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A Fuzzy System for Impact Analysis of Advertisement Billboards in Soccer Telecast

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***Abstract*— Advertisement billboards placed along the periphery of a soccer field in popular tournaments are used to promote specific products or the brand image of a company. In this paper, we introduce a fuzzy logic based approach for estimating the visual impact of such billboards when broadcasted through the television medium. The present system estimates the persistence effect of a billboard on human mind by using a two stage fuzzy rule based system. In the first phase, a shot level analysis is carried out, which is followed by an inter shot analysis to estimate the overall impact. In both the stages, parameters of the fuzzy set membership functions are tuned using the Particle Swarm Optimization algorithm. The system works on top of a billboard detection system and the results have been compared against a user survey.**

Index Terms – Fuzzy logic, Billboard, Soccer video, Video shot, PSO, Visual impact.

I. Introduction

Advertisement billboards surrounding the playing arena in a soccer tournament are viewed by the spectators present in the field and, more importantly, by those watching it via TV broadcasting. The number of viewers of important soccer telecasts like the Soccer World Cup, European Cup, English Premier League and Spanish League, is estimated in billions. Data published by FIFA [1] show that the television coverage of World Cup 2006 hosted by Germany had been covered by 376 channels and it reached 214 countries with 73,072 hours of dedicated programming. The total number of cumulative audience was 26.29 billion. The upcoming Soccer World Cup 2010 in South Africa is expected to surpass these numbers. Therefore, analysis of strength and weakness of an advertisement is particularly important for the sponsor since a lot of money is spent on it and due to its potential impact on a large number of viewers at the same time.

Estimation of visual impact is quite subjective in nature and, therefore, fuzzy modeling is felt to be appropriate for it. It is intuitively obvious that visual impact is certainly dependent on the size of the advertisement billboard as viewed on a TV screen as well as the time duration for which it remains on the screen. The primary purpose of viewing a soccer telecast is to watch the game and not the advertisement. Therefore, an advertisement billboard which frequently appears on the TV screen and is of sufficient viewable size has better chance of being remembered even though billboards are not specifically observed by the viewers.

In a soccer video, which billboard is more likely to appear on the screen is dependent on the location of the billboard as well as the various events occurring in a particular match. For example, as the play moves from the center of the field to the sidelines, the billboards become more visible since the camera zooms in on the players, thus highlighting the action going on near them. The amount of time for which a particular billboard remains visible would depend on the duration for which an action or an event occurs near it. The size of the billboard as seen on the TV screen depends on the level of zooming used by the camera capturing the action.

In this paper, visual impact analysis is done as a two stage procedure. The first stage is intra shot analysis while the second stage is inter shot analysis. A shot is a consecutive sequence of frames captured by the same camera [2] [3]. Estimation of visual impact within a shot is carried out by inferencing using one set of fuzzy rules. The results so obtained, are further used as input to another set of fuzzy rules for analysis across different shots. It may be noted that our research group has developed a system for detecting billboards from soccer videos [4]. The main contribution of the current work is a fuzzy framework for analyzing the impact of billboard advertising which combines various attributes of billboards as identified by the billboard detection system. Although the current approach considers our own billboard detection system, it can work seamlessly with any other such system. New features can be suitably plugged in making it more effective. The parameters of the fuzzy membership functions are tuned by Particle Swarm Optimization (PSO) [5] [6].

The rest of this paper is organized as follows. Section II is a brief compendium of contemporary work on video based analysis of advertisements. Section III presents our visual impact analysis procedure based on fuzzy logic. In Section IV, we show how PSO is applied to optimize the parameters of fuzzy membership functions. Section V contains the results of experiments with our fuzzy system and we conclude in Section VI of the paper.

II. Related Work

Computer aided advertisement impact analysis is a relatively new area of research. One such work has been reported by Haritaoglu and Flickner [7]. They describe a computer

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vision system that analyzes the strength and weakness of an advertisement by extracting customer behavior information. It tracks multiple persons as they wait and watch advertisements on a billboard or a new product promotion at a stand. Such an analysis is important for Customer Relationship Management (CRM) since data gathered from this system can be analyzed offline to know the number of people who watched the advertisement and how long they had looked at it. Another system targeted towards advertisement impact analysis in the agriculture domain has been introduced by Schiebel [8]. Ramalingam et al. [9] use Artificial Neural Network (ANN) for measuring the effectiveness of TV broadcast advertisements (toothpaste) by discovering important factors that influence the advertisement effectiveness. Effects of each of these factors have been studied, which is used for measuring the overall impact. Neural network is also used by Poh et al. [10] in analyzing effects of advertising and promotion on sales.

In the field of advertisement detection, one popular area of research is TV commercials detection. Yeh et al. [11] proposed a two level commercials detection scheme for news videos which uses shot characteristics and color coherence features. Hua et al. [12] use Support Vector Machine (SVM) in their system which employs audio and video features that can be used for commercials detection. Huang et al. [13] developed a two stage neurofuzzy inferencing system for detecting television commercials. Two systems have been designed by Lienhart et al. [14]. Their first system is based on statistical techniques and the second system is based on recognition of commercials with the help of template matching. They also present a self learning commercials detection system which uses a combination of both the approaches.

So far, there have been three research articles that detect advertisement billboards placed on a soccer ground. One such system was developed by Cai et al. [15]. They first segment potential regions which might contain billboards. Subsequently, billboards are searched only in these regions. Their detection process does not consider video related characteristics, like shot and also the test data is quite small. Another approach has been proposed by Medioni et al. [16]. Their method is a real time billboard substitution system which can operate with compressed videos like MPEG. The authors detect a number of points, called 'interest points', in the video having some special characteristics. Usually, a large number of points are detected. These points are ranked and insignificant points are eliminated. A similar set of points is computed for a given template and the two sets of points are matched. If a billboard is found, then it can be replaced by another set of billboards.

A third approach has been proposed by our group [4]. This system first detects and classifies shots in the video. The detected shots are then classified into two types, namely *close shot* and *long shot*, which are distinguished on the basis of the quantity of grass pixels present. Potential regions (also called the Region of Interest or the ROI) that may contain billboards are identified within each shot. Video frames are then segmented into grass and non-grass pixels by a method called *hue slicing*. The purpose of this segmentation process is to find the ground boundary using Hough transform. Once the ground boundary line is obtained, it is used as reference to detect other straight lines which are possible candidates for the upper edges of the billboards. The number of billboards is determined using the aspect ratio of billboards and the height of the region of interest. If more than one billboard is present in the region of interest, Canny's [17] edge detection algorithm is applied to detect vertical lines of separation between billboards. Template matching is then applied to recognize the billboard of interest [18].

To the best of our knowledge, no analysis on the impact of billboards as advertisement instruments has been done so far.

III. Fuzzy Approach for Visual Impact Analysis

Visual impact of a billboard advertisement can be estimated by measuring persistence of that billboard in the human mind. The persistence effect of a particular billboard depends on its size, frequency of occurrence, graphics and message. Among these criteria two of the most important and easily measurable features are size and duration of occurrence of that particular size. Other features are more or less the same for every billboard since all of them are prepared by professionals. Therefore, to analyze the persistence of a billboard, size of the billboard and the duration for which it has been shown are considered. Visual impact analysis is done in two phase, the first phase being a shot level analysis and the second phase being an inter shot analysis. We assume that the size of a billboard within a shot remains unchanged since drastic variation within a shot is unlikely, although the actual size could slightly vary due to zooming effect.

A. Intra Shot Impact Analysis

A billboard can appear in various sizes on the TV screen and for different durations. Each of these two input parameters is assigned a linguistic variable. The linguistic variable *size* can assume different linguistic values depending on the perception of the size of a billboard as appearing on the TV screen. In this work, the linguistic values corresponding to the linguistic variable *size* are assumed to be *small, medium* and *large*. Similarly, perception of the time duration in which a particular billboard has been seen, can be described by three linguistic values, namely *short, moderate* and *long*. The output of this fuzzy system is the fuzzy variable *visual impact per shot* which has three terms in its term set: *poor, medium* and *high*.

The membership functions for the linguistic values of input and output fuzzy variables are trapezoidal in nature given by the equation below.

$$\mu(x) = \begin{cases} 0, & \text{if } x \leq a \\ \frac{x-a}{b-a}, & \text{if } a \leq x \leq b \\ 1, & \text{if } b \leq x \leq c \\ \frac{d-x}{d-c}, & \text{if } c \leq x \leq d \\ 0, & \text{if } d \leq x \end{cases} \quad (1)$$

To define the linguistic values in the term set of *size* and *duration*, it is required to estimate the four parameters, namely, a, b, c and d. These four parameters are initially defined from the experimental data. We first choose the range of the parameters for linguistic values of *size* and *duration*. Afterwards, the parameters of the membership functions are optimized using PSO (Particle Swarm Optimization) as described in the next section.

For determining the parameters of membership functions of linguistic values (*poor*, *medium* and *high*) of *visual impact*, we conducted a survey in which 10 viewers were shown 16 soccer matches and asked to rate different billboards in the range between 0 to 10. The rating indicates how good a viewer remembers a particular billboard. The survey was carried out in two stages. At first, the complete video was shown to a viewer and he was asked to rate the billboard. Afterwards, the user was shown the shots of the same video and was asked to rate different billboards on a scale of 0 to 10. It may be noted that the viewers were pre-conditioned to become familiar with all the types of billboards under consideration so that their affinity towards these was well-controlled. A range for each parameter in the membership function is chosen and the final values of the parameters are obtained from PSO. Although, the rating is between 0 to 10, the values are scaled between 0 to 1 before using PSO.

The average size of a given billboard s_k and its duration d_k for the k-th shot S_k, where $k = 1, \ldots, N$ (N is the total number of shots), are calculated. The size and duration are used to estimate the impact within the shot S_k by evaluating the fuzzy rules laid down in Table I. Mamdani's method,

Size	Duration	Visual Impact
Small	Short	Poor
Small	Moderate	Medium
Small	Long	Medium
Medium	Short	Poor
Medium	Moderate	Medium
Medium	Long	High
Large	Short	Poor
Large	Moderate	High
Large	Long	High

TABLE I
FUZZY RULES FOR SHOT LEVEL ANALYSIS

which uses max-min composition for rule evaluation, is used for inferencing in the fuzzy system. After evaluation of the fuzzy rules of Table I for all S_k ($k \leq N$), the next step is defuzzification which in this work is *centroid method of defuzzification*. The defuzzified output y_k for the shot S_k is the visual impact on a scale of 0 to 1. For all y_k it has some membership value in all the three fuzzy sets which is used to define the consequent part of the rules. This is calculated by evaluating $\mu_{poor}(y_k)$, $\mu_{medium}(y_k)$ and $\mu_{high}(y_k)$. Therefore, each output y_k is a numeric value between 0 to 1 which can also be interpreted as having a linguistic value. For this, maximum membership grade corresponding to the defuzzified value y_k is calculated in fuzzy sets *poor, medium* and *high*. i.e., we evaluate

$$I_k = \max\{\mu_{poor}(y_k), \mu_{medium}(y_k), \mu_{high}(y_k)\} \quad (2)$$

where, I_k is the maximum membership grade. The fuzzy set producing the maximum grade is the linguistic value for the output y_k.

TABLE II
FUZZY RULES FOR INTER SHOT ANALYSIS OF OVERALL VISUAL IMPACT

Poor Impact Shot (X)	Medium Impact Shot (Y)	High Impact Shot (Z)	Overall Visual Impact
Small	Small	Small	Poor
Small	Small	Medium	Moderate
Small	Small	Large	Moderate
Small	Medium	Small	Poor
Small	Medium	Medium	Moderate
Small	Medium	Large	High
Small	Large	Small	Moderate
Small	Large	Medium	Moderate
Small	Large	Long	High
Medium	Medium	Small	Poor
Medium	Medium	Medium	Moderate
Medium	Medium	Large	High
Medium	Small	Small	Poor
Medium	Small	Medium	Moderate
Medium	Small	Large	Moderate
Medium	Large	Small	Poor
Medium	Large	Medium	Moderate
Medium	Large	Long	High
Large	Medium	Small	Poor
Large	Medium	Medium	Moderate
Large	Medium	Large	Moderate
Large	Small	Small	Poor
Large	Small	Medium	Poor
Large	Small	Large	Moderate
Large	Large	Small	Poor
Large	Large	Medium	Moderate
Large	Large	Large	High

B. Inter Shot Impact Analysis

In the second stage, we combine results across different video shots to finally determine the impact of an advertisement billboard in a soccer video. This stage also involves evaluation of a set of fuzzy rules. Before evaluation of rules, we compute relative frequency of duration of each linguistic output. The relative frequency of each such output can be *poor*, *medium* and *high*. Before enumerating the rules, we list down the following three symbols.

- X = relative frequency of duration of shots in which visual impact is poor.
- Y = relative frequency of duration of shots in which visual impact is medium.
- Z = relative frequency of duration of shots in which visual impact is high.

The cumulative duration of shots where the visual impact is *poor* can be *small* or the cumulative duration of shots in which the visual impact is *high* can be *small*. Three fuzzy sets, namely *small*, *medium* and *large* are defined with universe of discourse $[0, 1]$. A total of 27 rules are possible and they are evaluated to finally determine the overall visual impact. The fuzzy rules are given in Table II.

After evaluation of the rules, they are defuzzified by centroid method. The defuzzified outcome is a numeric value

which needs linguistic interpretation. Therefore, maximum membership grade corresponding to this numeric value is calculated among the three fuzzy sets, namely *poor*, *medium* and *high*. The fuzzy set which gives the highest membership grade is the linguistic outcome of the system.

IV. Fuzzy Set Parameter Selection using Particle Swarm Optimization

We optimize the parameters of the fuzzy set membership functions used in the rule base using Particle Swarm Optimization. Each fuzzy system is encoded as a particle and, therefore, each represents a solution. Given some objective or fitness function, which forms a hypersurface, designing the optimal fuzzy system is equivalent to finding an optimal point on this hypersurface. The hypersurface is generally found to be infinitely large, non-differentiable, complex and multimodal, which makes evolutionary algorithms quite suitable for searching as compared to traditional gradient based approaches [19] [20].

A. PSO to Optimize Fuzzy System

A trapezoidal fuzzy set membership function has four parameters, encoded as a four tuple. The PSO method as applied to fuzzy rule base optimization is outlined below.

- To encode multi input single output (MISO) fuzzy system, we consider all the antecedent and consequent fuzzy sets. For example, let A, B, C, D and E be five fuzzy sets in a rule base. The shape of all the membership functions is assumed to be trapezoidal. The encoded particle, k is given by the vector.

$$k = \left(\underbrace{A_1, A_2, A_3, A_4}, \ldots, \underbrace{E_1, E_2, E_3, E_4} \right) \quad (3)$$

  The above vector represents the position of the particle k in the 20 dimensional search space.
- Our system uses M ($M = 50$) number of particles. Each dimension of a particle is initialized randomly between an upper and a lower limit. Constraints are used to validate each particle after its position is updated. For example, the fuzzy set A represented by trapezoidal membership functions has four parameters. A constraint $A_1 < A_2 < A_3 < A_4$ is needed to be checked to validate that the parameter set represents a proper membership function.
- A termination condition also needs to be specified. We choose error threshold, $E \leq 0.1$ and maximum number of iterations, $IT_{max} = 2000$. The PSO stops whichever is encountered earlier.

B. Training and Testing of the PSO

We distributed videos of different soccer matches and viewers were asked to fill in a questionnaire both for intra shot level analysis and inter shot analysis. In case of intra shot level analysis, a total of 16 videos were distributed and viewers were asked to rate five billboards (Hyundai, Carlsberg, Cannon, MasterCard and JVC) for each shot after viewing the shots. Similarly, for inter shot analysis, viewers were shown a complete soccer match and then they were asked to rate the five billboards. From these two surveys we came up with an initial range for the parameters of the membership functions experimentally. Starting with these experimentally chosen value, PSO is applied to obtain the tuned set of parameters.

Size							
Small		Medium				Large	
1^{st}	2^{nd}	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}
3.93	6.77	4.26	9.98	12.89	18.60	10.70	15.85
Duration							
Short		Moderate				Long	
1^{st}	2^{nd}	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}
1.5	5.3	3.19	7.45	8.41	13.25	11.40	16.54
Visual Impact							
Poor		Medium				High	
1^{st}	2^{nd}	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}
0.22	0.49	0.26	0.42	0.53	0.70	0.47	0.69

TABLE III
Result of tuned parameters for intra shot analysis

In each case (intra and inter shot level) 6 videos are used for training and the remaining 10 videos are used for testing. The cost function being used is mean square error function.

For intra shot level analysis, we have nine fuzzy sets which are encoded into particles of 24 dimensions. In case of inter shot analysis, we have twelve fuzzy sets which are encoded into particles of 32 dimensions. Tables III and IV show the tuned set of parameters.

V. Performance of the Tuned Fuzzy System

In this section we present the experimental results of our billboard impact analysis system. In total, there are sixteen videos in MPEG-2 format and the duration of each video is 120 seconds. Out of these, six videos are used for training the fuzzy system using PSO while the remaining ten videos are used for testing. In this paper, due to page limitations, we present detailed results of two videos only. The others also have similar performance. Each video contains a number of billboards but we consider five billboards, namely, Hyundai, Carlsberg, Cannon, MasterCard and JVC for our experiments. It may be noted that the proposed fuzzy system for impact analysis runs on top of an existing billboard detection system [4]. The performance of the fuzzy system is, therefore, affected by the accuracy of the underlying billboard detection system. Keeping this in mind, we carry out experiments in two phases. In one phase, we apply the impact analysis step on the output of the billboard detection system. In the other phase, we apply impact analysis on manually identified billboard locations in videos. In this case, errors caused by the billboard detection system do not affect the impact analysis results. However, it should be kept in mind that a real impact analysis system has to perform in conjunction with a billboard detection system.

Fuzzy sets							
Small		Medium				Large	
1^{st}	2^{nd}	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}
0.02	0.055	0.05	0.08	0.11	0.16	0.14	0.29
Overall visual impact							
Poor		Moderate				High	
0.24	0.45	0.25	0.34	0.55	0.74	0.55	0.73

TABLE IV

RESULT OF TUNED PARAMETERS FOR INTER SHOT ANALYSIS

Billboard name	Shot Number			
	S_1	S_2	S_3	S_4
Hyundai	0,0	0,0	0,0	1029, 13
Carlsberg	0,0	20,60	0,0	1605, 13
JVC	298, 16	0,0	17, 30	0,0
MasterCard	0, 0	18, 60	18, 10	506, 13
Cannon	0, 0	18, 60	0, 0	1175, 13

TABLE V

SUMMARY OF VIDEO 1

Billboard name	Shot Number				
	S_1	S_2	S_3	S_4	S_5
Hyundai	0, 0	0, 0	0, 0	1295, 12	0, 0
Carlsberg	0, 0	0, 0	0, 0	1553, 12	0, 0
JVC	348, 15	0, 0	46, 30	0, 0	28, 35
MasterCard	0, 0	0, 0	0, 0	630, 12	0, 0
Cannon	0, 0	0, 0	0, 0	145, 12	0, 0

TABLE VI

SUMMARY OF VIDEO 2

Billboard name	Shot Number			
	S_1	S_2	S_3	S_4
Hyundai	P	P	P	H
Carlsberg	P	P	P	H
JVC	H	P	P	P
MasterCard	P	P	P	H
Cannon	P	P	P	H

TABLE VII

INTRA SHOT IMPACT ANALYSIS RESULT FOR VIDEO 1 WITH MANUALLY IDENTIFIED BILLBOARDS

Billboard name	Shot Number				
	S_1	S_2	S_3	S_4	S_5
Hyundai	P	P	P	H	P
Carlsberg	P	P	P	H	P
JVC	H	P	P	P	P
MasterCard	P	P	P	H	P
Cannon	P	P	P	M	P

TABLE VIII

INTRA SHOT IMPACT ANALYSIS RESULT FOR VIDEO 2 WITH MANUALLY IDENTIFIED BILLBOARDS

Billboard name	Shot Number			
	S_1	S_2	S_3	S_4
Hyundai	P	P	P	H
Carlsberg	P	P	P	H
JVC	H	P	P	P
MasterCard	P	P	P	H
Cannon	P	P	P	H

TABLE IX

INTRA SHOT IMPACT ANALYSIS FOR VIDEO 1

A. Video Summary

Tables V and VI contain the summary of two soccer videos. Each table shows the number of shots found by manual inspection and the average size and frequency of occurrence of each billboard within a shot. S_1, S_2, S_3 etc., are the serial numbers of the shots. The frequency of occurrence and the average size within each shot are represented as the tuple $< frequency, size >$. For example, $1029, 13$ in the first row, fourth column of Table V indicates that in shot S_4, Hyundai billboard has been found 1029 times and the average size (rounded to the nearest integer value) of the billboard is 13 pixels. The size of the billboard is determined manually from the video frames having width 320 and height 240.

B. Results based on Manually Identified Billboard Location and Size

The results of intra shot impact analysis are shown in this section. In this set of results, the billboard detection system was bypassed and manually identified locations as summarized in Tables V and VI were used for the fuzzy impact analysis. Tables VII and VIII show the impact of each shot marked as "High", "Medium" or "Poor", which are written as "H", "M" and "P", respectively.

C. Results based on Billboard Detection System

In this section, we present the results of intra-shot analysis where the fuzzy system uses the data generated by the billboard detection system developed by our group [4]. Tables IX and X contain the results of this phase of analysis. It is observed that some cases of misdetection occur when the billboard detection system is used. For instance, for shot number S_3 in Table X, the visual impact for the JVC billboard is "medium". But, the impact is found to be "poor" for the same shot and the same billboard (Table VIII) if manually prepared data set is used. Similar cases might occur for other videos and other billboards as well. After having shown the impact of individual shots of the two videos, we present the overall impact analysis result in the next subsection.

D. Result of Overall Impact Analysis

As mentioned before, the fuzzy system has been applied on ten videos with five billboards. Out of the total 50 cases, 44 cases match with the users' ratings when manually prepared datasets are used and 42 cases match with the users' ratings when the billboard detection system is used. Here, we present the results of overall visual impact analysis (combining inra-shot and inter-shot analysis) for each of the two videos in

Billboard name	Shot Number				
	S_1	S_2	S_3	S_4	S_5
Hyundai	P	P	P	H	P
Carlsberg	P	P	P	H	P
JVC	P	P	M	P	P
MasterCard	P	P	P	H	P
Cannon	P	P	P	H	P

TABLE X

INTRA SHOT IMPACT ANALYSIS FOR VIDEO 2

Billboard name	Results given by viewers	Results based on manually prepared dataset	Results based on billboard detection system
Hyundai	High	High	High
Carlsberg	High	High	High
JVC	High	Medium	Medium
MasterCard	Medium	Medium	Medium
Cannon	High	High	High

TABLE XI

OVERALL IMPACT ANALYSIS RESULTS FOR VIDEO 1

Tables XI and XII. In each table, impact of all the five billboards is shown for one single video. The overall ratings given by the viewers are also included in these tables. Since multiple users were requested to give their ratings on each video for each billboard, the ratings chosen by the majority of the viewers have been considered here. Results of the fuzzy system using the manually prepared data set as well as the data set generated by the billboard detection system have been shown. Out of 10 cases presented here, there are 9 matching results when manually prepared dataset is used. On the other hand, 8 results match when the billboard detection system [4] is used.

VI. CONCLUSION

This paper has covered the details of our method for visual impact analysis of advertisement billboards in soccer telecasts. We have suggested a two-stage fuzzy system. Two parameters considered in this work are size and duration as perceived by the viewers. These parameters are used in the first stage to obtain intra shot analysis which is followed by an inter shot analysis of visual impact.

The proposed fuzzy system is not dependent on any particular billboard detection system and can work on top of any such system that returns the location and size of billboards in video frames. A more accurate billboard detection system would enable better matching between the fuzzy systems output and human viewers' assessment of the impact of various billboards in a given video.

Billboard name	Results given by viewers	Results based on manually prepared dataset	Results based on billboard detection system
Hyundai	High	High	High
Carlsberg	High	High	High
JVC	Medium	Medium	Medium
MasterCard	High	High	High
Cannon	Poor	Poor	High

TABLE XII

OVERALL IMPACT ANALYSIS RESULTS FOR VIDEO 2

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