Multi-agent System based on Blackboard System for Soccer Robot Implementation

Nitiwat Sanornoi, Boonchana Phurahong, and Pitikhate Sooraksa

Info-dynamic Laboratory, Department of Information Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

Abstract: This paper reveals the utilization of the multi–agent system that based on the Blackboard system basis as the controller of Soccer Robot. This system is a portion of developing the Soccer Robot team for Robocup 2004 Competition. In this development, the intelligent control system was initiated by the combination of parallel and distributed blackboard structures with the principle design that generated from human body structures, which consists of the combination of two main systems, the organs system and the brain system. The system is designed using the control system theory based on Blackboard basis. Modification of the initial structures to corroborate the Soccer Robot and the structure's constituents are clarified accordingly. To demonstrate the idea, ITE–Gold team is given as a case study.

Keywords: Multi-agent system, Blackboard system, Soccer Robot, Artificial Intelligent

1. INTRODUCTION

A tangible examination for the Robot could be done through the competition that was stipulated with the circumstance to be capable to compete in the competition. At the present, Robot Soccer competition is the most reliable examination field. [17] We would be able to utilize the competition regulations to stipulate the circumstance that appropriately work with the modern technologies. It is adjustable according to a more complicate system depending on the time and new technologies. Obviously the highest accomplishment is the efficiencies in competing with the correspondence to human regulations, which is to develop a robot that would be able to play soccer just like man. Development procedures must be related to the regulations that must be adjusted annually in order to enhance new developments. Competitor's difficulties are occurred with new regulations became the systems needed to be modified accordingly. As a result solutions for the initial regulations could be ineffective to the new regulations, algorithms adaptations, and hardware. The main objective for developers is to continuously develop the robot, but these consequences would be useful if they could access the source of future development without any destruction of the developed systems.

Innovation of multi–agent system on the Blackboard system basis is essential for robot developers, as the system does not only represent the new trend for a more complicated problems, it is also the most effective controlling system. It could satisfactory response to needs of robot developers. In this paper we would like to present architecture on Blackboard system basis for Soccer Robot. As the theme of this development could be related to a general robot development and it is suitable for our architecture examination. Part 2 show the problems and needs for Soccer Robot development covered different circumstances. Part 3 describes the multi–agent system on Blackboard basis. Part 4 proposes a suitable architecture. Part 5, the case study of ITE–Gold team in Thailand's Small League Competition is given as a case study. The final part is the conclusion and the suggestions for future development.

2. DEVELOPMENT EVALUATION

Comparison and the consequences of the multi-agents structure that based on the Blackboard basis shown in [16] have proven that this structure could activate the basic needs such as intelligent behavior, the utilization of various sensor combinations, and the support in destroying the target object, system robustness and system reliability. Using the distributed structures could solve the default of this structure that is non-reactivity to the environment.

2.1 Distributed Development Demands

In system development, various man forces are needed in constructing the Soccer Robot, the responsibilities are then divided into different responsibility areas. The structure that have been mention is capable and could easily be implemented to each part as the structure is logically divided into small parts, helped the development to be carried out individually. Not only that, the error for each particular part could be easily detected. From this consequence, it helps to reduce basic development procedures and time, as well as debug process.

2.2 System Evaluation Demands

A good system should provide a self-learning ability for development, likewise for this Soccer Robot. The structure could support the needs, by implementing algorithm which is used to develop the Evolutionary Agent in learning and it is comparable to a professional that has the self-learning ability. With the increased capabilities, there must be no effect on other parts nor should further adaptation on software.

2.3 System Adaptation Demands

Adaptation is a procedure that could not avoid in development. Structures must be supportive to adapt with the least effects. In this Soccer Robot development, algorithm adaptations in agents are needed to gain the highest efficiencies. Therefore, individual adaptation would effect on particular parts while remaining the rest constantly.

2.4 System Benchmarking Demands

Measurement on efficiency essential for each developer in adaptation. Efficiencies are tested parallel to the development which be could help due the adaptation to have more standard and could be able to compare with the original system.

3. BLACKBOARD SYSTEM THEORY

Blackboard system was originally known as one of the Expert System that was originated from Hearsay II system [1] used to solve the speech understanding problems. The most interesting point in this article is not the utilization of logarithm in problems solving but instead it is the architecture

that is drawn the attention. The utilization was then developed and applied continuously. It was then that this structure is being developed and adapts to meet certain requirement.

This structure is comparable to various specialist professionals that are gathered together to help solve problems with just the basic functions on the blackboard system basis. Problems are individually divided as to be easily solved by particular requirements which based only on the data in the Blackboard system as the raw materials in solving the problems. After finding the solutions, it will be written back to the blackboard. This procedure will be occur continuously until the problems are being answered. This could be easily explained by the example [1] which is the problem in Jigsaw puzzle.

3.1 Original Blackboard System Structure

The original objective of the Blackboard system was to solve the complicated problems [1]. By which the Blackboard will be evaluated from the raw data into data as the answer for that particular questions. It works alphabetical order and the structure as shown in Figure 1.

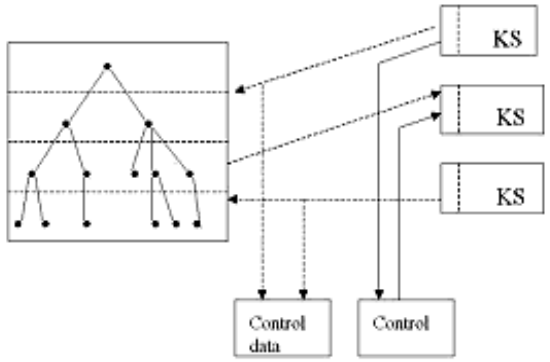

Fig. 1 Classical Blackboard System.

From the Fig. 1, the data will be kept in the Blackboard data structure, which is made up of various layers together (constructed form various layers). This Blackboard data structure will keep the data that are evaluated from the Knowledge source, and the data could be functioned as input data, partial solution, and alternatives or as final solution. Evaluation usually directs from downward to upward and the final solution will be in the top layer. In each layer, the relation of data will be connected as “in-support-of” relation. And in between the same layer, data will be related as “next–to” or “follows” relation.

Knowledge source(KS) will be function as the professional solve specific problems. The objective of KS is to gather all the data in the interested area to evaluate or solve the specific problems in its responsibilities. The data will then be transferred to be kept in the Blackboard data structure. Transferring of data could be taken place in the same or different layers. Therefore, either procedure will be indirectly passed through the Blackboard data structure.

Control Module could be comparable to the controller or to make arrangements for KS by monitoring data in the Blackboard data structure as a command to choose which KS should be in the process or which should not be. Therefore the control module will be the component that commands the solution to the different objectives. The control data is the separated data in the Blackboard data structure for which to support the more convenient in understanding.

Blackboard system could solve the complicated problems by evaluating the data into the solution to the problems, in which the control module will send a command from the KS to evaluate the objective data. This could be easily explained by the above mentioned Jigsaw puzzle problems.

For the new Blackboard system structure will be shown in the extended original structure research. The system will consists of various agents working independently parallel together without control module. This system is called parallel blackboard system [11]. Beside, there might be a system consisted of different Blackboard system combining together by communicating between systems, which is called distributed blackboard structure [10].

3.2 Control Modification of Blackboard System Structure

In the present controlling process, the Blackboard system needs more component than a classical system. Hence, complications takes place and turns the simple control system to a higher qualified system to control, multi–agent control system is then developed as a combination of various sub-systems together. Systems that are autonomous could not avoid the needs of Intelligence in it. Thus, the adaptation of the Blackboard system in process control is implemented to fulfill the requirement [6]. This is where the original objective has been changed form the support to solve the complicated problems.

As for a classical blackboard system, let us we name the layers by the objective of use in each layer accordingly. The layer will be adjusted according to the relations of data allowed the data flows from downstream to upstream (from the bottom to the top) that means the top data will be used. In another words, data will be arranged according to the target’s solutions. From this, the objective in evaluation is to evaluate the raw data or the input and convert into the answers to the problems by the agents. By considering the original structure, one can see that the top layer is the answer or the solutions and the bottom layer will be the raw data input. And the middle layers are the answer to the problems that use the lower layer data in solving. At the same time, the data will then be the data to support the solution for the following layer in finding solutions.

When the objectives changed, the sequences of the procedures will be definitely changed as well. For the control process, the data needed are the data that will be fed to the input of the actuator. The data will then be evaluated according to the objectives of each control system. Layers and relations for new structures will be arranged differently from the original structure. The process will be evaluating the target data to input data, the data which is in the bottom layer and the data will flow from the top to the bottom.

4. SOFTWARE ARCHITECTURE FOR SOCCER ROBOT

We got the idea on implementing a robot system that based on the Blackboard system from [2,3] by developing the attribute of both the Distributed Blackboard and the Parallel Blackboard combed together. Each blackboard will communicate in order to exchange data and evaluating the result in distributed. Not only that, agents in each system will work independently from each other. From the structured analysis presented in [6], system consists of three main parts which are the Abstract Environment, Expert System and Low-level control system connected to each other. This could be easily understood by comparing with human beings that consisted of three main parts that are the environments for forming of data, brain part which for

decision making part and the organs for conducting its functions.

Modification upon the original structure could be done by clearly indicated the name of each Layer and specified the type of agents appropriated for the Soccer Robot development (developing the Soccer Robot). The structure as shown in Figure 2 a system represents a robot.

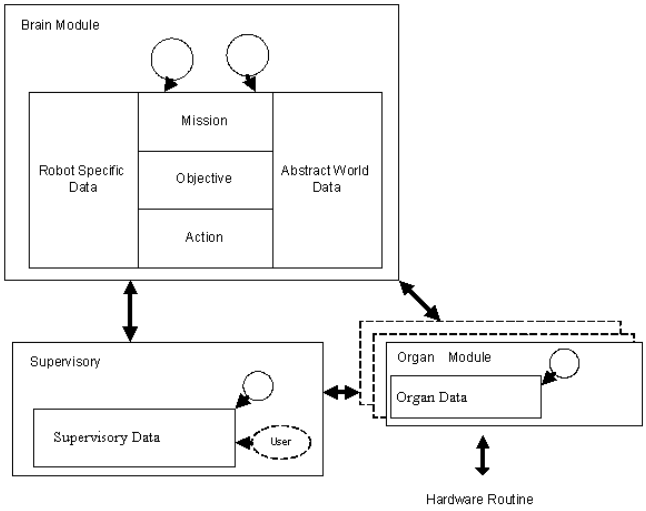

Fig. 2 The presented structure

4.1 Brain Module

A central component in decision making for Soccer Robot could be called as the brain of the system. It is responsible for transferring the environmental data to be evaluated according to the specified objectives into data for controlling the lower part. It is consisted of Mission Layer, Objective Layer, Action Layer, Abstract Layer and Robot Specific Layer. The structure is slightly different from the original in the horizontal layers distribution, which includes the relation and the exchange between the related layers.

Abstract World layer is a layer that has a connection with every other layer. The data in this layer is the environmental data converted into data that are ready for the evaluation. The data is received from the Sensor Organ Module, which is then transformed into environmental data. Robot Specific Layer is another Layer that has the similar connection with the Abstract World Layer. It is a layer that contains the specific data necessary for the system in the evaluation procedures Mission Layer is the top layer in the data flow. It is a place where command mission for Soccer Robot is kept. The data is transferred through the Supervisory Module and is evaluated a mission by Abstract World Layer.

The Objective Layer is the data central layer, and is a place where data evaluated by the agents utilized data in Mission Layer. These data will be transmitting from the mission data to the targeted data. It is digested before being evaluated by agents to Action Layer accordingly. Action Layer is the bottom layer. Data in this layer will be digested in order to be able to carry on to Organ Module immediately. The main data will be formed the evaluated data by the agents in Objective module.

4.2 Organ Module

A module that connected to hardware of the Soccer Robot by imitating human organ for in exchanging data between itself and the brain. These organs could be separated into two types; which are the Sensor Organ Module and Actuate Organ Module.

Sensor Organ Module is responsible for gathering the actual data from the environment and is evaluated into data that could be used in further evaluation. This procedure is the exchange of data between Supervisory Module and the Brain Module, comparable to the Soccer Robot senses.

The agents in this Module will be function in evaluation data from Sensor Hardware and communicate with Hardware by mean of one way communication which is received data from the Hardware only.

Actuate Organ Module receives data from Action Layer of the Brain Module for physical action, as an organ that response physically to the environment. Agents in this Module are the actuator control hardware. From this point, it has been proven that the entire algorithm used in controlling could be modified into this module. The communication with the hardware has be two ways communications due to the necessary use of data from the sensor in controlling process.

We may conclude that the specified types of Actuate Organ Module and Sensor Module do not just depending on the types of communication between the Module and the sensor hardware, but it also concerns in the types of exchanging data between Brain Module and itself.

4.3 Supervisory Module

This Module is a module to communicate with human in order to manage all the procedure in Soccer Robot, by using the User Interface as a transmitter. Communication in exchanging data from Brain Module and Organ Module of Soccer Robot to the understanding and the commanding directly. Agents in this module will be responsible in gathering data from modules transformed into human understandable data (data that could be understood by man) and also receiving the command from user through User Interface back to Soccer Robot.

4.4 Specification of Agent

Agents are responsible for evaluating data according to the assigned function. The system works accordingly only when the agents coordinate accurately. Soccer Robot is involved in many other types of researches and it consists of the combinations of various types of technologies. Involved researches are able to implement into agents by software structures. Agents could be separated into the following types.

Normalize Agent is the agent that evaluate, modified data into an appropriate and correct system pattern as a preparation for other agents in further evaluation without any mistakes or errors occurred. This agent could not be specified into any types of module. It is responsible in preventing any errors that might be occur in evaluation due to the Overflow data. It might also be responsible for data preparation in the following process. But for some other agents, a more complicated function is assigned for transmitting the Algorithm, such as Obstacle Avoidance [20] the waypoint., speed additional in agents to appropriate according to the types of battery, passed to wheel Organ Module.

Strategic agent is responsible for analyzing data from Data Structure into Mission that the system is needed to accomplish. Data to be analysis is the raw data input that could be found generally in the each layer as to conclude in concluding the next procedures which should be in process done by indicted a clear linguistic.

Mission–to-Objective agents could be found in the Brain module, are responsible for evaluating the data as mission data in the Mission Layer into target data and pass to Objective Layer. Mission data is in linguistic which is difficult to

translate data into lower command immediately. Modification is needed in order to an evaluate data. In a Mission, there are various subtract goals. Therefore in accomplishing the mission, we need to have sub target which are the components. For example, Mission in testing the battle / field and it will contain the target data, which are the Waypoints. Mission testing in the field will follow the Waypoint according to Algorithm that will be use as a planning [18,19,21,7] and behavior [15,5] could be able to implement all into this type of agents.

Objective–to–action is an agent responsible for translating the mission data to Objective Layer of the Brain Module into action data in Action Layer which was continuously evaluate from Mission-to-object agent. The evaluation done by this agent is similar to Mission–to–Objective agent, but will be different only with the types of data that will be from the different layer. Therefore, translating into mission data need to transmit data from Waypoint to the wheel speed angle passed through Actuate Organ Module that controls the Soccer Robot wheels. For example, leading the Robot [9] implementing Actuate Organ Module needed to be transmitted into this type of agents.

Data acquire-dispatch is the agent that responsible for receiving and transporting data or both between Blackboards. As for the initial structure transferring data between layers and Blackboard data structure will need agent to be the transmitter. Evaluation will be done by agent in the Blackboard will be the automatically data transformation but t the system structure that consisted of various Blackboard, the transferring of data could be both evaluated and not. Physically, in each Blackboard, might need an indirect transmitter such as LAN, RS-232, etc. Thus these agents are responsible in coordinating with each module to be able to communicate with one another.

5. A CASE STUDY

ITE–Gold has started developing the Soccer Robot for the Robocup Thailand competition in 2003. After the competition, the team was awarded with third place. System used in the competition had the vision part was burried to the Artificial Intelligent and supported only in controlling the “Puthon Kicker ” Model, which was the two wheels wheel chair robot using only stepping motor without any other special components.

After the league season, information was gather among the members in our team in order to accomplish the goal for the year 2004, a creation of robot that is capable to challenge with the nationwide competitors according to the national standard regulations is reassigned. Even we encountered with the limitation of only a year period of development, six man forces and a slight amount of budgets, we came to the conclusion of the system specification as follows:

- System should a Distributed System in order to support the development, AI and vision as the parallel structure development.
- System should able to support the control of two wheels or wheel chair robot[8], three wheel Omni-directional[9], and other system in the future [12,13,14].
- Able to support both robots with special equipment (Shooter, Dribbler, etc.), with some special equipment or with non special equipment.
- Able to apply with different models in the same competition.
- AI system must be fixed to only one computer in evaluation by combining the GUI together.

We have used Physical system shown in Figure 4 as to save the budget and to be able to separate the working parts.

After the 2004 League season, we were awarded with third place and received the best technique award. Various types of Robots as shown in Table 1 can be controlled by our system.

From the targeted specification, we have to design the structure that is harmonious with the limited factors. In the regulations, each team is allowed to submit five robots all at once, and it is the reason why we have to separate the Brain Module into five individual modules. There were two Organic modules that are used to communicate with the five robots and the Vision evaluates components. There is only a Supervisory Module that coordinates with all the Brain Modules, structures as shown in Figure 4.

Table 1 ITE-Gold robot model.

Model	Mechanism	Special part	Driving Motor
Phuthon Kicker	Wheel chair	-	Stepping
Big Foot	Wheel chair	Spinning Kicker	DC
Anurak	Wheel chair	Dribbler, Kicker	DC
Goblin	3 Wheel omni-directional	-	Servo
Freedom	3 Wheel omni-directional	Dribbler, Kicker	DC

5.1 Brain Module

We intended to design each robot to be intellectually independence to each other. Therefore the Brain Module is equivalent to the numbers of robots that are in the competition. Independence of this component helps to utilize each module all at the same time. However, even with the independence module, data remains the same.

The Robot Specific Layer keeps only the necessary data for the Robot, which is also necessary for the agent in evolution. The data will be assigned from Supervisory Module in the starting procedure and it could be corrected by the team manager in rearranging the plan according to the situations.

Abstract Word Layer is the data received from Vision Organ Module and is also kept the necessary data factors of the field competition which sets the data/ value from Supervisory Module through the Vision acquired agent. This agent will transmit the raw data from Vision Module into number data and transfer these data to be kept in the Abstract World Layer. Positioning data will also inform us the status of the object such as if the data is shown as remain, it means the robot still remain in the competition field. But if it shows the disappeared, it means that the robot is no longer in the field. However, unavoidable error still be found due to the incorrect data, for example if the target (ball) was blocked by the robot due to the angle of the camera, the data will be shown as disappeared, even with the fact that the target object is still there. Fortunately these errors are solved by the World’s Data normalization Agent.

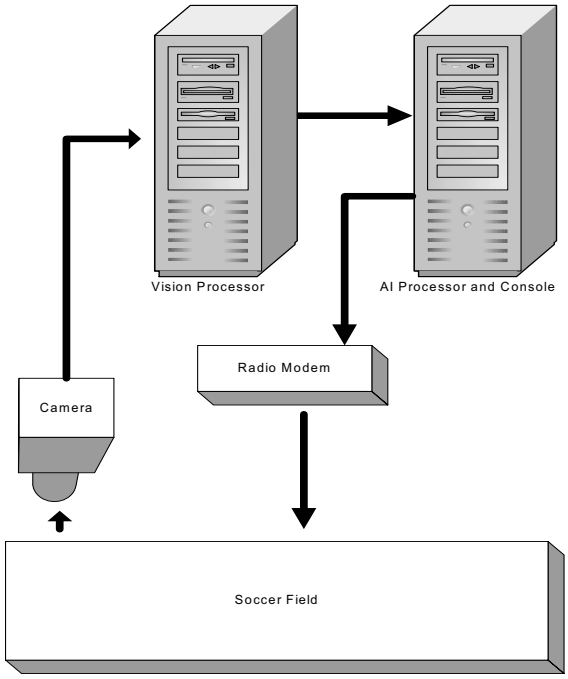

Fig.3 Physical System that was limited

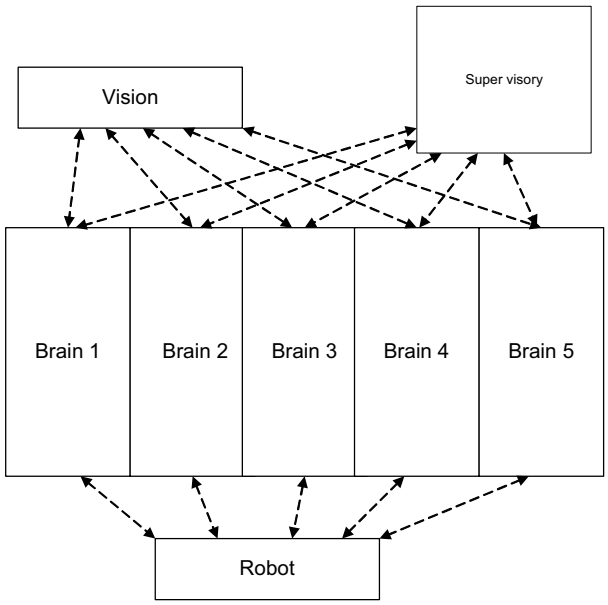

Fig. 4 Software Structures that ITE–Gold team used in Robocup Thailand 2004

Linguistic-mission data is made up of data from Mission Generate agent by evaluating data from both Robot Specific Layer and Abstract World Layer that are suitable for each circumstance. These data will be taken as the events that took place and the Behavior agents will convert the orders to data in Objective Layer which consisted of waypoint and the robot's actions.

In avoiding from the barriers or the defenders in the competition, the new Waypoint is needed to be reconstructed / rebuilt on the original one by Obstacle Avoidance Agent. But if there is no crushing the barriers in the analysis, data changes will not be necessary. Therefore, with the Real–time working system, the robot will automatically avoid the barriers.

The group of Navigation Agent will function as data converter at the Waypoint by using Algorithm [8] for two wheels wheelchair module and [4] for three wheel Omni–direction module. It converts the data into the wheel speed level and will be recorded in Action layer. Types of Waypoint will stipulate the speed of running. And Action layer converts the event data to control data for each organ. And the last procedure is that the Robot Dispatch Agent converts the data to a format that will be transfer to Robot Organic module. From this experiment, we would be able to extract the Linguistic data into a controllable data during the last procedure for the Real–time working system.

5.2 Organic Module

Vision Module is functioned as an eye of the Robot by the Com–port acquisition agent will be gathering the data of the Real–time from the Evaluation part via RS-232.

Robot's organic module will be sharing likewise to the Vision Module and its function is to gather the information from Action Layer, which is the ready data to be passing through to the robot. All data will be passed through the com-port by the wireless system through the Radio modem agent. Data will pass the String data. As for the freeze agent is responsible for correcting all command data to a stop. When the status of Robot Specific Layer is off, the robot will then evaluate the command and act accordingly. It could be noticed by the robot in the competition would function as an organ, which is the Actuator that responses to the environment in the reality.

5.3 Supervisory Module

Supervisory Module is a component that is used to communicate with the Operator. Its function is to gather all the data in other module in terms of GUI (in GUI form) which could be understood by the Operator as shown in Figure 6. Not only that, another function is to be the central transmitter in order and correct the data in Data Structure in other Modules. For example, in the situation that the Operator needs to change the plan while the game is stopped by concentrating on the forwarding. There will be a changes in some of the robot position from the defender to the forwarder that would also need to change the position data in Robot Specific Layer of the Brain Module by passing through the GUI of this Module.

6. CONCLUSION

This article shows the excellent implementation capabilities of the Multi–Agents system structure based on Blackboard System with the Soccer Robot. The advantage of this system can be measured by the results of applications. The outstanding part is the capability to control the robot consisted of different Model together at the same time within the competition. This helps reduction of development period from 5-6 years down to only 2 years.

We are definitely unable to avoid the system developments, due to the change of regulations and new leagues that will be organized. These developments must be consist to each other, which they should be more complicated developments with the Agent and Data structure, but the overall structure should remain the same. From the implementation in this research, the leading system will mainly base on the waypoint which in terms of adaptation into others ways such as Vector Field [21] could be done by just changing parts of the Agent and Data Structure.

Regulations for Robocup Thailand Competition were not much different from the previous competition. Therefore, our ITE Gold team's development approaches were just firstly modified the original into a four wheels Omni–directional robot. Increased the shooting forces, the fetch and throw abilities, vision development were done to support the utility of various cameras as to solve the poor vision problems. These developments were unavoidable effected on the determination part. Agent that was responsible for leading the four wheels Omni–directional model robot was added and other agents were adapted to suite the new model robot. From this point, the new proposed structure shows the excellent support on the developments and we do believe that this structure could definitely support the future challenges.

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