Robotics and
Machine Intelligence

RMI Inductions ‘23

BASIC TASKS

Weekly Tasks Track

Greetings from RMI!

Welcome to the RMI Inductions ‘23! Over the next few weeks, you will be given a progression of tasks designed to help you learn and explore different domains involved in robotics.

The inductions will be conducted in two stages:

1. The Practical Implementation Stage: Here, you will be given a set of tasks to work on, that will facilitate your learning and understanding.
2. The Personal Interview Stage

The Practical Implementation Stage is split into three sections: Basic, Intermediate, and Advanced. This document outlines all the Basic tasks to be completed. **Acceptable partial completion of at least one Basic Task from each domain is compulsory for further qualification.**

The problems are designed in such a way that even a beginner can learn by implementing these tasks. You might face issues or difficulties in completing the tasks, but do not give up. It is quite normal to hit roadblocks while progressing. In any case, feel free to contact any member of the club.

Rules:

1. It is advised for people who don’t know their domain of interest to attempt tasks of all the domains. **At least one task from every domain should be completed for further qualification.** The more, the better.
2. Topics associated with each task are also listed. Please go through them to understand the concepts behind the tasks.
3. It is good to work in teams, but the tasks are not meant to test your teamwork. The problems must be solved individually. Learning how everything works is key. Make sure you understand everything well.
4. Create a drive folder named “<Roll Number> - Basic Tasks” and sub-folders named “<Roll Number> - <Domain Name>” for each of the domains. Create folders for each task in a particular domain. Follow domain specific submission guidelines.

General Instructions:

1. Go through the problem statement and understand the task well before you start working on it. A task misunderstood and completed will not be considered. If you have trouble understanding it feel free to contact anyone of us.
2. We expect you to understand the concepts and write your own code. It is acceptable to refer to code snippets online but copying the code is not an option. You will be extensively questioned based on the code and will be asked to make modifications during PI's.
3. Divide a complex task into modules and work on the individual modules. Completing the modules will be appreciated even if you are unable to complete the entire task.
4. Partial submissions are accepted. What we look for is your approach and zeal, rather than the entire solution itself.
5. The Internet is your biggest resource. All your doubts are a Google search away. You can always reach out to us regarding any doubts, queries or issues through the WhatsApp group or PM one of us through the same. We will be glad to help.

HAPPY ROBOTICS!!!

Electronics and Embedded Systems

Task 1:

The temperature sensor TMP36 interfaced with an Arduino Uno. An RGB LED is used as an indicator of the temperature detected in the sensor. For temperatures less than 30 degrees, blue light should glow; for 30 to 60 degrees, Green light should glow; for greater than 60 degrees, Red light should glow.

Note: Temperature ranges mentioned are in Celsius scale.

Topics to learn: Working of RGB LED

Bonus Question: Instead of changing the colour for different temperature ranges, let the RGB LED emit only red light at all temperatures but with varying intensities corresponding to temperature.

i.e., at a temperature of -40 degree Celsius (min. temp.), red light should glow with the least intensity and at a temperature of 125 degree Celsius (max. temp.), red light should glow with the maximum intensity.

Task 2:

Make a table fan(DC Motor with power rating:12V,540mA(default)) whose speed can be varied by 4 switches as 4 levels of increasing speed (i.e. level 0 = zero speed, level 3 = full speed) and also use an extra push button to swing the fan. For sideways oscillations, use a servo motor instead of a four bar mechanism in real scenarios.

Topics to learn: DC motor speed control with PWM signals and servo motor control using PWM.

Bonus Question: Does maintaining a fixed duty cycle in a PWM voltage signal ensure constant speed of rotation of the motor? If not, How can we ensure that it rotates with constant speed?

Task 3:

Build a 7-segment LED decoder circuit only using Gates, which inputs a 2-bit binary number and displays the corresponding number(from 0 to 3) in a 7-segment LED.Use 2 push buttons or 2 slide switches for taking in the 2-bit input.

Note: Do not use a decoder IC or any MICROCONTROLLER.

Topics to learn: Basic logic gates working, Building basic combinational circuits using logic gates.

Learning Resources:

1.https://youtube.com/playlist?list=PLPK2l9Knytg5s2dk8V09thBmNl2g5pRSr

2. https://circuitdigest.com/tutorial/what-is-pwm-pulse-width-modulation

3. https://www.javatpoint.com/digital-electronics

Submission Guidelines:

1. The submission folder must contain a text file having the Tinkercad simulation link, code and the screenshot of the circuit.
2. All the code must be commented well enough and circuit labelled for easier understanding.
3. Make sure the visibility is set to 'Public' in Tinkercad.

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Computer Vision

Task 1:

Aim: To identify contours and recognise shapes in OpenCV

Task:

Use OpenCV to recognise the various geometric shapes present in the given image. Print the names of these shapes above the corresponding shapes. Save the resultant image to a specified location on your desktop.

Concepts to Learn: Thresholding, contour detection, placing text in images.

https://drive.google.com/file/d/1QAnvuZojtkjRVBXAKkhwLT3qm29xOd0O/view?usp=sharing

Use this image to perform the task

Task 2:

Aim: To isolate colors of your choice using OpenCV

Task:

Your task is to isolate objects of a particular color of your choice - say red - from a webcam stream, and display the webcam stream in such a manner that only these red objects are visible on the screen. These red objects are to be overlaid over a black background in real time.

Bonus: Try isolating objects of multiple colors and displaying them in the same stream.

Concepts to learn: Color masking, Bit Manipulation, using Webcam in OpenCV

Task 3:

Aim: To compute the histogram of a given image.

Task:

A low light image is given to you in the link given below. Plot the

distribution of pixel intensities of the image as a histogram. How do you think you can improve the contrast of the image? Perform the required operation and plot the modified histogram of the image.

Concepts to learn: Histogram Computation and Histogram Equalisation

images.jpeg - Google Drive

Use this image to perform the task

Task 4:

Aim: To draw basic shapes using OpenCV

Task:

Create a blank white screen using OpenCV and draw the shape of the castle as given in the link. Follow the same colours. Now save the picture that you have drawn as 'castle.jpg'.

Concepts to learn: Drawing shapes in OpenCV, Saving an image

https://drive.google.com/file/d/1JnEhfi8MD3oKxrVvYSuEBeHzlX7qlVxs/view?usp=sharing

Use this image to perform the task.

Task 5:

Aim: To gain familiarity with fundamental concepts in OpenCV

Task:

Take any image of your choice. The aim of this task is to introduce you to some commonly used operations in OpenCV. Find the dimensions of this image. Extract the red, blue and green channels separately and display the same. Convert the image to grayscale (and other colour spaces as well!) and display it. Try distorting the image by adding noise. Also, blur the image and display it! Have fun experimenting with different operations!

Concepts to learn: Colour Spaces, Size of image, Noise, Blurring an image.

Learning Resource:

https://youtu.be/oXlwWbU8l2o

Submission Guidelines:

1. Make a drive folder titled “Computer_Vision” in the main folder.
2. Make sub-folders titled with <Q_questionno>, eg. “Q1” for question 1.
3. Upload all files related to the task into the folders.
4. Files to be uploaded include the .py file, along with the screenshots of output terminal, input image and output image. The screenshot must cover the whole window/screen and must not be cropped.
5. For each question, upload a one-shot video of the code working and explanation of the same. You can either screen record using any of the available software or use a mobile camera for the same. But ensure the whole window is captured clearly and your voice is audible while explaining.

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Algorithms

Instructions:

You are free to choose among C, C++, and Python to code the problems in this domain. We expect well commented code, (it's also optional to lint your code in case of Python) so that it is easier for us as well to understand what you were trying to do even if there is a bug in code/does not perform the expected output. Sometimes your approach speaks louder than your final output!

Task 1:

You're working as a librarian and a new bundle of books has arrived to your library. There are *n* no. of books in a bundle and i^{th} book of the bundle contains m_i no. of pages. Your task is to arrange those books in an order such that the book with more no. of pages is on the left.

Input:

- First line contains no. of bundles *B*
- Next 2*B* lines contain, the no. of books *n* and no. of pages in those *n* books alternatively.

Output:

There should be *B* lines with books with the most no. of pages on the left of the same bundle separated by a space.

Constraints: $1 \leq B < 20, 0 < n < 1000, 0 < i \leq n, 0 < m_i < 2^{35}$

Example:

Input	Output
2 5 321 529 231 89 53 3 12 5 9	529 321 231 89 53 12 9 5

Concepts to Learn: Sorting

Task 2

What do you mean by complexity of algorithms? Explain all the five asymptotic notations used in algorithmic analysis. What is the time and space complexity of the following code snippet? (Assume that the variables not defined here were already defined.)

```
i = 0;
total = 0;
arr2 = [];
while (i<n):
    arr2.append(arr1[i]);
    total += arr1[i];
    i += 1;
arr3 = []
i = n-1;
while (i):
    total *= arr2[i]
    arr3.append(arr2[i])
    i //= 2
else:
    print(total)
```

Task 3

Write a ***bash*** program which does the following.

- Read the given file as command line argument.
- Should change the names of the departments from Science-A and Science-B to Physics and Chemistry respectively in the file.
- Finally, you print the three-digit roll number padded with zeros, whose CGPA is greater than or equal to *7.5* in a new line.
- You need to submit the script with executable permissions, with group and user ownership as *root* in a ***Tar GZ*** *file.*

Example:

Original lines in file	`98 Section-A 8.03`
	`2 Section-A 7.23`
	`129 Section-B 9.23`

Modified lines in file	`98 Physics 8.03`
	`2 Physics 7.23`
	`129 Chemistry 9.23`

Output to screen	`098` `129`

Concepts to Learn: Linux scripting - Streamline editing, file handling, permission handling.

Task 4

You're using a microcontroller, which can't store integers greater than 64 bits long.

Input: Two lines of integers.

Output: The first line should contain the addition of those numbers, the second line should contain the difference between the first and second numbers, and the third line should contain the product of the two numbers.

Note: You should not use libraries or built-in methods to convert the string to any type of integer which can accept more no. of bits because it is not supported in that microcontroller.

Input	`132143214312512341890512332141` `651288721384712734821213`

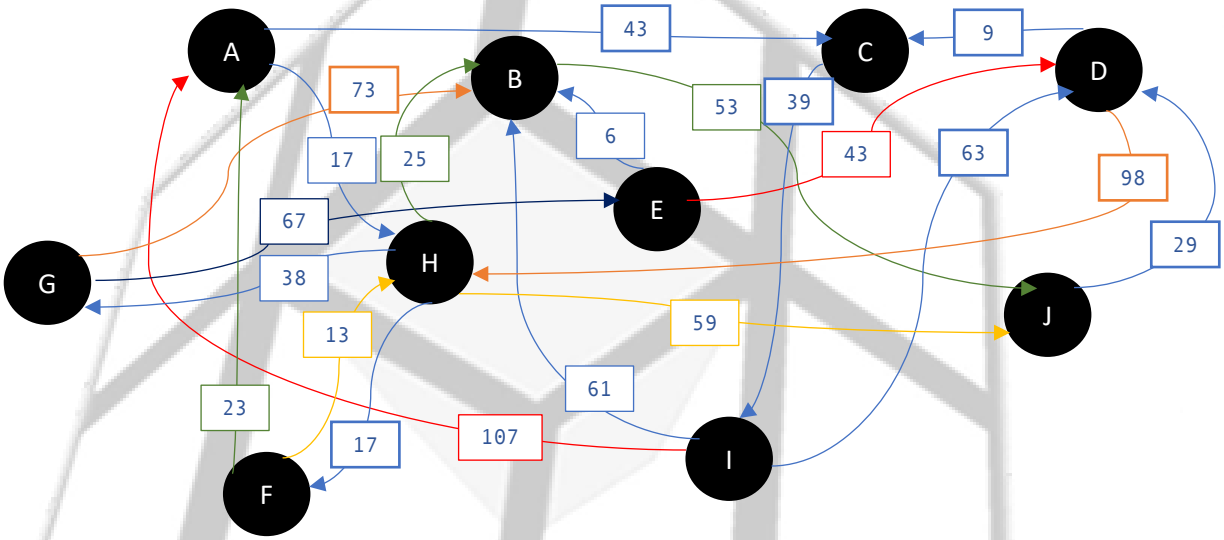
Output	`132143865601233726603247153354`
	`132142563023790957177777510928`
	`860633850892622348128187777475020074406`
	`13487308507033`

Constraints: $1 < numbers < 10^{300}$, and no leading zeros exist.

Task 5

During the trajectory planning of a robot using parabolic interpolation of its velocity along the possible path of given points, we found the time taken to reach from one point to another point. Your task is to minimise the time so we can reach any point from one point in the least amount of time possible. The output should be the optimised cost adjacency matrix.

Bonus: You can write a program to solve this problem.



Concepts to learn: All source shortest path.

Task 6

You're playing a card game against Alien Z. Initially there'll be *n* cards, and you're going to play first, and it is a turn-based game. The rule of the game is that, during your turn you need to arrange the cards from the field in a stack such that, the no. of cards in all the stacks is equal. In the next turn, one card from each of the stacks is withdrawn from the field and the game continues. The player must form a stack that shouldn't contain all the cards or stacks of height 1. The game ends when the player has no possible way to play, and the opponent wins the game. Assume that both

of you play the game optimally. Output Me if you win the game, or Alien Z, if he wins.

Constraints: $0 < n \leq 123$

Concepts to learn: Dynamic Programming

N	Output	Explanation
1	`Alien Z`	T1: Initially, there is only one card, so you can't form a stack with different count. Hence, Alien Z wins.
4	`Me`	T1: Initially, there are 4 cards, so you'll arrange it in 2 stacks of 2 cards. T2: One card from each stack, so 2 cards will be removed. Alien Z can't form stacks with single card, and he can't use all the 2 cards to form a stack.

Bonus: Try to solve the answer with $O(1)$ time complexity.

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Mechanics

Task 1:

Aim: To get to know about mechanisms, degrees of freedom of a mechanism.
Task:

a. What's a mechanism? Define the degrees of freedom of a mechanism. How many degrees of freedom does an ice hockey puck have assuming it is in contact with the ground at all times, Justify your answer. Arrive at Grübler's equation for planar linkages in your own words. Calculate the minimum number of links you should have in a mechanism that has mobility of 1.
b. Now extend this knowledge to derive the degrees of freedom for any spatial mechanism with "l" number of links and "h" number of higher pairs and "j" number of lower pairs.

Topics to learn: Links, joints, types of joints, mechanisms, degrees of freedom of a mechanism, Grübler's Equation.

Task 2:

Aim: To understand a very standard mechanism - four bar mechanism.
Task:

a. What is a four-bar mechanism? State Grashof's law. What are inversions of mechanisms? List down inversions of a four-bar mechanism. Give examples of four-bar mechanisms used in daily life.
b. Construct a four-bar mechanism with dimensions of links 4 mm, 7 mm, 12 mm, and 13 mm, if the 4 mm link is grounded. Now, is it possible to run the mechanism with a DC motor at one of the joints of the fixed link?

Topics to learn: Four bar mechanism and its inversions, Grashof's law.

Task 3:

Aim: To understand Euler angles, quaternions and Rotation matrices for any arbitrary rotation of coordinate axes.
Task:

a. What are Euler angles? List all the combinations of them and give a visual representation of any 1 combination. What's a quaternion? What is a rotation matrix? List the advantages of using quaternions while performing rotation of coordinate axes over Euler angles.
b. A coordinate frame xyz is transformed into a new coordinate frame x''y''z'' by rotation in two steps. First, rotation about the y-axis by an arbitrary angle α to form the x'y'z' coordinate axis. Second, Rotation about the newly formed x' axis by an arbitrary angle ß to form the x''y''z'' coordinate axis. Now, express a vector p which is originally in the x''y''z'' coordinate in the xyz coordinate frame in terms of α and ß using rotation matrices.

Topics to learn: Euler angles, quaternions, and rotation matrices.

Learning Resources:

1. Robotics 1 U1 (Kinematics) S3 (Rotation Matrices) P1 (Rotation Matrices)
2. https://www.autonomousrobotslab.com/frame-rotations-and-representations.html

Task 4:

Aim: To explore and get some hands-on experience with solid modelling software.

Task:
Design a bolt and nut pair with a pentagonal head and buttress thread having a pitch diameter of 7.3 mm and a pitch of 0.8mm. The length of the bolt should be 50 mm of which only 40mm is threaded. The thickness of the bolt head and nut is 8mm.
Topics to learn: Threaded fasteners, types of threads, Solid modelling: Sketching, Extrusion, Sweeping.

Learning Resources:
Solidworks Nut and Bolt, Thread Feature and Animation

Task 5:

Aim: To learn about gears, and their applications in real life.

Task:

a. What are gears? What is meant by gear ratio? What is meant by meshing of gears and how do you ensure that two given gears are properly meshed?
b. A minute hand of a clock is rigidly mounted on a gear ‘A’ of diameter 100 mm such that there’s no relative motion between them. Now design a gear train with at least four gears including at least one compound gear to drive gear ‘A’. Mention radius, angular velocities and direction of rotation of each gear. The maximum radius of any gear can be 50 mm and minimum radius can be 25 mm. Also, calculate the power of the motor with which the gear at the end of the gear train (other than ‘A’) should be rotated if the effort it takes to run the minute hand of the clock is 20 N-m.

Topics to learn: Gears, types of gears, gear ratio, and types of gear trains.

Submission Guidelines:

1. For design tasks, submit your solid models in *.stl* format, along with screenshot of the model taken from different angles. You can add a text file to explain about different features in your model.
2. For other tasks, you can either make a typed document or handwritten document in PDF format with sketches and steps mentioned clearly wherever needed.
3. Each file should have the following common prefix: ***Basic_M_<Roll_Number>***

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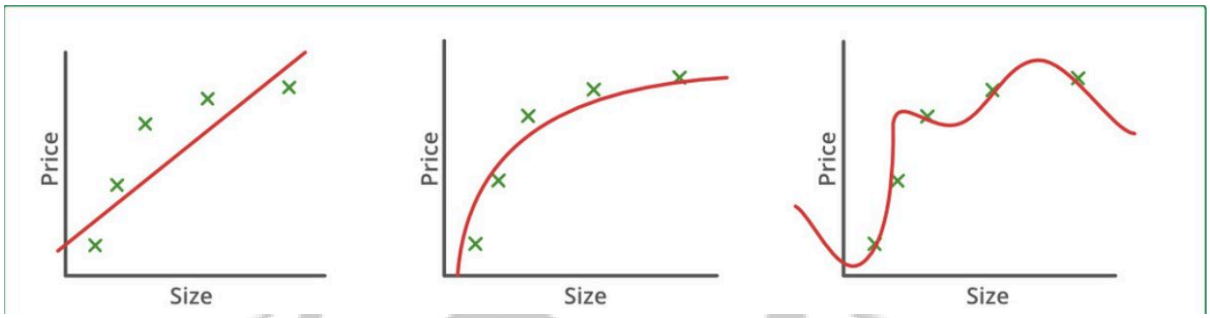
Machine Learning:

Task 1

Aim: To understand the importance of model fitting



In machine learning, model fitting represents how well the model will perform on datasets that are similar but not identical to the training dataset. A well fitted model will result in more accurate outcomes.

Task:

The above graph shows different models that are fit to a given dataset.

i) In which case do you think the model is best fit to the above dataset?

ii) What is the issue in the other two cases? Why does this issue arise?

iii)How can it be rectified?

Explain the above graphs in terms of bias and variance.

Concepts to learn: Model fitting, bias, variance.

Submission Instructions: Type or write your answers and submit the same as a PDF file.

Task 2

Aim: To understand multi-class classification

In machine learning, classification is a predictive modeling problem where the class label is anticipated for a specific example of input data. The commonly used logistic regression model is capable of performing binary classification. Now, assume we have a model that needs to identify k classes such that k>2.

Task:
What are the changes you will make to the activation function and the cost function? Mention the corresponding functions in both cases.

Bonus: Given a dataset of the details of people working in a particular company(link) Perform binary classification based on the data given and predict whether a given employee met with a work accident or not.

Note: Use only Numpy and Pandas for implementation.

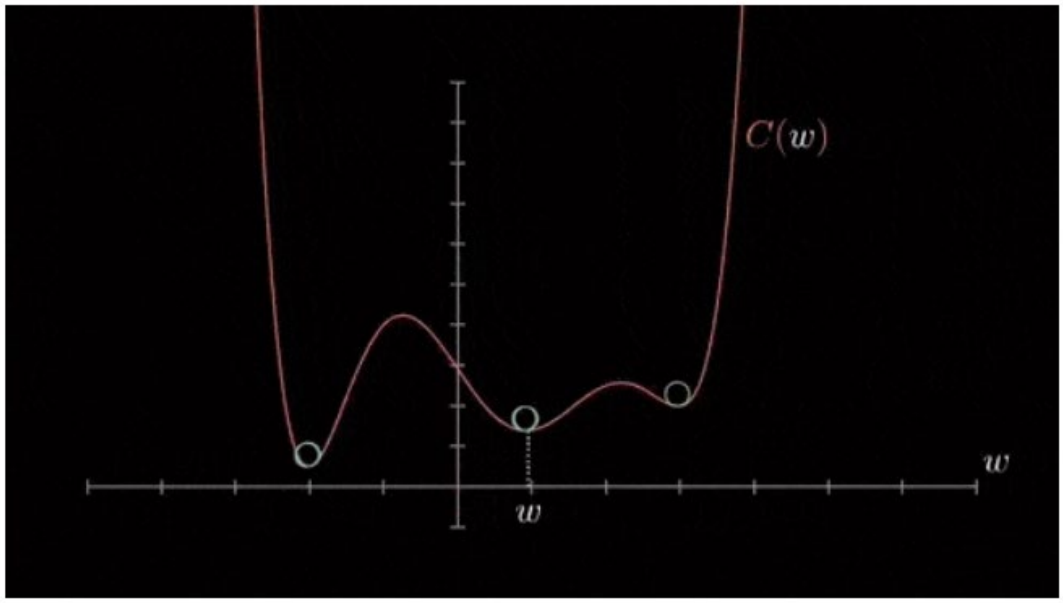
Concepts to learn: Logistic Regression, Multinomial classification, activation function

Submission Instructions: Type or write your answers and submit the same as a PDF file. If bonus is attempted, submit a well-documented .ipynb file.

Task 3

Aim: To understand Gradient Descent Optimization algorithm.
Gradient descent, a powerful optimization algorithm, encounters challenges that can impact its performance. These challenges arise due to the existence of multiple minimum points in the cost function, as the gradient can settle on any of these minima depending on the initial parameters and hyperparameters. Consequently, different starting points and learning rates can lead to convergence at different points.

Task:
Brief some of the difficulties that can affect the performance of gradient descent and solutions to overcome them.



Bonus: Write a code to perform one pass of forward and backward propagation with
input features: [2.3], output: 1, weights: [0.5,-0.2], bias: 0.3, sigmoid activation function, Mean squared error loss function and learning rate: 0.01. Use these to update the weights and bias.

Concepts to Learn: Gradient Descent, learning rate, forward and backward propagation.

Submission instructions: Type or write your answers and submit the same as a PDF file. Submit a well-documented python code if bonus is attempted.

Task 4:

Aim: To understand and perform the basic concepts of CNN.

Convolutional Neural Networks (CNNs) are a type of deep learning model that are particularly effective in processing and analyzing visual data, such as images. The core building blocks of CNN are convolutional layers. These layers apply a set of learnable filters, also known as kernels or feature detectors, to the input data.One of the important considerations when performing convolutions is the padding strategy.The stride

determines the step size at which the filter is moved horizontally and vertically across the input image.

25	100	75	49	130
50	80	0	70	100
5	10	20	30	0
60	50	12	24	32
37	53	55	21	90
140	17	0	23	222

x

1	0	1
0	1	0
0	0	1

h

Task:
Apply these concepts to the given question.
i) Performing convolution on the 5x5 image using a 3x3 kernel without any padding.
ii) Apply max pooling to the resulting feature map with a stride of 2.
iii) Flatten the output obtained from the max pooling operation to a 1D vector.

Concepts to Learn: Convolution, Max pooling, Padding, Stride, Flattening.

Bonus: Write a code to perform the above following operations to any input image without using any libraries except numpy.

Submission Instructions: Type or write your answers and submit the same as a PDF file. Submit a well-documented python code if bonus is attempted.

Learning Resources:
1.https://machinelearningmastery.com/gradient-descent-for-machine-learning/
2.https://www.youtube.com/watch?v=NWONeJKn6kc

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