS receiver or your mobile phone, you look for the geocache and as soon as you have found it, you write your name and the date in the logbook. Then you put the geocache back in the same place, so that others can also search for the geocache.

The following video explains how geocaching works: https://youtu.be/vuFiLhhCNww

The assignment for the second semester is very similar to geocaching, but the way it works is slightly different. Instead of looking for a geocache, the user gets their hands on the geocache at the start. However, the geocache is locked and will not open until the user brings the geocache to a specific GPS location. Hence the name *reverse* geocache. This principle is illustrated in Figure 1.

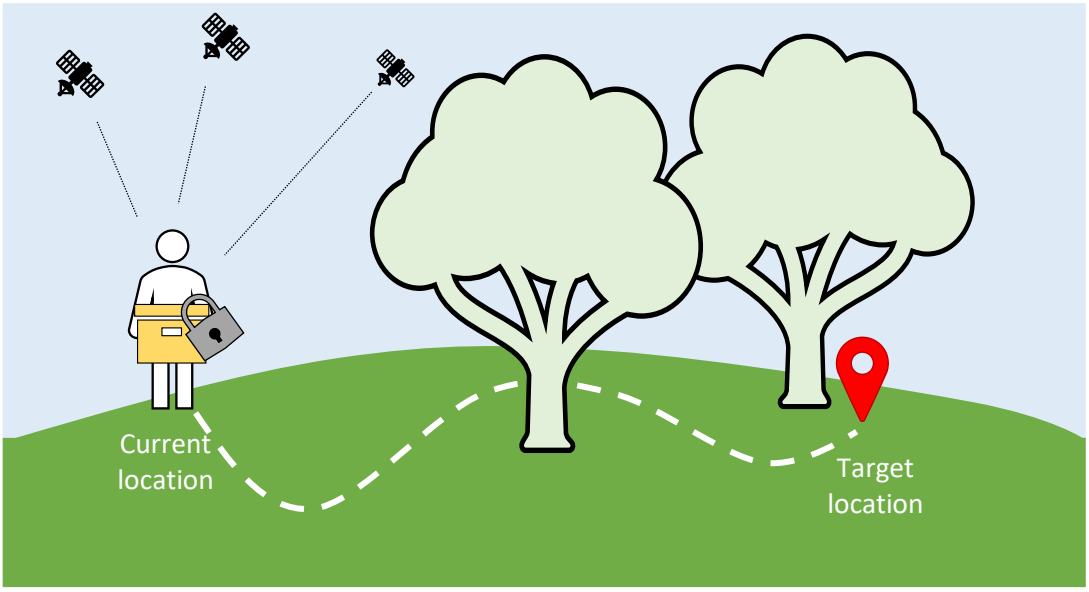



*Figure 1. Reverse geocaching.*

A reverse geocache consists of at least the following components:

- An enclosure that can be locked
- A GPS receiver to determine the current location
- A processing unit to determine the distance between the current location and the target location
- A visualization of the distance between the current location and the target location
- A lock that can be operated by the processing unit
- A battery

As soon as the target location is reached, the enclosure automatically unlocks and the user can access the contents of the reverse geocache. For example, the content can consist of a nice reward. After that, the reverse geocache must be returned to the owner.

To make the game more challenging, the reverse geocache needs to be provided with extra puzzle elements. The following puzzle elements serve as examples and inspiration.

- The distance to the target location should only be viewed a limited number of times by pressing a button.
- Instead of one target location, three target locations must be visited.
- If there are multiple target locations, the next target location must be reached within a certain amount of time. Otherwise, the user will have to go back first.
- In the case of multiple target locations, each location gives a number with which the lock can be opened.
- As soon as a target location is reached, a puzzle appears on a display (sudoku or similar) and that puzzle must first be solved.

The project group itself has to come up with a proposal which puzzle elements will be added and clearly describe them in terms of functional requirements. These functional requirements must be approved by the client!

In addition to the user of the *reverse geocache puzzle box*, there is also a so-called *administrator*. It should be possible for this administrator to update the target location(s). This can be done in one or more of the following ways:

- With the reverse geocache puzzle box itself, for example by typing in the GPS locations via a keyboard. Or by first taking the route yourself.
  The option must be accessible via a menu that is protected for the normal user.
- Via a companion PC application with graphical interface.

That PC interface also serves another purpose. Namely, displaying logged information. As soon as the reverse geocache puzzle box is connected to the PC application, the logged information is loaded into the PC application and clearly displayed. For example, the last route travelled, the time to get from one GPS location to another, the distance travelled, etc. Use mock-up screenshots in the functional requirements to show what the graphical user interface will look like.

### 3.2 Requirements for the prototype

The project group is tasked with designing, realising and testing a working prototype. The requirements for the prototype must be determined in consultation with the client. The project group itself comes up with proposals that are submitted to the client. It is advisable to start this conversation with a sketch of the complete system, i.e. both the reverse geocache puzzle box and the PC application.

### 3.3 Prerequisites and requirements

Below are general requirements and wishes for the reverse geocache puzzle box.

- Use the ATGM366H GPS module, available from TinyTronics, among others.
- Make use of an actuator to operate the lock.
- In addition to the GPS locations, the reverse geocache puzzle box logs at least one environmental factor, such as temperature, humidity, light intensity, etc.
- The status of the GPS reception is clearly visible to the user, for example if there is no fix (yet).

- The reverse geocache puzzle box runs on a battery. Log information is stored continuously and is retained once the battery is removed. The battery has a separate compartment, which can be opened without having to open the lock.
- Use the FRDM-MCXA153 microcontroller board used in the MIC3/MIC4 classes as the base for the processing unit.
- The processing unit of the reverse geocache puzzle box communicates with a PC/laptop.
- A graphical user interface on the PC/laptop should display the status of the reverse geocache puzzle box, such as values of the sensors and actuators present.
- The total combined cost of additional parts and materials other than the FRDM-MCXA153 should not exceed €50,-.
- A user manual explains step-by-step how to use the reverse geocache puzzle box and what options or settings there are and how they are adjusted.

### 3.4 Research

Analysis is part of the project and includes conducting explorative research. You describe the results of the research in the appendices of the product report. Below are a number of research questions and sub-questions that need to be answered in order to be able to make informed choices within the project. Describe the results as a coherent whole and as you learn in the Research Skills course.

1. What interface does the ATGM366H GPS module use, what is the message format, what information is relevant and how can that information be converted into a usable format for computations in a microcontroller? Is there a library available for that conversion?
   *TIP: first use an uart-to-usb converter (can be borrowed via ARLE) and view the messages from the ATGM366H GPS module via a terminal application (such as TeraTerm) on your laptop.*
2. What are different formats to describe GPS coordinates and how to convert between them?
3. How is the distance between two GPS coordinates calculated?
4. Which actuators are suitable for locking a box (rapid prototyping)?
5. Which sensors are suitable for measuring environmental factors?
   a. What are the specifications for measuring the environmental factors (e.g. range and precision) and which sensors meet them?
   b. What is needed to get these sensors operational (rapid prototyping).
6. What interface is used between the reverse geocache puzzle box and the PC application? And which message format (existing (CSV, JSON, etc.) or self-developed) is used?

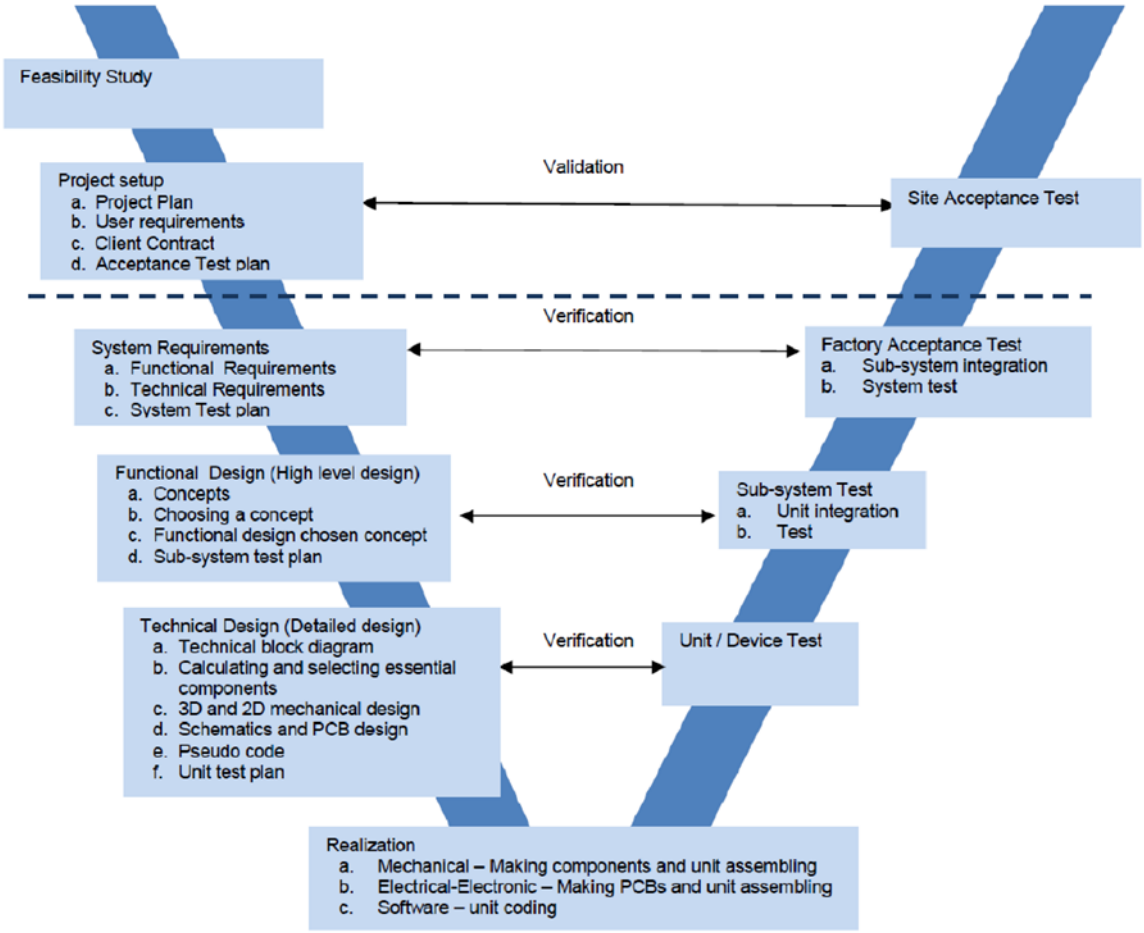
**Requirements with regard to the research:**

Below are rules and guidelines that must be followed when describing the research. These serve as a supplement to the Research Skills course.

- Content or quotations from sources of information must be enclosed in quotation marks and clearly identifiable. The source of information must also be referred to, otherwise it is plagiarism.
- Acknowledgment of sources must be done according to the APA standard.
- Tests and/or measurement setups can be used to get answers to research questions.
- Research is described in the appendices of the product report. The results of the study are used to substantiate choices in the rest of the product report (with a reference to the relevant research in the appendix).

## 4. The design process

The project is structured by applying the V-model.




*The V-model schematically depicted (Dijk, 2012)*

This V-model is a design methodology. In the left side of the V are the development steps, such as making plans, drawing up functional and technical requirements, making the functional design, making the technical design and the realization. The right side of the V indicates how each development step is verified.

We therefore distinguish the following 6 phases:

I. Orientation
II. Analysis
III. Functional Design
IV. Technical Design
V. Realization
VI. Verification/Testing

Phases I to IV will take place in period 3 and phases V and VI in period 4. The six phases are briefly described below.

### 4.1 Phase I Orientation

In this phase, you will make a Plan of Approach together. The plan of approach will largely be based on this manual. You record contact details and make a division of tasks for the (professional) products. You also agree on how you will deal with the responsibilities. (see attachment).

### 4.2 Phase II Analyse

In this phase, you will analyse the problem. You delve into the requirements for the product and draw up a package of functional and technical requirements. By delving into applicable theory, you will gain a better understanding of the theoretical backgrounds. You will learn to what extent the theory under investigation is in line with the practical situation by experimenting and taking measurements.

### 4.3 Phase III Functional design

In the functional phase, you develop an idea into a feasible concept. This means that the concept must meet all functional requirements. So you describe what you want to make.

### 4.4 Phase IV Technical Design

In the final phase of the design process, you will further develop the chosen functional design technically. So how are you going to make it. At the end of this phase, it can be demonstrated how the product is technically put together; calculations (energy, power, construction), drawings, diagrams, parts, materials, production, assembly, functionalities, ... Everything is fixed.

### 4.5 Phase V Realisation

This is building the product. You will also make use of the knowledge gained in S1, for example with regard to the use of the equipment in the ARLE.

### 4.6 Phase VI Verification/Testing

Everything that has been realized can be tested and verified whether it meets the functional and technical requirements set in the analysis phase. According to the V-model, interim test plans could also be written.

## 5. Deliverables and deadlines

During the project, you will work on a single product report of which you will need to complete the various parts (chapters, attachments, drawings, calculations, models, etc.) at certain times. The table below shows the schedule of the deadlines for the products to be returned

### 5.1 Period 3

The table below indicates the deliverables and the corresponding deadline. The first week of the class is called Week A, *the second week* Week *B*, etc.

| Deadline | Product | Where | Comments |
|---|---|---|---|
| Week A | Schedule chairman and minute-taker | Tutor | - |
| Week B | Plan of Approach | Tutor | See Appendix 1 Also describe who will be working on which exploratory research. Build a prototype with for example the Xplained mini board, an Arduino, etc. to gain insights. These insights will later be captured in the product report appendices if you took the Research Skills course. |
| Week C | Exploratory research | Tutor | Discuss individual progress |
| Week D | Exploratory research | Tutor | Discuss individual progress |
| Week E | Exploratory research | Tutor | Discuss individual progress |
| Week F | Chapter 'Functional design' to get feedback on this from your tutor. | Tutor | - |
| | IPV form 1 | Tutor | - |
| Week G | - | - | - |
| Week H | Product report so far: PvA, Preliminary Research Chapter, Functional Design Chapter, Technical Design Chapter, and appendices. | HandIn | - |

### 5.2 Period 4

The planning for period 4 is given roughly. Fill it in detail in due course in consultation with the team. The first week of the class is *called Week A, the second week* Week *B*, etc.

| Deadline | Product | Where | Comments |
|---|---|---|---|
| Week A | - | - | - |
| Week B | - | - | - |
| Week C | - | - | - |
| Week D | - | - | - |
| Week E | - | - | - |
| Week F | IPV form 2 | Tutor | - |
| Week G | - | - | - |
| Week H | - | - | - |
| Week I | The entire Product Report | HandIn | Merge the chapter Introduction, Functional Design and Technical Design and Realization and Testing into one |

| | | | |
|---|---|---|---|
| | | | logical report. And also include the introduction, summary, and conclusion. |
| | The process report | HandIn | The process report describes two things:<br>1. For each student, a personal reflection (½ A4) on their own contribution to the product and on the process (collaboration in the project group)<br>2. A proposal for the individualization of the result (see H6 for more info) |
| | ZIP file with source files, such as PC application, microcontroller code, cad drawings, etc. | Handin | - |
| Week J | Product, product presentation and demonstration. | Tutor and client | - |

## 6. Project grading

The project yields two grades: PRJ2a-V (period 3) and PRJ2b-V (period 4). The project is part of the educational units (OWEs) Project 2a and Project 2b. These OWEs also include the courses Skills2a-V and Skills2b-V respectively, which are concluded with a PASS/FAIL. For each OWE there is a study load of 5 ECTS.

**PRJ2A-V**
This grade is made up of:

- A PASS/FAIL for the Plan of Approach;
- A grade for the product report with chapters 'Functional Design' and 'Technical Design'.

**PRJ2b-V**
This grade is made up of:

- A grade for the product;
- A grade for the presentation demonstration;
- A grade for the complete product report;
- Individualisation of the PRJ2b-V grade, e.g. on the basis of the Individual Project Skills (IPV) surveys.

  For the purpose of this last point, the project group is expected to submit a proposal for the individualization of the project result. If the project group cannot resolve this on its own, the tutor will take the lead. This distribution must be described in the process report. In principle, the contribution per project member is a factor of *1.00*. However, the project group is free to come to a different distribution together, as long as the total of all contribution factors is equal to the number of project members.

  *Example. The group consists of five members. The total of contributing factors is then 5.00. The result achieved for PRJ2b-V is a 7.0. In the process report, the group proposes the following distribution:*
  *Student A: contribution factor 1.10*
  *Student B: contribution factor 1.00*
  *Student C: contribution factor 1.00*
  *Student D: contribution factor 1.00*

*Student E:* *contribution factor 0.90*

*This gives the following individual grades for PRJ2b-V:*
*Student A:* *PRJ2b-V grade* $= 1.10 * 7.0 = 7.7$
*Students B, C, and D* *PRJ2b-V grade* $= 1.00 * 7.0 = 7.0$
- *Student E* *PRJ2b-V grade* $= 0.90 * 7.0 = 6.3$

The tutor determines to what extent this proposal will be adopted. The contributing factors must be known before the PRJ2b-V grade for the project group is announced. In this way, artificial contributing factors are prevented.

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## Appendix 1 The Plan of Approach

When carrying out a project, you have to work in a systematic way. An important tool for this is the Plan of Approach. This document provides a detailed description of a project.

A Plan of Approach consists of several chapters. We ask you to provide a concise document that contains at least the following sections/chapters:

- Cover Sheet
- Index
- Backgrounds
    - Where (in which environment) will the project take place?
- Problem definition
- Project result
    - Why are you doing the project (objective)
    - What is the final result of the project to be delivered?
- Project activities and (intermediate) products to be delivered
    - What do you have to do to achieve the result?
    - Which intermediate products do you deliver?
- Project organization
    - Who participates and how do you work together?
- Planning
    - When will who do what?

For more information about which aspects should be addressed per chapter, see the book Project Management by Roel Grit (Grit, 2014).

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