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COACH: A two level expert planning assistant for high school football

Gary F. Hasman

Rochester Institute of Technology
School of Computer Science and Information Technology

COACH
A TWO LEVEL EXPERT PLANNING ASSISTANT FOR HIGH SCHOOL FOOTBALL

by
Gary F. Hasman

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Approved by:

John A. Biles

William McAlee

Peter G. Anderson

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ABSTRACT

This thesis describes a two level expert planning system that first helps to develop a game plan for a high school football game and then aids in the selection of plays during that game. Built using Rulemaster, an expert system development tool, the system, called COACH, is initially provided observed data through the answering of questions which represents the receiving of a scouting report. This information is stored in a data file for further use. Also created during this questioning period is a data file containing comparisons of key players on the offense against their counterparts on the opponent's defensive team. Using a rule base established from interviews with an expert football coach, COACH creates a constraint file, the game plan, which is used during the play selection portion of the programming. During this phase, COACH is provided the current game situation and subsequently selects one or more plays from the game plan deemed most likely to be successful.

Keywords

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1. Introduction and Overview.

The field of artificial intelligence is slowly creeping into every facet of our daily lives. We have seen it insert itself into medical, military, and industrial settings. The use of artificial intelligence, in particular expert systems, to solve everyday problems is definitely on the rise. Artificial intelligence was first demonstrated in the realm of game playing, where strategy was defined as the selection of the best choice from among many. The game of chess was the focus of the initial thrusts, with checkers, backgammon, go-moku, and the like not far behind.

While these games involve strategy, they are concerned with pre-definition of the search space because, while the number of possible moves from a given situation is great, it is finite. Also, these moves can be the same ones that would occur repeatedly given a particular state of the game board. Introducing dynamic factors into the game, such as different strength pieces of the same type, or a board situation that could change while the next move is being considered, would seriously confound the established paradigms for playing the games by computer.

The game of football, at any level of play, has these dynamic factors. Additionally, while the basic situation of a game may be relatively consistent from game to game, the personalities of both the players and the coaches have a definite influence on the outcome of any particular play.

This thesis looks at two levels of planning within the confines of the game of football. At the strategic level, a game plan is developed by the coaching staff after looking at weekly scouting reports. This game plan is a list of plays that are deemed potentially successful against this week's opponent. It is carried into the game, and from it each play is selected as the game progresses. This single play selection represents the second level of planning, the tactical level.

The strategic level is enacted through a question and answer session that elicits the same information found in a scouting report. This information is then used by the expert system to create a series of files that represent the various sections of the game plan. Also created at this level is the player comparison file, which provides a relative rating between specific offensive and defensive players.

Double Space

The tactical level is enacted through a rule-based expert system, which uses the game plan files, the player comparison file, and user input. Here, the user is asked to provide information on the current game situation to allow the expert system to refine its search for the proper play.

At the end of each game plan creation or play selection, the user is prompted for continuation of the current session or for termination and return to the next higher level of the system. At the top level, quitting the system is one of the user's options.

Chapter 1 of this paper provides a short introduction of the entire project. It includes a brief overview of what the project entails and a chapter-by-chapter summary of the paper.

Chapter 2 covers the background necessary to understand what the project is doing. Include here is a short introduction to the game of football with basic information on the offense, the defense, and the coach's general preparation before each game. In the section on the computer's use in football, a short description of a professional football team's use of statistics is discussed. This is followed by an introduction to the planning process in two different environments; the corporate and the military. Next several computer-based planning systems are reviewed in an effort to formulate the requirements for the planning system of this paper. Finally, this chapter concludes with the extension of the discussion on planning into the game of football.

Chapter 3 describes the computer program (COACH) that was implemented. Include is what the program does, and does not do and what limitations were imposed and the reasoning behind them. A description of the files used and generated, an introduction to the software used, the creation of the system, and the testing process are also covered in this chapter.

Chapter 4 summarizes the project. It discusses the overall success of the project in terms of goal achievement and practicality. Also mentioned are the shortcomings of the final program and some proposals for future improvements.

Chapter 5 contains the bibliography for the research portion of this paper.

Chapter 6 contains the appendices. Here is found a short glossary of football terms and a series of diagrams to aid in understanding the game itself. Also included is a list of the plays used as the basis for game plan creation and

play selection. Here too, are the input data for the testing of the programming at both the strategic and the tactical level and the output generated by these inputs.

2. Background.

2.1. The Game of Football.

2.1.1. General Concepts.

A football game is a series of strategic and tactical moves and countermoves between two opposing teams who are usually coached by experienced individuals. The game is played in a restricted space called the playing field (Figure 1). Within the confines of the playing field, movement is unrestricted laterally and vertically.

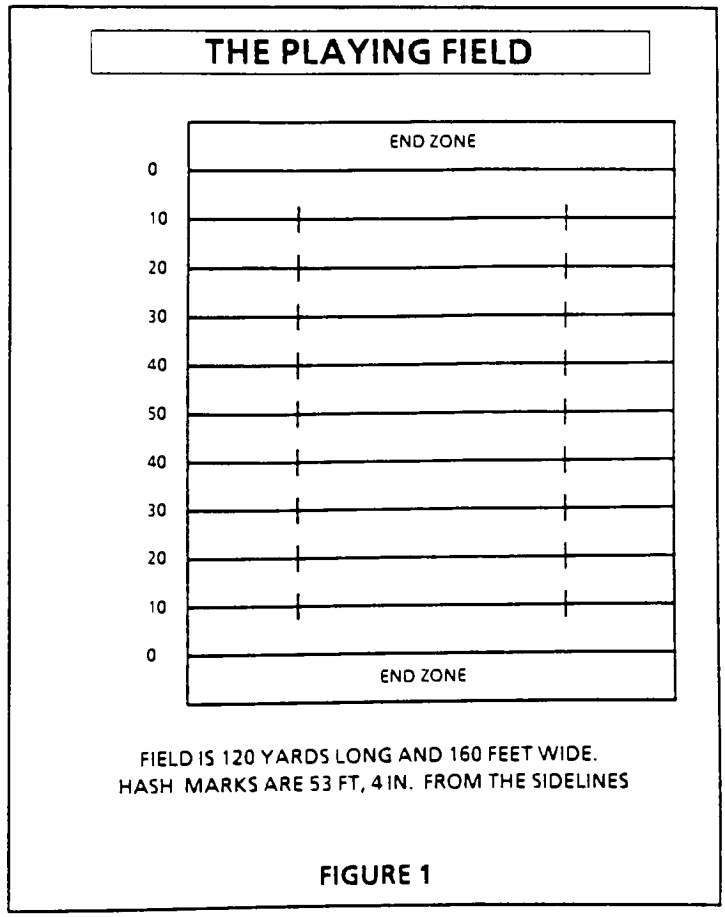

FIGURE 1

The coaches have at their command a cadre of player personnel who make up the various parts of the team. These parts include the offensive unit, the defensive unit, and the special units such as the kickoff, return, and punt units. Each of these parts, when on the field, have 11 players. Some of the players may participate on more than one of the different units. In addition to the 11 on the field, there are usually replacement personnel on the sidelines during the game in case of injuries or other reason for inability to play. The offensive portion of the team is led by the quarterback, who puts the coach's plans into effect. It is the offense's job to advance the ball down the playing field with the intention of scoring points against their opponents. This is done by repeatedly moving the ball at least 10 yards in four attempts until the end zone is reached. If the end zone is not attained, then a field goal may be used to score, the ball may be kicked away to the opponents, or the ball may be given over to the opponents at the point of failure to attain the necessary yardage. A standard offensive alignment is shown in Figure 2.

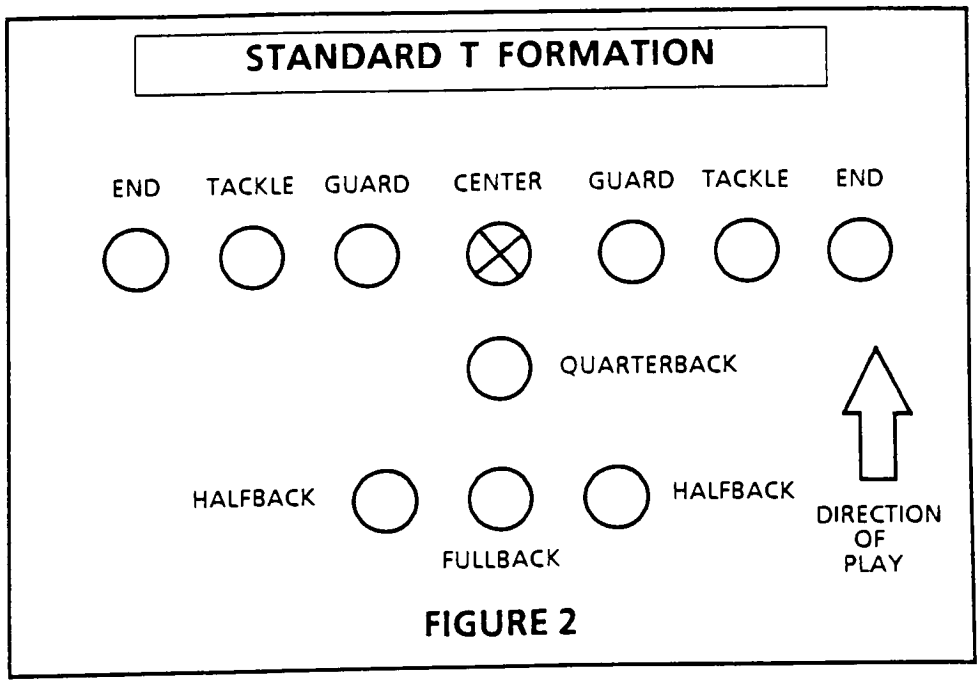

FIGURE 2

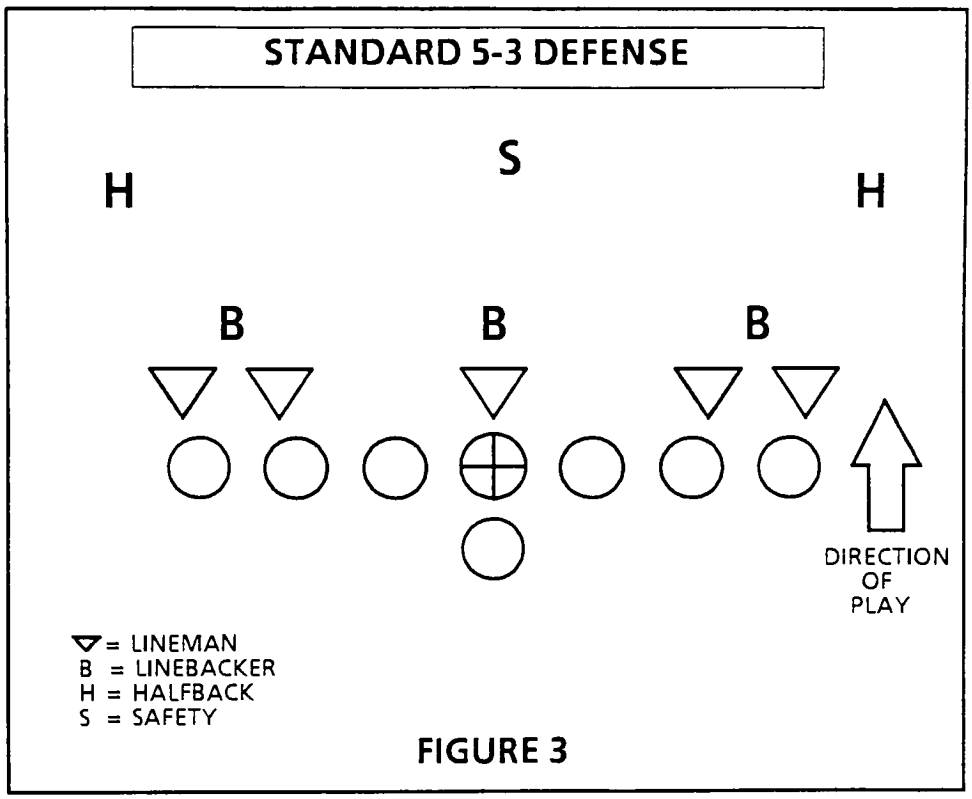

FIGURE 3

The defensive squad (Figure 3) is responsible for preventing the opponent's offensive unit from scoring. It must be able to guess the opponent's intentions on each of the downs and react accordingly to impede their progress. The kicking unit is used to kick the ball to the opponents at the beginning of each half of play and after any scoring event. The return unit is used to catch the opponent's kickoffs or punts and return the ball as far as possible before being tackled. The punting unit is the one that kicks the ball to the opponents when the offense has failed to make the required yards for a first down.

2.1.2. Offensive Strategy.

Because this thesis will be concerned with play selection, only the offensive part of the game will be considered. To that end, the formulation of general offensive strategy of a coach will now be discussed.

2.1.2.1. The Game Plan.

Before any game has started, the coaching staff plans its strategy for the upcoming opponent. One or more members of the staff will attend the opponent's games and make notes about that opponent's play of those games. These scouting reports are then studied and discussed to formulate an overall game plan for the upcoming game.

The game plan is simply a list of offensive plays that the coaching staff feels will prove successful in gaining yardage against the scouted opponent. The game plan sets the overall tone of how the opponent will be attacked and where that attack will take place. If all goes well, the game plan can be followed quite closely. If, however, the opponent has made significant changes to his defensive strategy, the game plan may be abandoned in part or in whole.

2.1.2.2. Player Personnel.

The coach must not only know his opponent to determine the best offensive strategy, but he must also know his own team's abilities and capabilities. The coach must be keenly aware of his players' strengths and weaknesses. Does the quarterback throw better while moving to his right or to his left ? Can his right tackle block better to the outside or to the inside ?

These types of questions are answered for every player on the team. The coach then matches his players against their expected opponent on a one-to-one basis. This enables the coach to determine the likelihood of his player being able to control his opponent during the game. It is this control that will eventually determine the outcome of the game.

2.1.2.3. Play Selection.

Armed with the above information, the coach leads his team onto the playing field. As the game progresses, the coach will select plays based on this information as well as factors that are present at the time of selection. These additional constraints can include, but are not limited to, quarter of play, the opponent's defensive arrangement, down, yards to go, and player injuries.

Not all these factors are relevant on every play. The dynamics of the game allow for varying degrees of impact for each factor. It is usually a conjunction

of a few factors which, when combined with the scouting report and the player comparison chart, determines which play to select.

It should be remembered that the coach can control some of these factors. However, there are some he cannot. The extent of control he has is generally not important, but the coach's ability to manage the effect of these factors on his team, and the game, is.

2.1.3. The Playbook.

As mentioned, the game plan is a list of offensive plays selected by the coach and his staff as having the greatest potential for success against this week's opponent. But where do these plays come from ?

Over the years the coach and his assistants have studied successful teams and selected plays from their repertoires. The coach has then either used the plays outright, or modified them to fit his teams' capabilities. Additionally, he and his people have designed their own plays. These plays were drawn up to fit the particular abilities of key players on the current squad. All these plays may be written down in a playbook or simply kept mentally. As the seasons progress this playbook is constantly revised and updated with new, better, or just different plays in order to keep opponents from being able to predict what the coach will do next.

2.2. The Computer in Football.

2.2.1. Statistical Analysis.

David Coursey in the October 12, 1987 edition of MISWEEK [Coursey 87] indicated that the Dallas Cowboys of the National Football League (NFL) enter every offensive play and defensive alignment of the season into their mainframe computer. The coaching staff then examines "hundreds of pages of detailed analysis" and selects the plays most likely to succeed in the coming game. They can also query the system and obtain answers to questions such as "Who are the Redskins (another NFL team) likely to pass to on third down with long yardage?". This system is a purely statistical analysis of past performances, but at this high level of play, the consistency of each team's style lends itself to statistical analysis and also to predictability.

2.2.2. Beyond Statistics.

These statistics provide data before the game begins and are actually a highly sophisticated scouting report. While statistics can be of value, however, they leave out many factors important to the game, especially those that appear during the game. The personality of the coach could provide the exception to the rule when warranted by the situation. An injury to a key player picked by the statistical approach could lead to a nonstatistical player being selected to handle the football. These kinds of factors force the analyst away from the purely statistical approach and into the realm of the knowledge engineer.

An expert system could insert this kind of information into the decision-making process and, as a result, lead to better play selection at the time of the play, rather than before the game began.

2.3. Expert Systems in the Planning Process.

2.3.1. An Introduction to Planning.

In its most basic form, planning is simply the establishing of a course of action that is designed to reach some end result in a favorable manner. Planning is used by the housewife to do the shopping at local stores, by Fortune 500 executives to control their particular part of the business world, by generals to win wars, by governments to win or keep allies, and by coaches to win football games.

Planning occurs on three generally accepted levels: strategic, tactical, and operational. At the strategic level, the overall objective is established and the means to gain that objective are delineated. For the industrial setting, this objective is usually to increase the general net worth of the corporation [Bogue 86]. For the military commander, it is generally the employment of force and military resources to conquer some piece of physical territory [Cushman 86, Peacock 84]. For the football coach it is to win the next game.

At the tactical level, corporations take management action to achieve the changes required by the strategic plan [Fry 86, Tourangeau 81]. In the military, tactics lie in and fill the province of the combat arena [Liddell Hart 67]. In

football, the tactical level involves selecting the next play to counter the expected defense put forth by the opponent.

The operational level is concerned with the day-to-day nuts and bolts execution of the previously decided strategy and tactics [Espy 86]. This corresponds to the individual worker, soldier, or player level of the respective organization.

2.3.1.1. Corporate Environment.

In corporate America, each company, large or small, must map out where it is going in its line of business and how it intends to get there if that company expects to have any future success, or any future, for that matter. Numerous books have been written describing the planning process, both in theory and in practice. We will examine the basics of corporate planning to provide a foundation for further discussion.

2.3.1.1.1. Strategic Planning.

As previously mentioned, the main objective of the strategic planning process in business is to improve the economic value of the company. After agreeing on this point, authors go on to point out that the planning process also should define strategies, policies, and the detailed plans to achieve them

[Steiner 69], identify past and prevailing strategies [Fry 86], and develop ideas and concepts that will guide the company over some period of time [Espy 86]. If these things are done correctly, the entire process would, according to [Ewing 68],

> *...lead to a better position or standing for the organization*
>
> *...help the organization progress in the ways that its management considers most suitable*
>
> *...help keep the organization flexible*
>
> *...indicate to management how to evaluate and check up on progress toward planned objectives*

[Crego 86] supports this contention and continues it by saying that

> *...in addition to providing a logical and rational sense of direction for the organization, a [well thought out] plan*
>
> *...can identify strengths and weaknesses of the firm*
>
> *...can identify potential problem areas*
>
> *...coordinate and ensure consistency in the plans of various units or divisions [of the company]*
>
> *...establish a framework for making key decisions in the ongoing management process*

To accomplish all this, many hours of study must go into the planning process. Managers and executives must look at every aspect of their organization.

They must examine the current state of the industry. They need to become deeply familiar with their competitors.

Self examination requires management to analyze, in depth, its internal strengths and weaknesses [Hind 83]. These can reveal whether or not previous planning has recognized and set strategic goals soundly [Ewing 68]. By knowing the limitations of the company, executives can plan ways to expand these limits. By recognizing the things it does well, the company can move to take better advantage of these strengths. This analysis can also determine whether these strengths and weaknesses are real or artificial. Subsequent planning can remedy inconsistencies and provide an overall strengthening of the organization.

Examining the state of the industry and its markets will reveal those areas where more effort is required. This , in turn, will generate the marketing strategy portion of the overall strategic plan and will show company managers where additional opportunities exist on which to capitalize [Espy 86].

Nearly every author addressed the need for management to become very knowledgeable about the competition in their segment of the business world. Because every competitor is different in its internal structure , and therefore, in its strategy in the marketplace, each have inherently different strengths and weaknesses [Bogue 86]. It is imperative that each competitor be analyzed thoroughly. [Sammon 86] cautions that

a business strategy anchored in an obsolete understanding of the competitive situation and the key factors that drive it is a ticket to stagnation and slow decline.

2.3.1.1.2. Tactical Planning.

Tactical planning is the next level down in the hierarchy of planning. Essentially, it deals with the more immediate objectives of the company and has a significantly more restricted time span [Tourangeau 81]. Once the corporate strategy has been defined, each subdivision of the company must generate plans of its own to accomplish their portion of the overall company objectives. These plans will delineate the sequence of actions necessary to implement the company's strategy [Sackman 72]. [Glaser 75] suggests that tactical planning is more practical than strategic planning and closely corresponds to allocative planning, which is concerned with the distribution of available resources among competing users within the company.

A good strategy does not guarantee good tactics. In fact, according to [Bogue 86]

given a specific strategic course, the result is likely to be only as good as the implementation.

The implementation referenced is that provided by the tactical plan. The success of this implementation will depend on management's ability to clearly and effectively communicate the organization's strategy to lower

levels. This implies not only good communication skills, but the communication of corporate objectives that at least appear to parallel the objectives of the employees [Tourangeau 81]. This cohesiveness of purpose is critical to any organization's continued success.

2.3.1.2. The Military Environment.

The military establishment has, of course, used planning for centuries. Whether around a Mongol campfire or in a Pentagon conference room, military leaders have established goals or objectives for their respective armies and devised means for achieving those goals.

These methods of planning have been revised and refined over those same centuries to the extent that most military organizations send their officer personnel to schools to learn those methods. At these staff colleges they study Pericles, Clausewitz, Sun Tzu, and many others to learn, not only how to give orders, but how to decide which orders to give. In simpler terms, they learn to plan.

2.3.1.2.1. Strategic planning.

In many of the books read in preparation for this paper, numerous references were made to the fact that after years of neglect, corporations were beginning to pattern their planning activities after the military's. However, there is some conflict over who is copying whom. [Sackman 72] claims that

"military planning is similar to corporate planning." Others see corporate planning as following the traditions established by the military. In fact, William E. Peacock's Corporate Combat [Peacock 84] is a guidebook for chief executive officers to follow in their effort to win the corporate wars.

Peacock maintains that corporations can pattern their strategy on the military because the objectives of each are similar. Where the military seeks to gain physical territory, the company is seeking to gain sales outlets and other markets.

This points out the main difference between corporate strategy and military strategy. In the military planning process the term "target" is prevalent. While this term has crept into corporate conversations, the connotation to the military mind is one of conquest by force of arms. This leads to a strategy that can be defined as the process of getting forces onto the battlefield, the *"where and what of war"* [Cushman 86]. Cushman goes on to state that, therefore, strategic planning involves

> *...the setting of goals, the organizing of forces, the ordering of campaigns, the development and perfection of operational and tactical concepts.*

When all is said and done, the military planning process involves steps very similar to those discussed under the corporate planning process. The astute military commander must examine his army's abilities and capabilities so that its weaknesses can be minimized and its strengths can be used optimally. He

must analyze the target and the surrounding terrain to determine the best approach to the goal. And finally he must fully understand the enemy whether through the use of direct observation or through the use of accurate intelligence.

Knowing all this, the military commander may then *"see opportunities and threats in the future and, respectively, exploit or combat them as the case may be"* [Steiner 69]. With proper planning he can *"diminish the possibility of resistance ... by exploiting ... movement and surprise"* [Liddell Hart 67].

In all, he will cause his operational subordinates to develop proper tactics through clearly communicated objectives that allow them to take a line of operation that offers sufficient alternatives so as to guarantee success.

2.3.1.2.2. Tactical Planning.

Military tactical planning involves the

> *"formulation of specific, concrete goals and objectives ... [and] ... the development of specific means for achieving the [previously defined] strategy"* [Espy 86]

The tactics generated become the application of strategy at a lower plane [Liddell Hart 67].

As with corporate tactics, resource allocation plays a major role in the development of successful military tactics. As we shall see, this becomes the major constraint when determining what to attack, how to attack it, and with what forces.

[Cushman 86] notes that as within the corporate arena, "*if tactical competence is not there, any operational scheme is in jeopardy regardless of its conceptual excellence.*" So we again see that good strategy does not guarantee good tactics.

One area open to discussion is the need for the individual soldier to see, and agree with, the overall objectives of his superiors. This becomes increasingly controversial because of the very nature of the military. Decision making is mostly a unilateral, downward flow of information in which the individual soldier has little say. In war, the discussion of the why of a particular event or action could cause the loss of some strategic or tactical advantage in time, position, or force. In peacetime this may have no immediate effect, but could lead to improper expectations in the next conflict. Additionally, a disgruntled soldier may not feel obligated to divulge information of possible value if he feels put out by the planning process.

In the corporate wars,

> *"those employees closest to the competition ... are best positioned to pick up the gradual or sudden shift in the tactical ... details that foreshadow strategic change"* [King 86]

On the battlefield, the personnel closest to the enemy would most likely have the best idea as to what the enemy is about to do.

In both cases, *"without the active input and feedback of these experienced collectors [of information] ... an important window on competitors [is lost]"* [King 86]. This means that one of a military commander's higher priorities is the morale of his personnel and that good communications is the key to achieving that priority.

2.3.1.3. Some Additional Comments on Planning.

Before continuing, it may be wise to look at two other aspects of planning. First we look at some of the things that planning is not. Then we'll look at a very important attribute of planning.

Many authors, while not exactly claiming so, leave the impression that planning can be a panacea to an organization's ills. In order to combat this misinterpretation of planning's place in the corporate life cycle, several other authors go to great pains to elucidate the things planning is not.

[Steiner 69] declares that planning is not forecasting. It does not predict consequences. Rather it develops a path to follow which, if nothing changes, will result in attainment of a particular goal. He goes on to state that planning does not eliminate risk. It does not make future decisions. It is not a

blueprint for the future. [Ewing 68] concurs with Steiner and adds that *"planning is not necessarily an attempt to improve operating efficiency"*.

All this leads to the second point: planning is dynamic [King 86]. It is a continuous process [Steiner 69] which should be reviewed and revised on a regular basis [Taylor 83].

No plan can be, nor should be, expected to be feasible forever. If the plan contains sufficient alternative routes to follow when conditions warrant, then it may require less frequent changing. On the other hand, narrowly designed plans must be revised in the face of new information or the organization can expect difficult times until necessary changes are actually made.

2.3.2. Computers in the Planning Process.

Call them decision aid systems, call them decision support systems, or call them computer aided planning systems. Whatever their name, corporate and military planners are looking to the computer to alleviate some of the burden of the planning process.

Using artificial intelligence technology, or more precisely expert system technology, systems have been developed at both the strategic and the tactical level. In this section we will look at the use of expert systems in the planning process. We will discuss the overall feasibility of using knowledge-based systems as planning aids and why they appear successful in this

application area. We will then look at several of the systems that are either currently in use or under study.

2.3.2.1. Expert Systems in the Planning Process.

Computer aided planning systems are not new. They have been in existence as practical tools, and as research topics, for at least 20 years [Tate 85, Merry 85]. They have progressed from single activity tools in the corporate boardroom to the staff agencies of the military services. As the research advanced, expert systems were, and continue to be, designed for broader applications. Because an organization's success is predicated on its ability to plan successfully, it was soon realized that any tool that could reduce the time spent in the planning process while improving its efficiency would be a welcome addition to any executive's arsenal [Palmer 86]. Being able to produce an effective plan quickly has become a necessity to survival.

The marriage of artificial intelligence techniques and organizational planning seemed natural from the start. Both areas deal with search, choice making, knowledge representation, and learning [Tate 85]. Planners must obtain knowledge about their own company, the market, competitors, etc., and be able to determine which pieces of information are applicable to the current situation. They must then decide what to do with that information and, based on previously made decisions, they must make new plans. In addition, expert systems and planning both require solutions to be justified and require elicitation of knowledge [Tate 85]. Therefore, it is not surprising

that expert systems have become valuable tools in the corporate and military environments.

[Tate 85] lists over a dozen applications tackled by computer aided planning systems. Obvious areas such as robot control (using STRIPS) and electrical circuit design (using NASL) were on the list. Some not so obvious systems included a house building planner (using NONLIN), a journey planner (using OPM), and AIRPLAN, an aircraft carrier mission planner.

The range of applications for expert systems is as varied as the users of planning. As can be seen, areas where planning is used range from simple movement to design to travel to military mission planning. In general, however, planning becomes the method to determine how to get from on state of being to another. Whether a robot arm moves from Point A to Point B, or a current flows from Switch A to Diode B, or a ship moves from a port to an armed engagement, planning determines the paths taken to achieve the objective.

In order for expert systems to be useful tools in the planning process, planning must be definable in "computer terms". First, planning involves very large problem spaces through which the planners must weave their way to produce a guide for achieving the objective. This search space can be either a state search space or a series of partially elaborated plans that will be connected or further defined during the planning process [Tate 85]. Moving through this search space in an elegant manner is not always possible.

On many occasions, planners do their job with incomplete information [Reichgelt 85]. Some phases may contain detailed knowledge while others may contain only sketchy outlines. [Tate 85] lists nearly a dozen techniques for searching. These include means-end analysis, dependency-directed search, and opportunistic search. [Kaiser 78] takes this incomplete knowledge problem one step further and suggests heuristic search. This method allows for solutions to be obtained, but does not require exhaustive searches of the problem state space. In actuality it is the method used by experts to find solutions in their areas of expertise. This ability to work with unquantified data and to be relatively unaffected by errors or failure along paths of reasoning make them quite suitable for planning purposes.

As people formulate new plans, they rely on the results of previous plans as part of the input to the new plan. The success or failure of those previous plans and their impact on the planning environment become part of the database on which the next plan is built. The parallel artificial intelligence construct to this process is learning. The updating of constraint files referenced by the expert system comes about either by the direct input of the user or through internal modification of the database as results of previous actions become known to the system.

Another area where the technology comes to the fore is in the sheer size of the search area. Often the planning process is very complex involving numerous inputs to the planner [Sackman 72]. The overwhelmed executive will tend to ignore many of the variables presented to him and concentrate on the more significant ones [Moser 87]. This trivialization can generate poor

plans that require constant tweeking as the ignored variables come into play. A knowledge-based system can hold the entire spectrum of variables and can incorporate their effects into a plan as required without conscious effort by the planner.

2.3.2.2. Some Examples.

In this section we will look at some of the many decision support systems that are in existence today. We will examine them to see how they define the planning process, how they assist the planner, and some of the basics of their designs. This will lead us to some design decisions for the expert system of this paper. The systems we will look at are BATTLE, DECIDEX, TATR, TACPLAN, and INTACVAL.

The first system, BATTLE, *"provides recommendations for the allocation of of a set of weapons to a set of targets"* [Slagle 85]. It can either take a set of data and provide a recommendation or carry on a conversation with the user interactively and provide recommendations based on user-altered input. BATTLE uses 55 factors relating weapons, targets, and battlefield situations in its determinations. These factors, represented as tuples in the database, include the probability that a given weapon (in this case, artillery) can reach a given target, target size, hits required to reduce the target to ineffectuality, whether the weapon has sufficient ammunition to do the job, whether the weapon can be resupplied and how quickly, and whether a single weapon or a group of weapons is required against a particular target. To carry on a dialogue with the user, BATTLE uses the Merit question selection system. This

system guides the questioning of the user for further information based on the ratio of probable importance to the situation at hand to the difficulty in obtaining the answer. Questions with higher ratios get asked first. This reduces the questions asked by allowing gaps to be filled by data related to the question and its answer.

Once sufficient data is gathered, either from the user or from the database, BATTLE analyzes the effectiveness of each weapon against each target. The results of these analyses are fed to an algorithm that looks at the possible composite allocations of weaponry and attempts to optimize the number of targets that can be totally reduced in value. BATTLE uses a pruning algorithm to reduce the search space to a manageable level rather than search the myriad of possibilities available. The authors claim this algorithm *"executes in acceptable time and yields nearly optimal results."*

DECIDEX, discussed in [Levine 87], is a decision support system that makes use of several expert systems to provide advice during the planning process. The creators see planning as a process of making decisions, where each decision is reached based on a set of previously made subdecisions. They believe that planners do not make decisions in a vacuum, but rely on the information passed to them by various experts within the planning environment. Even so, many of the decisions made are based upon uncertain and incomplete information. In spite of this, the authors believe most managers can develop some fairly good ideas about how their planning will turn out.

These ideas are what Levine, et.al., call scenarios. In their system, scenarios are possible arrangements of the actors involved in a plan and the possible

outcomes of those arrangements. This obviously creates a very complex environment in which the planner must function.

Because of this complexity, uncertainty and incompleteness, the authors see the need for several expert advisors to the planner to help fill in the gaps in the planner's reasoning. This fill-in takes the form of facts written into the database or of heuristics written as rules. These allow the respective expert system to render the subdecisions the planner needs to continue.

DECIDEX interactively helps the planner to build scenarios using a database of history about previous plans and their results, a spreadsheet to help with calculations, and several expert systems. The expert systems are designed to contradict an evaluation made by the planner. They start

> *"from the negation of the decision maker's point of view and applying their rules, they try to prove that this negation is true [thereby] contradicting the decision maker's assertion "* [Levine 87]

Failure of an expert system to contradict the planner does not guarantee the planner is correct, but success by the expert system should cause the planner some serious second thoughts. Additionally, the planner can use the explanation facilities of the expert systems to find the exact point of disagreement.

The tactical air target recommender (TATR) [Klahr 86] is a prototype planning aid for the United States Air Force. At the time the reference was written, TATR's primary functions were to *"provide a plan for attacking enemy*

airfields and to project the effects of implementing that plan" [Callero 86]. When completed TATR is expected to not only select the airfield, but also select specific targets at each airfield.

This planning aid is an airborne version of BATTLE. A target database contains pertinent information on each target, which has been gleaned from intelligence sources and from the user as effects of previous plans become known. The database contains 80 or more facts about each airfield. These facts contain, among other things, what targets are present at the airfield, their potential to damage friendly forces, their significance to the enemy, and what friendly forces would be required to neutralize them.

TATR prioritizes the airfields into four categories: excellent, very good, good, and unrecommended. These initial categories are based on the target's potential to harm friendly forces. It then selects the targets in the top three categories and determines what friendly resources it would cost to achieve the desired results against each airfield. These computations are calculated with input from databases that contain not only factual data about the friendly forces, but also strategic and tactical policies stated as constraint rules. After analyzing each target's defenses, a list of specific targets is generated. Then the current resources are matched to targets, and a plan that shows target, types of aircraft, types of munitions, and other information is provided to the user. The user then makes interactive adjustments to the proposed list, and TATR generates modified lists until the user is satisfied.

TATR is expected to become a very large database of targeting knowledge that will serve as a learning and research tool. By planning "what if" scenarios, the Air Force is expected to be able to determine optimal minimum force allocations in different theaters of operation in times of reduced resources. If not enough information is available to the planners, the lack of it will signal future intelligence requirements.

The last system we will look at is actually two. TACPLAN and its successor, INTACVAL, are designed to aid Army personnel in developing tactical plans for defensive purposes.

Designed for use on microcomputers, both systems have a graphics interface that uses an interactive video disk. The disk contains maps of the terrain over which Army units are expected to move. Using maps that are stored in various levels of scaling, planners can view overall terrain features or zoom in on particular sections of any map. Because the maps are the results of actual aerial reconnaissance, the planners can literally fly over the expected routes of movement using joystick or mouse control.

TACPLAN's databases are actually constraints to what the planner intends to do. These databases contain rules, facts, and heuristics pertaining to combat, terrain, military doctrine, weather, and mission types. As the planner places units on the maps and draws in intended routes of travel, TACPLAN evaluates this information and will warn the planner if a particular rule has been violated. The planner is then free to reroute the particular unit and clear the violation or to input additional data which may also clear the violation.

Because the databases are *"primarily oriented to the relationship between terrain type, maneuverability, and unit type"* [Andriole, et.al. 86], TACPLAN constrains what the planner wants to do rather than how the planning process is performed.

TACPLAN has an explanation facility that provides normal English statements whenever it tells the user of a violation. The creators felt that Army planners, and planners in general, would be more amenable to a system that acted as a *"support [to] the way they actually do business"* [Andriole, et.al. 86].

TACPLAN's follow-on, INTACVAL, goes one step further in the planning aid spectrum. While TACPLAN assisted the planner by advising of constraint violations, INTACVAL actually guides the planning process and can generate plans of its own from user provided input. It also assesses alternative plans based on its knowledge of tactical planning and allows the user to see how different plans compare against one another.

Two major differences between TACPLAN and INTACVAL are the object-attribute-value (OAV) data structure and the battle calculator. The OAV's encapsulate information and allow the use of direct inferences in the determination of constraints or constraint violations. For example [Andriole, et.al. 86]:

	OBJECT	*ATTRIBUTE*	*VALUE*
IF:	*terrain*	*forested*	*low-maneuver*
THEN:	*unit*	*armored*	*constrained*

Identifying the set of OAV's that pertain to tactical planning allows the system to search for patterns. These patterns represent the various concepts of operations, which in turn guide the process of plan development and check the planner's judgement for every unit and route suggested. The OAV's, through constant updating, also represent the learning mechanism of INTACVAL.

INTACVAL's battle calculator generates alternate plans based on user-provided operational concepts. Taking this general concept, the calculator evaluates the terrain, the current force structure, logistics, and such and graphically displays alternate plans. The user can watch various plans be executed and then call up comparisons of the plans in order to evaluate their performance against known terrain, doctrine, and combat constraints. The planner can then use this information to develop stronger plans.

INTACVAL moves beyond the advisory role of TACPLAN and into the role of an actual associate of the planner. It not only stores knowledge but uses that knowledge in the formulation of plans that the user can examine, evaluate, and modify as desired. Even so, it must be remembered that regardless of its role, the planning aid only generates or helps generates plans. The final decision as to which plan to accept still resides with the human user.

2.3.3. Planning in Football.

The previous discussion brings us to the point of this paper. Corporate and military planning can be paralleled in the domain of the game of football. The strategic level, where overall goals and objectives are determined, and the tactical level, where specific actions are planned to achieve those goals and objectives, each have their counterpart in football. The elements of each level also are closely related to those that comprise the respective level in the game. This leads to the distinct possibility that, if computer aided planning systems can be of benefit in the corporate and military environment, they can be of benefit in the sports environment.

2.3.3.1. Strategic Football.

At the strategic level, football's main objective is to simply win the game. The obvious question becomes: How? The coach and his staff must determine this and, in the process, formulate the best overall plan to achieve this goal.

This game plan will guide the coach and his players during the tactical portion of the planning process. Because strategy in football is *"the science or art of deploying your own attack against an opponent and attempting to outmaneuver him"* [Tallman 69], the game must be viewed from several possible positions rather than from a singular overall point of view. For this reason, the game plan (Figure 4) is divided into sections. Each section is

actually a sub-plan that deals with particular situations that normally arise during any game.

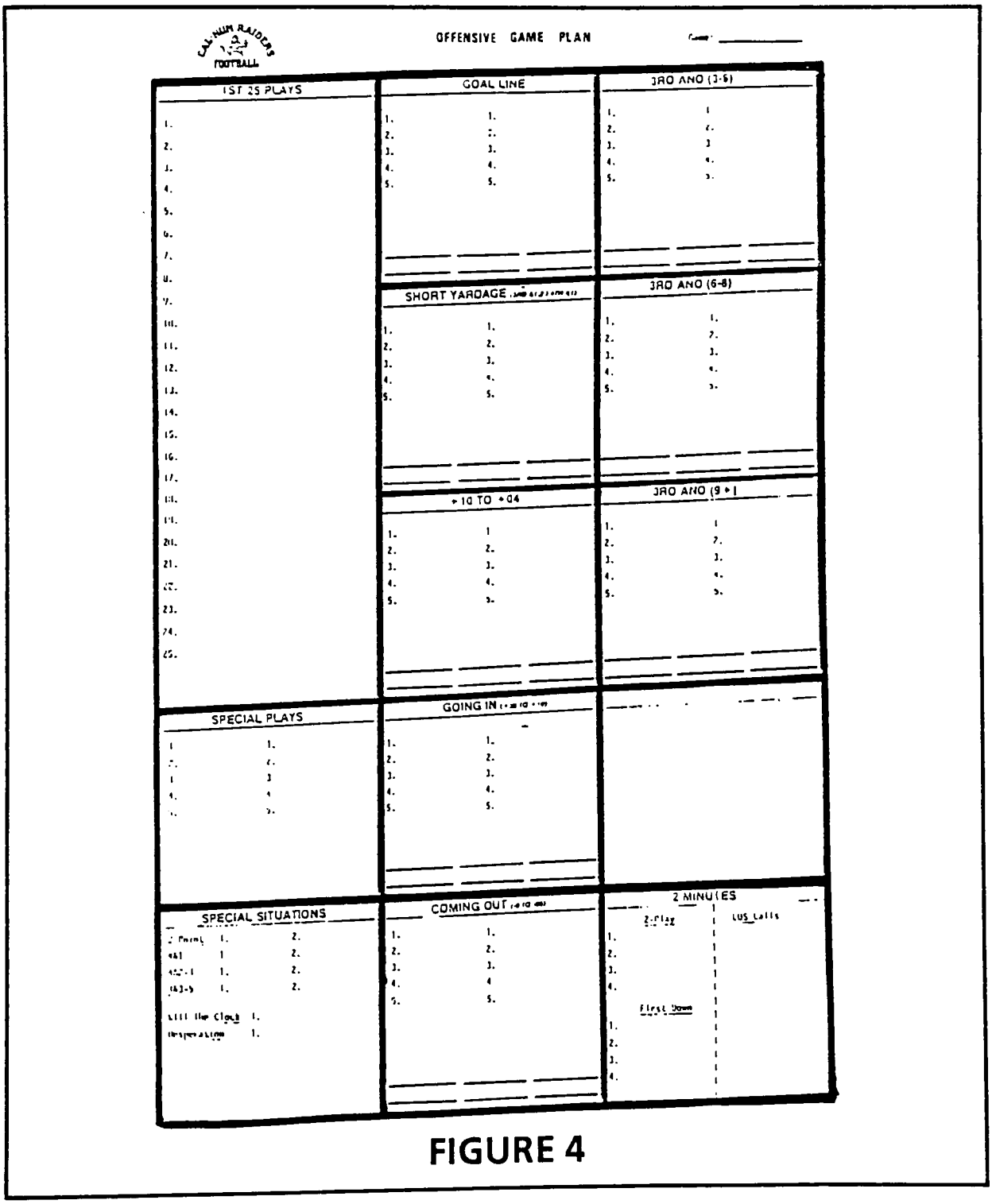

FIGURE 4

Rather than try to attack the opponent in some overall manner, the coach looks at these significant aspects, reviews his team and the opponent and selects plays that he expects will be successful in those general situations. The plays are usually listed in order of expected results, with the best at the head of the list.

Like the corporate executive and the military commander, the coach must study his team, the battlefield, and his opponent. He must weigh the information he has on hand, balance his resources against anticipated needs, and reach conclusions as to which course of action would be of greatest benefit.

In studying his own team, the coach must evaluate every player as to that player's capabilities and abilities. At each practice session and during every game, each player is watched for strengths and weaknesses. To gain the advantage, the weaknesses must be at least reduced, if not eradicated. Additionally the strengths must be constantly built up to higher levels.

The battlefield is studied in terms of where the game is to be played. Playing on one's home field has a distinct effect on the players; however, beating an opponent on his home field can cause players to reach new heights of effort. Also included here is the weather, which can play a key role in how the offensive unit moves against the defense. Also considered is the type of field the game is played on. Some players are more effective on natural grass, while others are better on artificial surfaces.

As indicated under both business and military planning, knowing and understanding the opposition is absolutely essential to good planning practices. In football this is also very true. Intelligence reports, in the form of scouting reports, are read and studied by the coaching staff on a weekly basis. What defenses are used by the opponent? Where are his best players positioned? How does his defense move in relation to various offensive attacks?

All these factors are studied constantly by the coach and his assistants. As new information becomes available, modifications are made, and, in the week before the game, the game plan is generated. Team practices become focused on the particular opponent and his style of play. Adjustments are made to deal with expected ploys, and the team finally enters the playing field to do battle.

2.3.3.2. Tactical Football.

At the tactical level, football has as its objective the making of 10 yards within four attempts. This allows the team to retain possession of the ball. Failure to make 10 yard will result in giving up the ball to the opponent. Without possession of the football, the coach cannot achieve the strategic objective of winning the game. Because the tactical level of planning is concerned with the specific actions needed to be taken to achieve the strategic goal, play selection becomes the paramount interest of the coach.

Using the game plan to start and, if initially successful, to continue the game, the coach modifies his thinking as the game develops. As the opponent changes, so must the coach. Every change by the opponent must be countered by the coach, or the strategic objective will slip away. Have players been moved from previously scouted positions? Has the basic defense been changed? Do they rush in situations where they were scouted to hold back? And so on.

Using his frontline troops, the players, and his assistants along the sideline and up in the booth, the coach gathers additional intelligence on the current situation. Coupling this new information with the game plan and feedback from previous actions, the coach selects the next course of action for his team. Each play selection determines the exact actions the offensive unit must perform to achieve the next portion of the tactical plan. This next portion is usually the next 10 yards of territory.

2.3.3.3. Using the Computer.

With the wealth of information kept by the coaching staff in its scouting reports, player assessments, and situational references, it seems logical to address the use of a computer to aid the planning process. As the season progresses, previous information is easily misplaced, lost, or forgotten. Being able to access this material and to use it in the formulation of game plans and in the actual selection of plays would seem to be a very real possibility.

One of the main benefits is the concept of corporate knowledge. The expert used in this paper does not keep records of previous years' efforts or results. While in itself this is no great loss, the idea that some valuable lessons may be lost and, therefore, not be available at a crucial time, could spell the difference between success and failure. Also, information on opponents from previous years, especially when the same coach returns to the job may provide just that extra insight needed to win the key game of the season.

Additionally, the computer, as a repository for a particular coach's knowledge, would certainly provide a young quarterback with a tremendously effective learning tool. With it he could run game simulations and see how his coach would handle particular situations. This could prove invaluable at times when the coach could not get the next play selection sent in to the quarterback in time.

Programmed with an opposing coach's expertise, the defensive coordinator would be able to train his players as to what to expect. This would enhance the tactical defensive play and could return the ball's possession sooner to the offensive unit.

3. Project Description.

This section of the paper describes COACH. First is described what COACH does. Secondly, we'll look at the expert philosophy that was used to build COACH. Next,the structure of the expert system is described. Finally, we will look at the specifics of COACH's implementation.

3.1. Design Overview.

COACH is a multi-file planning assistant for a high school football coach. It is a compiled C code program generated from files created using RuleMaster, an expert system shell based on example tables and Turbo C, a commercial C compiler.

3.1.1. What COACH Does.

At the strategic level COACH uses a modifiable player comparison file containing information matching offensive players' abilities against their expected defensive opponent. This file is coupled with another file containing information about the upcoming opponent which is gathered through user input using a question and answer session. This parallels the head coach's interrogation of his scouts and his reading of their scouting reports. The strategic expert system then generates a file containing the game plan. The game plan can then be displayed on the screen or printed out as hardcopy. Screen display is in the form of windows for each section.

At the tactical level, COACH uses the player comparison file, the opponent data file, and the game plan file as constraints for play selection. After the current game situation is input by the user, these files guide COACH to selection of the one to three most appropriate plays for that situation. COACH is based on a particular coach's expertise. COACH treats each situation as an isolated case rather than retain a history of preceding plays and their results. That is, COACH does not actually "play" a game. Rather it advises on each play of the game.

At the end of each portion of the system the user is asked to either continue or return to the next higher level of

Nauhl Space

the system. At the top level, exiting the system is one of the menu choices.

3.1.2. Keeping Things Reasonable.

As first envisioned, COACH was expected to be able to handle any number of defenses, opponents, and game situations. As the project developed, it was realized that certain restrictions or limitations would be required to keep the project feasible in both time and size. Conversations with the project expert led to restricting the defenses to the five most commonly found in high school football. The first three, the 5-3, the 5-2 monster, and the 4-4, are normally used during the major portion of any game, between the 10 yard line markers. The final two, the 6-5 and the 8-3, are commonly used for short yardage situations anywhere on the field and for goal line defense inside the 10 yard line.

Additionally, the 5-3 defense can have three modifications: the inside, the outside, or the headup versions. These variations position defensive players so as to strengthen particular portions of the defensive formation. (See Appendix 6.2 for additional information)

The user is allowed to "create" any number of opponents simply by answering the scouting report interrogation differently each time. Each team's characteristics are kept in a separate file under that team's name. Up to two files can be maintained for each opponent.

The game plan of Figure 4 has been reduced in size while retaining its basic form (Figure 5). The **+10 to +04** section was deleted because the expert doesn't use it. The **first 25 plays** section was changed to the **first 15 plays** section. **Special plays** was reduced to one play because the expert coach usually devises only one per opponent. The **special situations** section was deleted as these are standard plays regularly practiced and independent of the opponent played. Because the **two minute** drill is a special series of plays devised by the coaching staff to use the remaining time on the clock most efficiently, and is normally not based on scouting reports, it was eliminated. All other sections were reduced to a list of three plays for this project.

OFFENSIVE GAME PLAN		
1ST 15 PLAYS	GOALLINE	3RD AND (3-5)
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.	1. 2. 3.	1. 2. 3.
	SHORT YARDAGE	3RD AND (6-8)
	1. 2. 3.	1. 2. 3.
SPECIAL PLAYS	GOING IN	3RD AND (9+)
1.	1. 2. 3.	1. 2. 3.
	COMING OUT	
	1. 2. 3.	

FIGURE 5

Revised Cal-Mum Game Plan Worksheet

3.2. The Expert.

Much of COACH's expertise is patterned after the football philosophy of Mr. William McAlee, retired head coach of the Caledonia-Mumford (NY) High School Raiders. Mr. McAlee compiled a 114-13-1 (89.1%) record over 15 years at Cal-Mum. This makes him one of the Rochester area's winningest coaches. Other coaches have higher percentages, but none have sustained this level for the length of time Mr. McAlee has. His teams have won several league championships and have had numerous perfect or near-perfect seasons. Mr.

McAlee's style of offense is very run oriented. He uses just enough of a passing attack to open up defense to his running game. The key to Mr. McAlee's attack is the off-tackle play. If this play shows early success, he feels he has the upper hand in that particular game. Running a multiple set offense, Mr. McAlee shows several different offensive alignments to his opponents. These sets are designed to confuse the defense and/or put his offensive personnel into better positions to enhance his attack.

Additionally, he often puts a player in motion just before the snap of the ball to get one of two desired effects. It either misdirects the defense into thinking the play is going toward a particular location, or it causes a defensive player to shift his position just enough to generate a momentary weakness in the defensive alignment.

While all these factors are certainly important to game success, Mr. McAlee states that the ability to adjust during the game is absolutely essential to winning. No matter how well a coach plans before a game, it is his ability to detect an opponent's defensive modifications and, then, to correct his offensive tactics accordingly that really wins games.

Because the reader is not expected to understand all the "lingo" used in this paper, a summary of key information can be found in Appendix 6.1.

3.3. The Files.

Coach contains an opponent file, a player comparison file, the game plan file, and several files containing the expert system rule base (Figure 6). In addition there are several files which contain the prompts and do the necessary housekeeping for the system.

3.3.1. The Opponent File.

This file is created by COACH during the question and answer session in the game plan creation portion of the expert system. A separate file can be created for each team that is discussed. Using RuleMaster's concatenation function, the opponent's name is coupled with a ".dat" file extension to name the file after it is shortened to six characters. This file is then able to be opened for

reading and writing. this random access file is global to the system to eliminate the need for passing numerous variables. It contains 16 one character records which contain a number. Each of these numbers is the response to the 16 questions asked during the interrogation period of the execution of the expert system. These numbers are read from the file as needed during game plan creation and play selection.

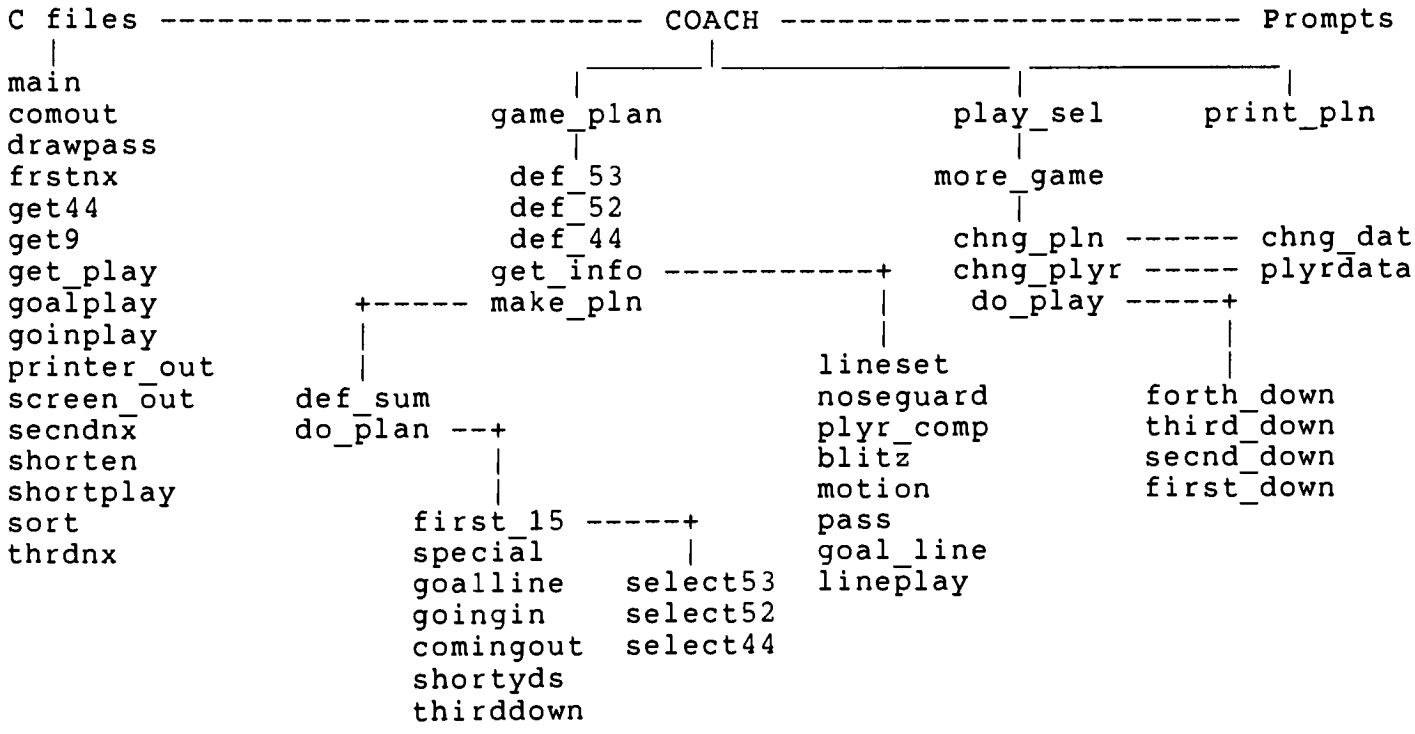

FIGURE 6

Caption

3.3.2. The Player Comparison File.

The player comparison file consists of three numbers that provide a simple comparison of various offensive team players to opponent's defensive players. During the scouting of upcoming opponents, the coaching staff watch particular defensive players to determine their abilities and capabilities. These players are compared against scheduled offensive starting players and a rating is determined. This rating can take on one of three values:

a) The offensive player is better than the defensive player (+)
b) The players are of equal talent (0)
c) The offensive player is not as good as the defensive player (-)

Numbers are generated to match the rating and then written to the random access file as follows:

1 for +
2 for 0
3 for -

Numbers were used in the file because when using RuleMaster's example tables the "-" means "any value" for the particular variable.

The offensive positions rated are:

left tackle (lt)
left guard (lg)
center (c)
right guard (rg)
right tackle (rt)

And the defensive positions rated are:

left defensive tackle (ldt)
noseguard (ng)
right defensive tackle (rdt)

Pairings are made differently for the 5-3/5-2 defenses and the 4-4 defense. The players are compared as follows:

5-3/5-2 defenses

lt vs rdt
c vs ng
rt vs ldt

4-4 defense

lg vs rdt
rg vs ldt

These numbers are written to a file created through the concatenation of the team name (again shortened) and "_player.dat".

For a play to be run successfully to a specific point on the line of scrimmage, the rating of each pair of players at that point must be "0" or "+". This indicates the fact that individual success leads to team success. For a play to succeed when the rating is "-", the formation must be such that an extra individual leads the attack at the specified point in order to assist the outmatched offensive lineman.

3.3.3. The Game Plan.

The game plan is actually a sequential file, each line representing a play. Each section of the previously described modified game plan is represented as follows:

SECTION	LINES
first 15 plays	1 - 15
special play	16
goal line	17 - 19
going in	20 - 22
coming out	23 - 25
short yardage	26 - 28
third and (9+)	29 - 31
third and (6-8)	32 - 34
third and (3-5)	33 - 36

The various sections of the game plan are not used equally, and some may not be used at all in a particular game plan. The one that will be used all the time is the **first 15 plays** section. This section is generated first using rules established by the expert. The **special play** section is generated next by simply concatenating the shortened opponent's name to the string "_specl" because this play is devised especially for the upcoming opponent and has no preconceived form. The **goal line** section is generated next and is based on the expected goalline defense. The going in, coming out, and **short yardage** sections are created next based on rules specified by the expert. The 3rd and (xx) sections are filled on the basis of what are referred to as frequency charts. These charts provide the total number of times a particular play has been run during the season and the average yardage gained per attempt. A group of files (see **3.3.5**) are hard-coded into the system to simulate these charts.

3.3.4. The Rule Base.

The "brains" of COACH are the rule base files. These files contain tables of examples that RuleMaster turned into nested IF-THEN-ELSE rules or rules written directly by the author in the specific nested IF-THEN-ELSE format. These rules are examined during the running of COACH to determine the proper action to be taken. A proper action is:

a) to read from, or write to, a file

b) to generate a game plan

c) to ask a question for further information

d) to select a play to run

The example tables, the prompts, and the particular rules were determined from over a dozen interviews with the expert coach.

3.3.5. The Data Files.

To provide input to the 3rd and (xx) sections of the game plan, several data files were written. Two sets of files

were created; one to represent early season statistics, and the other to represent late season statistics.

Each set contains one file for each basic defense mentioned earlier. These files are sorted and searched for proper plays for each section of the game plan. They are sequential files containing tuples of the form

play,average_yardage,hole/distance

where	play	=	a 15 character short description of the play (see Appendix 6.3)
	average_yardage	=	a real number with one decimal place
	hole	=	the line of scrimmage area where the running play goes
	distance	=	short (s), medium (m), or deep (d) for pass plays

The actual numbers used in the files were arbitrarily selected to provide sufficient diversity to the input to COACH.

3.3.6. The C Code Files.

Several C code files were written to perform some of the external functions needed by the expert system. Such things as sorting the data files in increasing order of average yardage, searching the data files for a play to a particular hole, retrieving the nine plays from the data files that average the most yardage, retrieving plays from the game plan for particular game situations, and generating output of the game plan to the screen or to a printer are their purposes. These files are attached to the system by RuleMaster during system creation.

3.4. Implementation.

3.4.1. The Hardware.

COACH was implemented on an IBM PC microcomputer with 640K of RAM and a 30 megabyte hard disk card. A Princeton HX-12 color monitor and a Microline 92 dot matrix printer are the output devices connected to the PC.

3.4.2. The Software.

Two commercial software packages were used to implement COACH. The first, RuleMaster, is an induction rule-based expert system shell by Radian Corporation of Texas [Radian 86]. Initially Rulemaster 2/PC was used. This was upgraded to Rulemaster 2/PCX, an enlarged version for the PC machine. Finally, a beta version of RuleMaster 3 was provided by Radian to complete the project. Turbo C, the second, is an inexpensive C compiler by Borland International Corporation for use in the PC environment [Borland 87]. Initially version 1.5 was used for the project, but version 2.0 was provided by Radian also to couple with RuleMaster 3 and the project was completed using the newer version.

3.4.2.1. RuleMaster.

RuleMaster uses a four step process to create an expert system (Figure 7). The framework file contains information about all the files which make up the expert system, which ties these files together during the assembly portion of the system creation. Induction files contain the system knowledge in the form of example tables or rules written by the knowledge engineer. Radial files are used if a computation or procedure is to be used or accessed repeatedly. There are three types of radial files. Primitive files create links to external programs or functions. Generic storage files create a data structure. Primitive generic storage files create links to external data structures. During the assembly phase of expert system creation, RuleMaster generates a radial file for each induction file in existence. In the generate portion, C source code is created. This faster-running code also allows the use of external functions. Upon compilation of the source code,

libraries are linked to the object code and an executable expert system comes into being. Prompt files are written by the knowledge engineer to provide simple English questions to the user for obtaining responses. Backup files are created by RuleMaster as a safety device for the programmer.

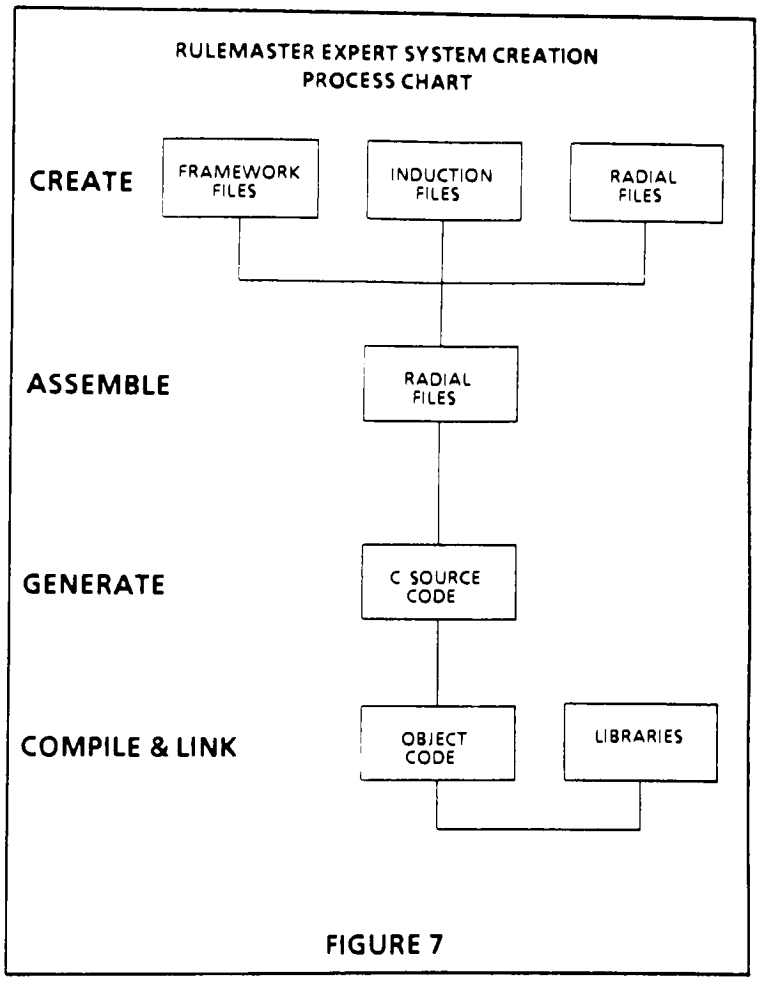

FIGURE 7

3.4.2.2. Turbo C.

The selection of Turbo C was based solely on Borland's reputation for efficient and successful language compilers for PC machines. Their PASCAL, PROLOG, and BASIC compilers have all been very successful in providing programmers with satisfactory environments in which to work. Additionally, Turbo C was inexpensive when compared to other C compilers (about 25% of their cost). Radian Corporation initially provided a run-time library for RuleMaster 2 to insure compatibility with Turbo C.

3.4.3. System Creation.

COACH was created from the transcribed notes of the interviews with the expert. These notes were examined for explicit, as well as implicit, rules which contained Mr. McAlee's approach to the game of high school football.

The project was divided into two distinct parts; development of the game plan, and selection of plays during the game. The first part required the determination of the fewest specific questions needed to fully describe the upcoming opponent's defensive strategy. For the second part it was desired to use as much previously determined information as possible, and only ask for a minimum of additional information.

A third menu choice at COACH's top level allows the user to view any game plan currently on file. This lets the user see pertinent information easily without having to completely execute one portion of the system first.

Knowledge acquisition "war stories?"

3.4.3.1. Game Plan Creation.

As previously mentioned, the game plan is created using two files which are created as the expert system executes. The first file is the .dat file which contains the answers to 16 questions posed during COACH's initial phase. The second file is the _player.dat file which contains the previously described three answers to the player comparison questions.

The 16 questions are:

1) What is the basic defense expected ?

This gets one of the three basic defenses known to COACH. Either 5-3, 5-2, or 4-4.

2) How do the inside linebackers play ?

If the defense is the 5-3 or the 5-2, this question is not asked and an N/A response is stored. If the 4-4 is being used, one of two choices, inside or outside the defensive tackles is selected.

3) How do the outside linebackers play ?

Similar to Question 2, N/A is generated for the 5-3 and 5-2 defenses. The 4-4 generates either inside, outside, or stacked behind the tackles.

4) How do the defensive tackles play ?

In all three defenses it is desirable to know where the defensive tackles play. The three choices are inside of, outside of, or headup on, the offensive tackles.

5) How does the noseguard play ?

In the 5-3 and 5-2 defenses there is an odd man front. The center man in this alignment is the noseguard. We want to know where he plays in relation to the offensive center, so the three choices are left, right, or headup on, the center. N/A is generated for the 4-4 defense.

6) Which way does the noseguard normally shoot ?

After placing the noseguard, we want to know which way he attacks the line of scrimmage. It is assumed that if the noseguard is playing to the left of the offensive center, he will attack right. Similar logic applies to a noseguard who plays to the center's right. If the noseguard normally plays headup on the center, this question is asked in order to provide the noseguard's tendency to attack in a particular direction (left,right,both).

7) Does the defense blitz its linebackers and how do they blitz ?

If the answer to this question reveals that the defense does not normally blitz, then Questions 8 and 9 are not asked and the file receives an N/A indicator. The other two choices here are that the linebackers loop around the

outside to blitz or they shoot straight into the backfield. Each of these defensive tendencies will lend itself to a particular offensive style of play.

8) On which down are they most likely to blitz ?

If the defense blitzes, we want to know when to expect them to do so. Most defenses will tend to blitz on a certain down and yardage situation fairly consistently, so we ask these questions.

9) How many yards are normally needed on that down ?

Yardage needed for the first down is the second factor to be considered by blitzing defenses. The normal choices here are short, less than three yards; medium, four to seven yards; and, long, eight or more yards.

10) Who moves to motion ?

Next we want to know if the defense is susceptible to movement by the offense. If the defense doesn't normally pay attention to a man in motion, N/A is entered here. If they follow any motion, we want to know which defensive players do so. The choices here are the linebackers only, the defensive linemen only, or both the linebackers and linemen together.

11) Does the secondary rotate in the direction of any motion ?

We also want to know if the defense rotates its secondary personnel in the direction of any motion. This again may open up an area of the playing field to attack. Answers here are yes or no.

12) Who covers the split end or slot man ?

In the 5-2 defense, the monster man has responsibility for wide coverage. In the other two defenses, however, responsibility is assigned to either the defensive end or the outside linebacker on that side of the field.

13) What pass coverage is used in the secondary ?

Each of the pass coverages allowed here (man-to-man and zone) have weaknesses. The man-to-man can create mismatched personnel and provide advantages if the proper mismatch can be generated. The zone defense has dead areas on the field due to their being on the boundaries between player's responsibilities. These can be taken advantage of with particular pass patterns.

14) Which goal line defense do they normally use ?

COACH recognizes two basic short yardage, or goal line, defenses, the 8-3 and the 6-5. Again, each requires a particular style of attack to be beaten.

15) How do the defensive ends play ?

If the defensive ends crash, they can be run around rather easily. If they box, then running inside is a good idea. If they hold their position and wait for the play to develop, they are susceptible to being blocked in a direction other than one in which they wish to move.

16) How does the defensive line play ?

Similarly, the defensive line offers opportunities depending on whether they penetrate the line of scrimmage or wait in their positions for the play to develop.

Once these questions are answered, COACH provides a generalized game plan to the user in the form of short statements which indicate generic plays or offensive strategies to use for the expected defense. This information is from examples selected using the 16 answers provided.

The user is then asked if it is early or late in the season, so that COACH can use the correct play frequency chart.

Using the .dat, _player.dat, and the proper frequency chart, COACH uses its next series of files (which contain the play selection rules) to generate the sections of the game plan. As each section is created, a message is output to the screen to keep the user abreast of the current execution status.

Upon completion, the user is told the game plan is ready, and is provided a print menu which allows viewing the game plan on the screen or sending the plan to an attached printer. Exiting to the main menu is also an option on this menu.

3.4.3.2. Play Selection.

The second part of COACH deals with selection of a play or plays from the game plan after the system knows particulars about the current game situation. This part is also divided

into two parts: the first eight plays of the game, and the rest of the game.

Each game plan contains a series of eight plays which will be run by the offense during the early stages of the game. These plays are designed to test the defense. They are selected to discover whether the defense has changed from when they were scouted or if they play as scouted. These plays are the first eight plays of the **first_15** section of the game plan.

If a play is to be selected, the user is asked if it is one of the first eight plays of the game. If it is, the user is asked which one in particular, and then is provided with that play.

If the user indicates that the play to be selected is for other than one of the first eight plays, COACH asks if the defense is playing as expected. If not, the user is given a brief summary of the scouting report and then allowed to change the contents of the .dat file.

If the defense is playing as expected, or after any changes to the .dat file have been made, the user is asked if the key player personnel (upon which the earlier comparisons were based) are the same as expected. If any key personnel have changed, the user is allowed to correct the comparison and reflect that correction in the **_player.dat** file.

At this point, it should be pointed out that the game plan does not change. The changes mentioned above allow for the adjustments critical to Mr. McAlee's success. They affect only play selection not game plan.

It should further be pointed out that this ability to change currently stored data is where the departure from normal game playing techniques occurs. Here, the playing pieces can actually change their relative strengths and the inputs to the decision making process are varied accordingly.

After any changes are made, the user is asked for the current game situation. Here the user is required to input the current down, yards to go for a first down, quarter of play, location of the ball consisting of the yardline and which end of the field the ball is in, and the scores of each of the two teams.

Using this information, COACH goes into the appropriate module to select the play or plays from the proper section

of the game plan. In some instances, COACH will provide an additional one to three plays if the user so desires.

After providing the play(s), COACH returns to the play selection menu to allow the user to continue with the same game plan, change to a different game plan, or exit to the main menu.

3.5. Testing.

To determine if COACH had reached any level of sophistication, three game plans were built, one using each major defense. The inputs used are listed in Appendix 6.4. This tested the system's ability to generate different game plans based on varied scouting reports. The expert reviewed each game plan and determined them to be appropriate for the inputs used.

To test play selection, each game plan was provided with several game situations (the same for each). The expert was provided with the list of plays selected by the system and judged them to be appropriate for the particular situation and opponent.

4. Conclusions.

4.1. Game Plan Generation.

Each of the strategic level sample data was provided to the system and three game plans were generated (see Appendix 6.4). These were presented to the expert who validated them as being representative of the possible game plans that could be devised against the defenses described.

Each game plan provided sufficient diversity to enable the expert's offense to attack the proposed defense successfully. Mr. McAlee commented that the plans were surprisingly accurate in following his basic philosophy and style of play.

4.2. Play Selection.

Each game plan was then provided the tactical level inputs of Appendix 6.5. These inputs generated the indicated outputs, which met with the expert's approval. Mr. McAlee again expressed agreement with the overall philosophy of the choices and even commented that in each case, at least one of the selected plays was the one he would have chosen.

4.3. Overall Conclusions.

In general, COACH performed above expectations. Early on in the creation process, it was felt that this system would achieve some of its goals in a somewhat mediocre fashion. It was also felt, by the author in particular, that COACH would be too slow to be of use during an actual game. As shown, COACH provides both reasonably good game plans for the tested opponents and proper selected plays which agreed with the expert's philosophy in particular situations. Additionally, COACH functions quickly enough to provide possible use on the sidelines during an actual game.

4.4. Future Enhancements.

This expert system ~~has a~~ shows great ~~deal of possibilities~~ potential for further research. Establishing a system "memory" to keep up with an ongoing game and to only ask questions as needed would make it a valuable tool for sideline use.

Also, building in additional defenses or creating a subsystem for creation of rules for additional defenses would also increase its useability. Additional defenses would also improve COACH's flexibility.

Ideally, the rule base for COACH would be expanded to the point that each play in the expert's repertoire would be represented by some particular combination of the 16 answers to the scouting report, the three player comparisons, and the seven game situation factors. This would also require the addition of a resolution rule base to handle conflicts. This would enable COACH to provide one specific play rather than three or more as it currently does.

Also, a capability to maintain the play frequency chart during the season would be beneficial. This would allow COACH to have up-to-date information for the creation of game plans and for the selection of plays during a game. This utility would be used immediately after a game had been played and before the next scheduled contest.

5. Bibliography.

[Adcock 57] Adcock, F. E., The Greek and Macedonian Art of War, University of California Press, Berkely, CA, 1957.

[Allen 70] Allen, George, Inside Football, Allyn and Bacon, Inc., Boston, MA, 1970.

[Andriole 86] Andriole, S. J., The Design and Development of an Intelligent Planning Aid, U. S. Army Research Institute for the Behavioral and Social Sciences, 1986.

[Andriole, et. al. 86] Andriole, Stephen J., Harlan H. Black, Gerald W. Hopple, and John R. Thompson, *Intelligent Aids for Tactical Planning, IEEE Transactions on Systems, Man, and Cybernetics*, Vol SMC-16, No 6, Nov/Dec 1986, pp 854 - 864.

[Argenti 69] Argenti, John, Corporate Planning: A Practical Guide, Dow Jones-Irwin, Inc., Homewood, IL, 1969.

[Argenti 74] Argenti, John, Systematic Corporate Planning, Halsted Press, London, England, 1974.

[Back 87] Back, J. F., et. al., Artificial Intelligence: Expert Systems for Corps Tactical Planning and Other Applications, U. S. Army War College, Carlisle Barracks, PA, 1987.

[Barr 81] Barr, Avron and Edward A. Feigenbaum, eds., The Handbook of Artificial Intelligence, Vol I, William Kaufman, Inc., Los Altos, CA, 1981.

[Bogue 86] Bogue, Marcus C. III and Elwood S. Buffa, Corporate Strategic Analysis, The Free Press, New York, NY, 1986.

[Borland 87] Borland International, Inc., Turbo C Reference Guide, Scotts Valley, CA, 1987.

[Branch 66] Branch, Melville C., Planning: Aspects and Application, John Wiley & Sons, New York, 1966.

[Buchan 70] Buchan, Alastair, ed., Problems of Modern Strategy, Praeger Publishers, New York, NY, 1970.

[Callero 86] Callero, Monti D., Donald A. Waterman, and James R. Kipps, *TATR: A Prototype Expert System for Tactical Air Targeting,* in [Klahr 86], pp 186 - 223 .

[Charniak 85] Charniak, Eugene and Drew McDermott, Introduction to Artificial Intelligence, Addison-Wesley Publishing Company, Reading, MA, 1985.

[Chorafas 86] Chorafas, Dimitris N., Applying Expert Systems in Business, McGraw-Hill Book Company, New York, NY, 1986.

[Clancey 87] Clancey, William J., Knowledge - Based Tutoring, The MIT Press, Cambridge, MA, 1987.

[Coursey 87] Coursey, David, *For the Dallas Cowboys, Computers Score Points,* MIS Week, October 12, 1987, pg 29.

[Crego 86] Crego, Edwin T., Jr., Brian Deaton, and Peter D. Schiffrin, How to Write a Business Plan, American Management Association, 1986.

[Croft 85] Croft, D., *Choice Making in Planning Systems,* in [Merry 85], pp 125 141.

[Currie 85] Currie, Ken and Austin Tate, *O-Plan - Control in the Open Planning Architecture,* in [Merry 85], pp 225 - 240.

[Cushman 86] Cushman, John H., *Strategic Planning in the Military,* in [Gardner 86], pp 26.1 26.20.

[Dresher 61] Dresher, Melvin, Games of Strategy, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1961.

[Dudick 83] Dudick, Thomas S. and Robert V. Gorski, eds., Handbook of Business Planning and Budgeting For Executives with Profit Responsibility, Van Nostrand Reinhold Company, New York, NY, 1983.

[Dudick 83] Dudick, Thomas S., *Analysis of Company Weaknesses (A Case Example),* in [Dudick 83], pp 350 - 357.

[Eden 86] Eden, Colin, Huw Williams, and Tim Smithin, *Synthetic Wisdom: The Design of a Mixed Mode Modelling System for Organizational Decision Making*, Journal of the Operational Research Society, Vol 37, No 3, 1986, pp 233 - 241.

[Espy 86] Espy, Siri N., Handbook of Strategic Planning for Nonprofit Organizations, Praeger Publishers, New York, NY, 1986.

[Ewing 68] Ewing, David W., The Practice of Planning, Harper and Row, New York, NY, 1968.

[Fry 86] Fry, Joseph N. and J. Peter Killing, Strategic Analysis and Action, Prentice-Hall, Inc., New York, NY, 1986.

[Gardner 86] Gardner, James R., Robert Rachlin, and H. W.Sweeny, eds., Handbook of Strategic Planning, John Wiley & Sons, New York, NY, 1986.

[Gevarter 84] Gevarter, William B., Artificial Intelligence, Expert Systems, Computer Vision, and Natural Language Processing, Noyes Publications, Park Ridge, NJ, 1984.

[Glaser 75] Glaser, Daniel, Strategic Criminal Justice Planning, National Institute of Mental Health, Center for Studies of Crime and Delinquency, Rockville, MD, 1975.

[Goul 86] Goul, M., Barry Shane, and Fred M. Tonge, *Using a Knowledge-based Decision Support System in Strategic Planning Decisions: An Empirical Study*, Journal of Management Information Systems, Vol 2, No 4, Spring 1986, pp 70 - 84.

[Grant 82] Grant, John H. and William R. King, The Logic of Strategic Planning, Little, Brown, and Company, Boston, MA, 1982.

[Hakong 85] Hakong, L. and F. R. Hickman, *Expert Systems: An Application in Statistics,* in [Merry 85], pp 45 - 63.

[Handler 85] Handler, James A., ed., Expert Systems: The User Interface, Ablex Publishing Corporation, Norwood, NJ, 1985.

[Hart 86] Hart, Anna, Knowledge Acquisition for Expert Systems, McGraw-Hill Book Company, New York, NY, 1986.

[Hausrath 71] Hausrath, Alfred H., Venture Simulation in War, Business, and Politics, McGraw-Hill Book Company, New York, NY, 1971.

[Hayes-Roth 85] Hayes-Roth, Frederick, *Rule - Based Systems*, Communications of the ACM, Vol 28, Number 9, September, 1985, pp 921 - 932.

[Hind 83] Hind, James F., *The Six-Step Planning Process*, in [Dudick 83], pp 124 - 127.

[Horowitz 70] Horowitz, Irving Louis, *Deterrence Games: From Casebook to Military Codebook*, in [Swingle 70], pp 277 - 296 .

[Hunt 86] Hunt, V. Daniel, Artificial Intelligence and Expert Systems Source-book, Chapman and Hall, New York, NY, 1986.

[Kaiser 78] Kaiser, Kate, *Applying Artificial Intelligence to Strategic Planning*, Proceedings of the 10th Annual Conference of the American Institute for decision Sciences, 1978, pp 230 - 232.

[Kaufmann 67] Kaufmann, A., Graphs, Dynamic Programming, and Finite Games, Academic Press, New York, NY, 1967.

[King 86] King, William C., *Formulating Strategies and Contingency Plans*, in [Gardner 86], pp 6.1 - 6.30.

[Klahr 86] Klahr, Philip and Donald A. Waterman, eds., Expert Systems: Techniques, Tools, and Applications, Addison-Wesley Publishing Company, Reading, MA, 1986.

[Kline 85] Kline, Paul J. and Steven B. Dolins, Choosing Architectures for Expert Systems, Rome Air Development Center, Griffis Air Force Base, NY, 1985.

[Lauenstein 86] Lauenstein, Milton C., What's Your Game Plan?, Dow Jones-Irwin, Inc., Homewood, IL, 1986.

[LeBreton 61] LeBreton, Preston P. and Dale A. Henning, Planning Theory, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1961.

[Levine 87] Levine, P., J. Ch. Maillard, and J. Ch. Pomerol, *DECIDEX, A Multi - Expert System for Strategic Decisions*, in [Sol 87], pp 247 - 255.

[Levine 86] Levine, Robert I., et. al., A Comprehensive Guide to AI and Expert Systems, McGraw-Hill Book Company, New York, NY, 1986.

[Liddell Hart 67] Liddell Hart, B. H., Strategy, Praeger Publishers, New York, NY, 1967.

[Liu 83] Liu, Yunfeng, and Zhu Jianjing, *Intelligence System and Football Game*, 1983 Proceedings of the International Conference on Systems, Man and Cybernetics, Vol 1, 1983, pp 506 - 509.

[Lorange 82] Lorange, Peter, Implementation of Strategic Planning, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1982.

[Luttwak 85] Luttwak, Edward N., Strategy and History, Transaction Books, New Brunswick, NJ, 1985.

[May 70] May, Francis B., Introduction to Games of Strategy, Allyn and Bacon, Inc., Boston, MA, 1970.

[Mayer 85] Mayer, Robert R., Policy and Program Planning: A Developmental Perspective, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1985.

[McGee 86] McGee, John and Howard Thomas, eds., Strategic Management Research: A European Perspective, John Wiley & Sons, Chichester, England, 1986.

[Mellish 85] Mellish, C. S., *Generalised Alpha-beta Pruning as a Guide to Expert System Question Selection,* in [Merry 85], pp 31 - 41.

[Merry 85] Merry, Martin, ed., Expert Systems 85, Cambridge University Press, Cambridge, England, 1985.

[Merry 85] Merry, Martin, *Expert Systems - Some Problems and Opportunities,* in [Merry 85], pp 1 7

[Moser 87] Moser, Jorge and Richard Christoph, *Management Expert Systems (M.E.S.): A Framework for Development and Implementation,* Information Processing & Management, Vol 23, No 1, 1987, pp 17 - 23.

[Negoita 87] Negoita, Constantin V. and Dan Ralescu, Simulation, Knowledge-based Computing, and Fuzzy Statistics, Van Nostrand Reinhold Company, New York, NY, 1987.

[NFL 73] NFL Properties, Inc., NFL Playbook, 1973.

[Palmer 86] Palmer, James D. and Peter H. Aiken, *Normative Computer - Aided Strategic Planning for Large Organizations*, Proceedings of the 1986 IEEE International Conference on Systems, Man and Cybernetics, Vol 2, 1986, pp 1403 - 1409.

[Peacock 84] Peacock, William E., Corporate Combat, Facts on File Publications, New York, NY, 1984.

[Radian 87] Radian Corporation, RuleMaster Reference Manual, Austin, TX, 1987.

[Rapoport 60] Rapoport, Anatol, Fights, Games, and Debates, University of Michigan Press, Ann Arbor, MI, 1960.

[Reichgelt 85] Reichgelt, Han and Frank van Harmelen, *Relevant Criteria for Choosing an Inference Engine in Expert Systems*, in [Merry 85], pp 21 - 30.

[Rothschild 76] Rothschild, William E., Putting It All Together: A Guide to Strategic Planning, AMACOM, New York, NY, 1976.

[Sackman 72] Sackman, Harold and Ronald L. Citrenbaum, eds., Online Planning: Towards Creative Problem Solving, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1972.

[Sammon 86] Sammon, William L., *Assessing the Competition: Business Intelligence for Strategic Management*, in [Gardner 86], pp 4.1 - 4.48.

[Simerly 87] Simerly, Robert G. and Associates, Strategic Planning and Leadership in Continuing Education, Jossey-Bass Publishers, San Francisco, CA, 1987.

[Slagle 85] Slagle, James R. and Henry Hamburger, *An Expert System for a Resource Allocation Problem*, Communications of the ACM, Vol 28, No 9, Sept 1985, pp 994 - 1004.

[Sol 87] Sol, H. G., et.al., eds., Expert Systems and Artificial Intelligence in Decision Support Systems, D. Reidel Publishing Company, New York, NY, 1987.

[Steiner 69] Steiner, George A., Top Management Planning, The MacMillan Company, New York, NY, 1969.

[Stringer 86] Stringer, Robert A., Jr. with Joel L. Uchenick, Strategy Traps and How to Avoid Them, Lexington Books, Lexington, MA, 1986.

[Sullivan 71] Sullivan, George, Pro Football Plays in Pictures, Gasset and Dunlap, New York, NY, 1971.

[Swingle 70] Swingle, Paul, ed., The Structure of Conflict, Academic Press, New York, NY, 1970.

[Tachmindji 86] Tachmindji, Alexander J. and Edward L. Lafferty, *Artificial Intelligence for Air Force Tactical Planning*, Signal, June 1986, pp 110 - 114.

[Tallman 69] Tallman, Drew, Directory of Football Defenses: Successful Defenses and How to Attack Them, Parker Publishing Company, Inc., New York, NY, 1969.

[Tate 85] Tate, Austin, *A Review of Knowledge Based Planning Techniques*, in [Merry 85], pp 89 - 111 .

[Taylor 83] Taylor, James W., *Ten Commandments for Realistic Planning*, in [Dudick 83], pp 44 - 50.

[Tourangeau 81] Tourangeau, Kevin W., Strategy Management: How to Plan, Execute and Control Strategic Plans for Your Business, McGraw-Hill Book Company, New York, NY, 1981.

[VanMelle 80] VanMelle, William J., System Aids in Constructing Consultation Programs, UMI Research Press, Ann Arbor, MI, 1980.

[Waterman 86] Waterman, Donald A., A Guide to Expert Systems, Addison-Wesley Publishing Company, Reading,MA, 1986.

[Williams 66] Williams, J. D., The Compleat Strategyst, McGraw-Hill Book Company, New York, NY, 1966.

[Wilson 68] Wilson, Andrew, The Bomb and the Computer, Delacorte Press, New York, NY, 1968.

6. Appendices.

6.1. Football Terminology.

Here is a list of the football terms used throughout this paper. It does not cover every possible term used in the game, but only those which help to clarify portions of this paper.

Line of scrimmage horizontal line on the playing field on whiich the ball lies; separates the offensive portion of the field from the defensive protion.

Line - the offensive or defensive personnel on the line of scrimmage.

Linebackers - second level of defensive players; normally deployed from two to four yards off the line of scrimmage.

Secondary third level of the defense; consists of cornerbacks, halfbacks, and/or safeties deployed from five to 20 yards off the line of scrimmage.

Blitz - the movement of one or more linebackers across the line of scrimmage at the snap of the ball.

Audible - the changing of the play called in the huddle at the line of scrimmage just before the ball is snapped.

Play action - plays in which the quarterback fakes a running play into the middle of the line and either passes or pitches the ball instead.

Option - play in which the quarterback or the running back has a choice to either run or pass the football.

Trap - running play in which a pulling offensive lineman blocks a penetrating defensive lineman.

6.2. DEFENSIVE AND OFFENSIVE ALIGNMENTS.

On the following pages are several diagrams which picture the offensive and defensive alignments mentioned in this paper. Additionally, the hole numbering scheme for play calling and some pass patterns are shown for reference.

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5-3 INSIDE DEFENSE

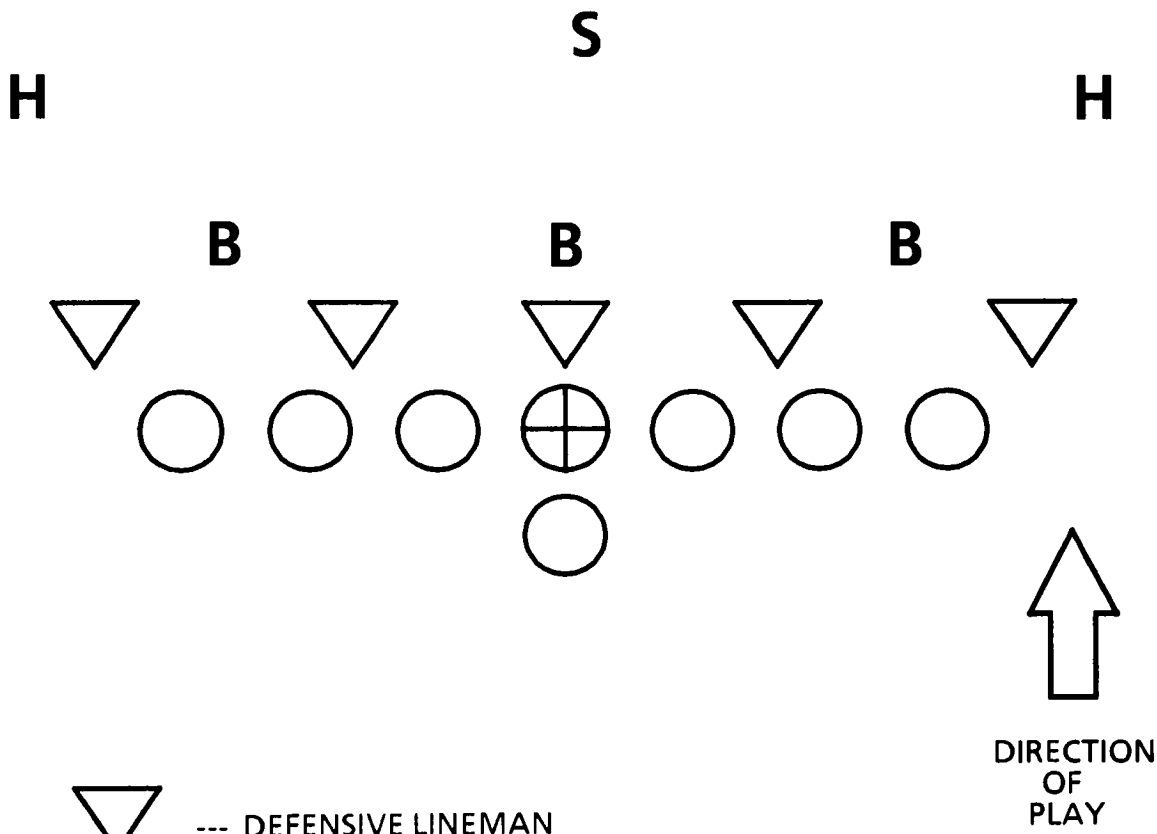
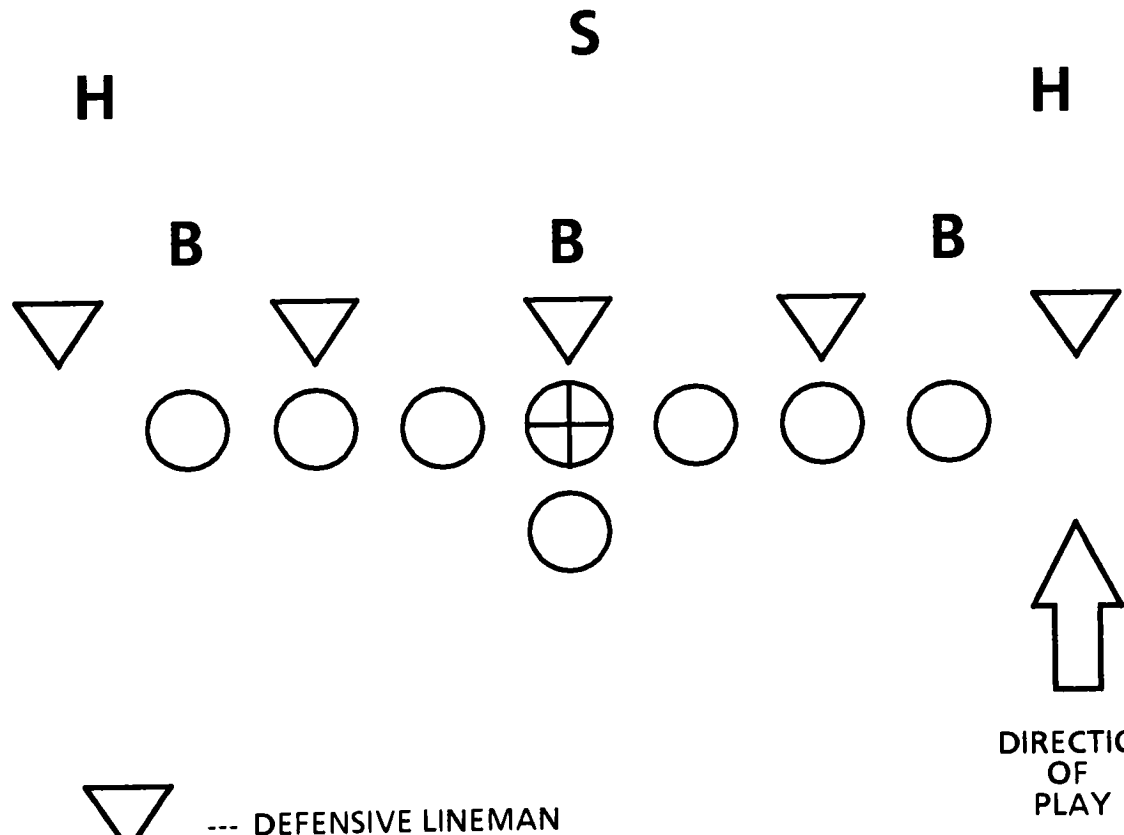


FIGURE 6-1

5-3 HEADUP DEFENSE



▽ --- DEFENSIVE LINEMAN

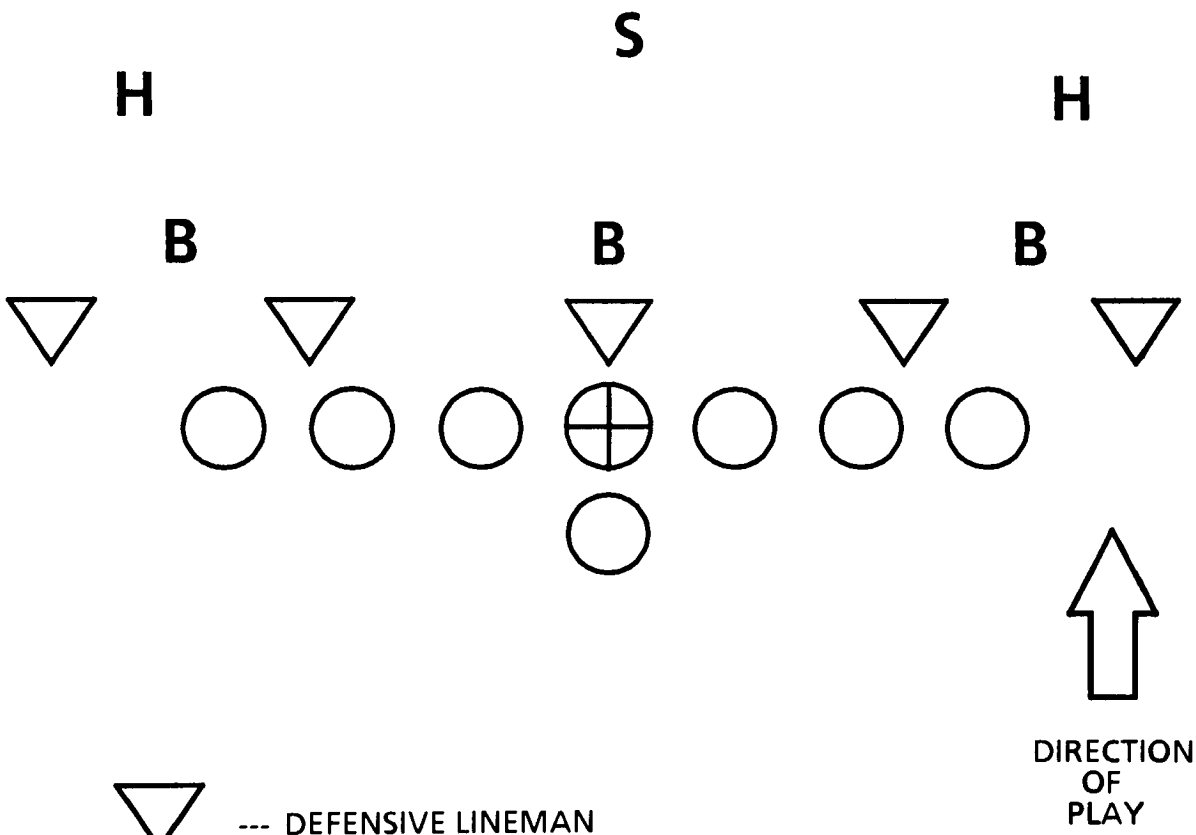
B --- LINEBACKER

H --- DEFENSIVE HALFBACK

S --- SAFETY

FIGURE 6-2

5-3 OUTSIDE DEFENSE



--- DEFENSIVE LINEMAN

B --- LINEBACKER

H --- DEFENSIVE HALFBACK

S --- SAFETY

FIGURE 6-3

5-2 MONSTER DEFENSE

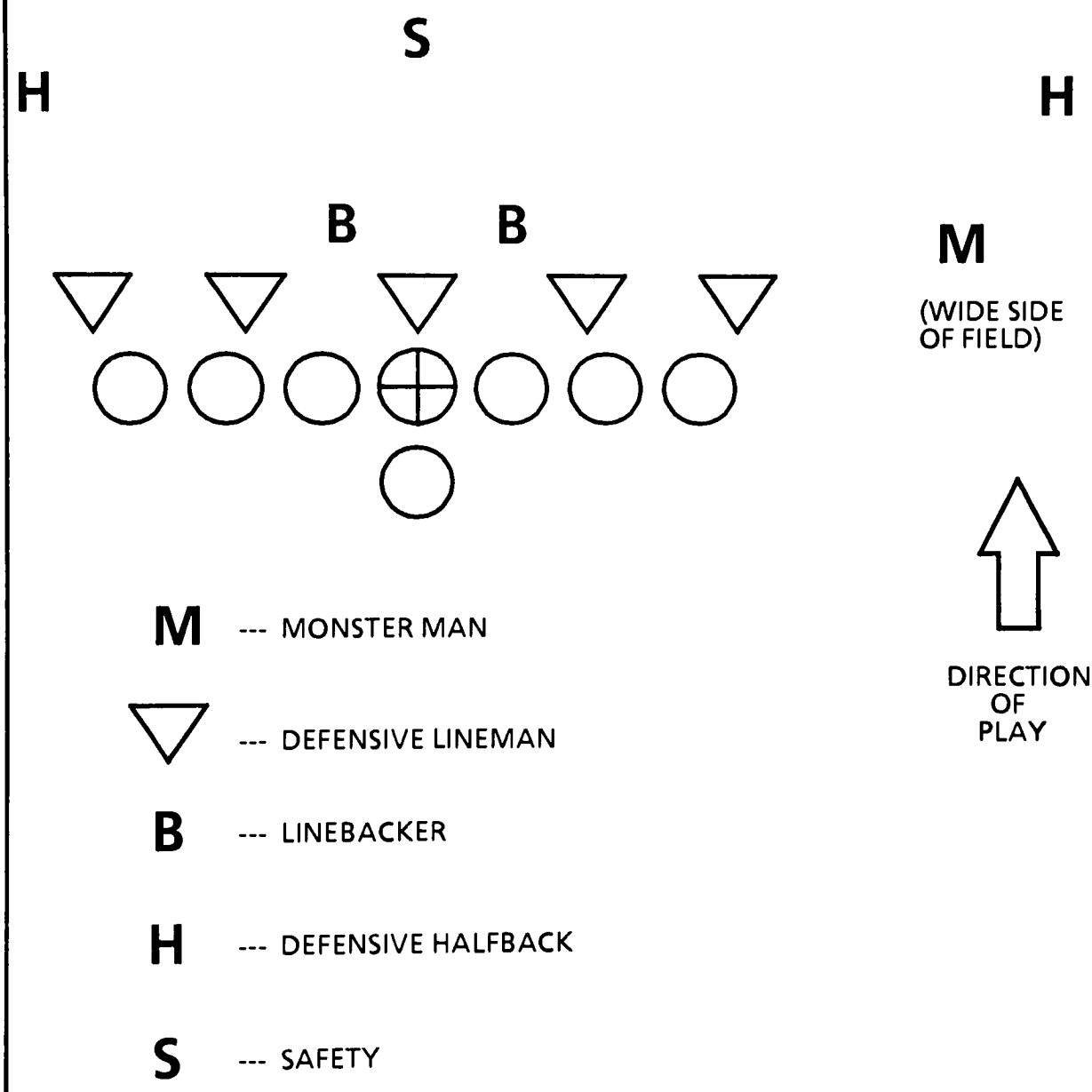


FIGURE 6-4

STANDARD 4-4 DEFENSE

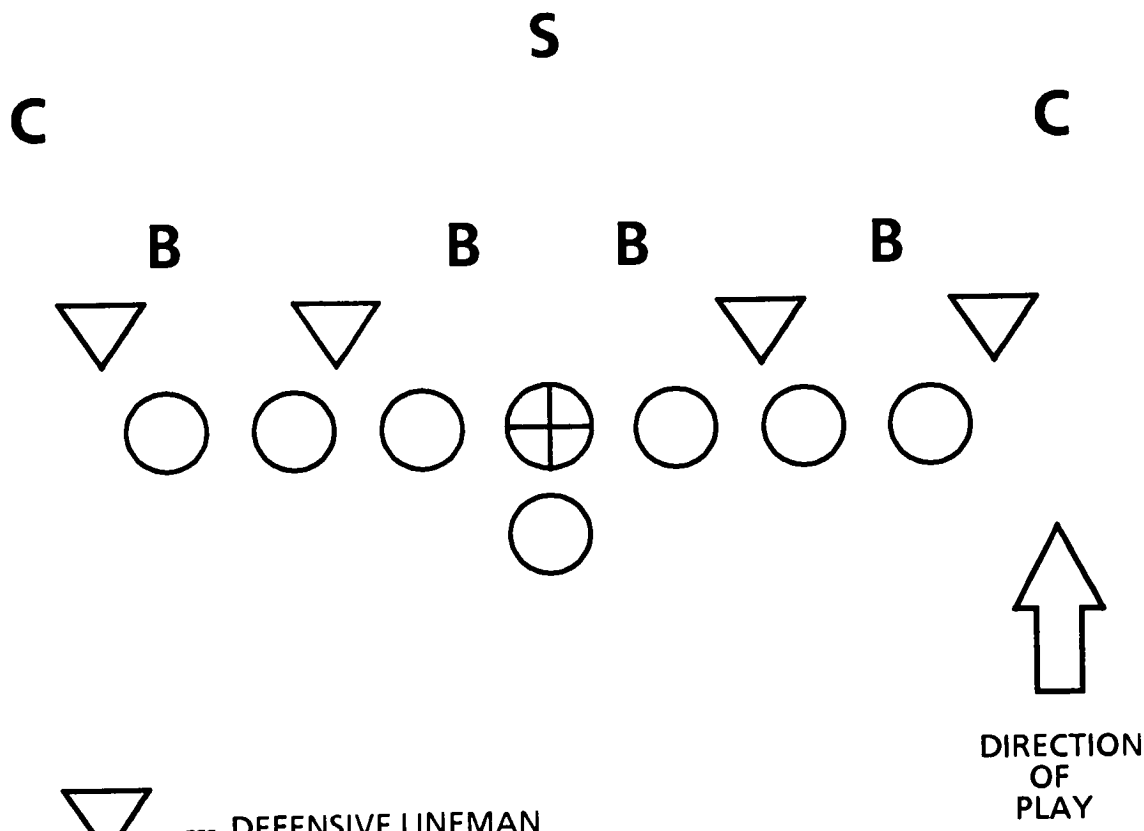
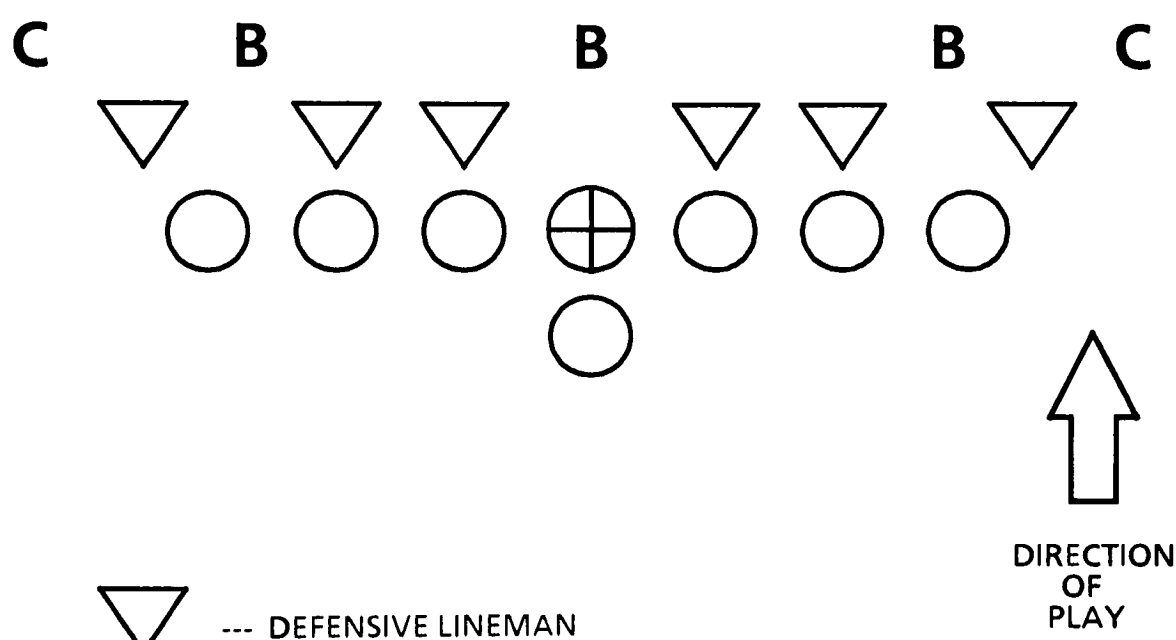


FIGURE 6-5

STANDARD 6-5 DEFENSE



--- DEFENSIVE LINEMAN

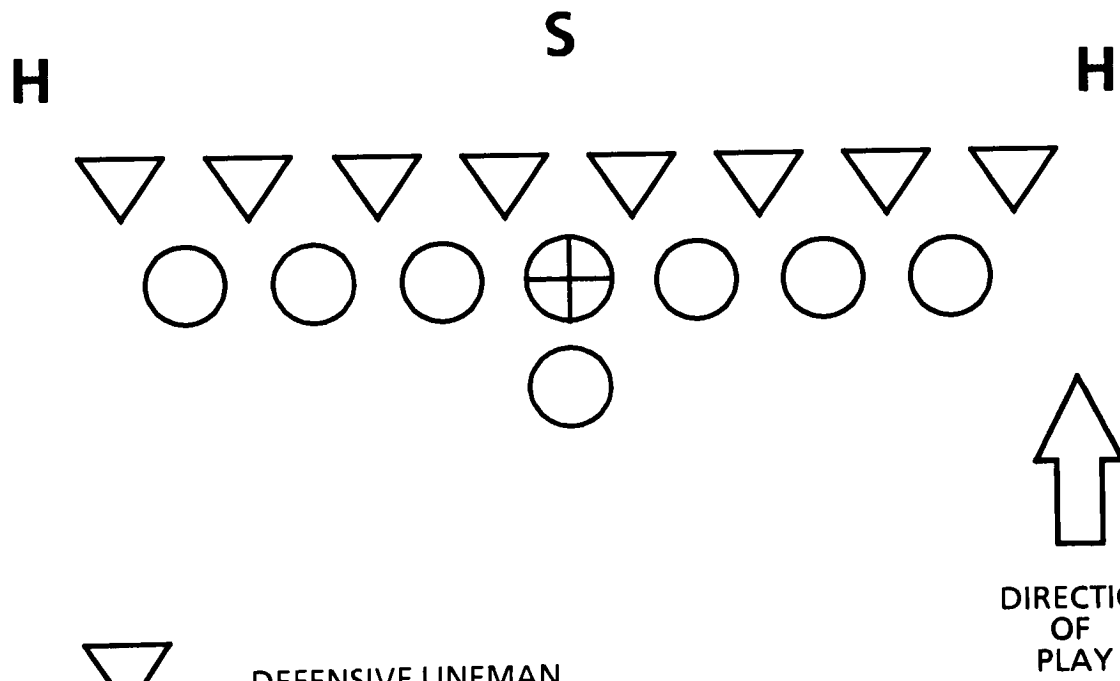
B --- LINEBACKER

C --- CORNERBACK

S --- SAFETY

FIGURE 6-6

STANDARD 8-3 DEFENSE



--- DEFENSIVE LINEMAN

H --- DEFENSIVE HALFBACK

S --- SAFETY

FIGURE 6-7

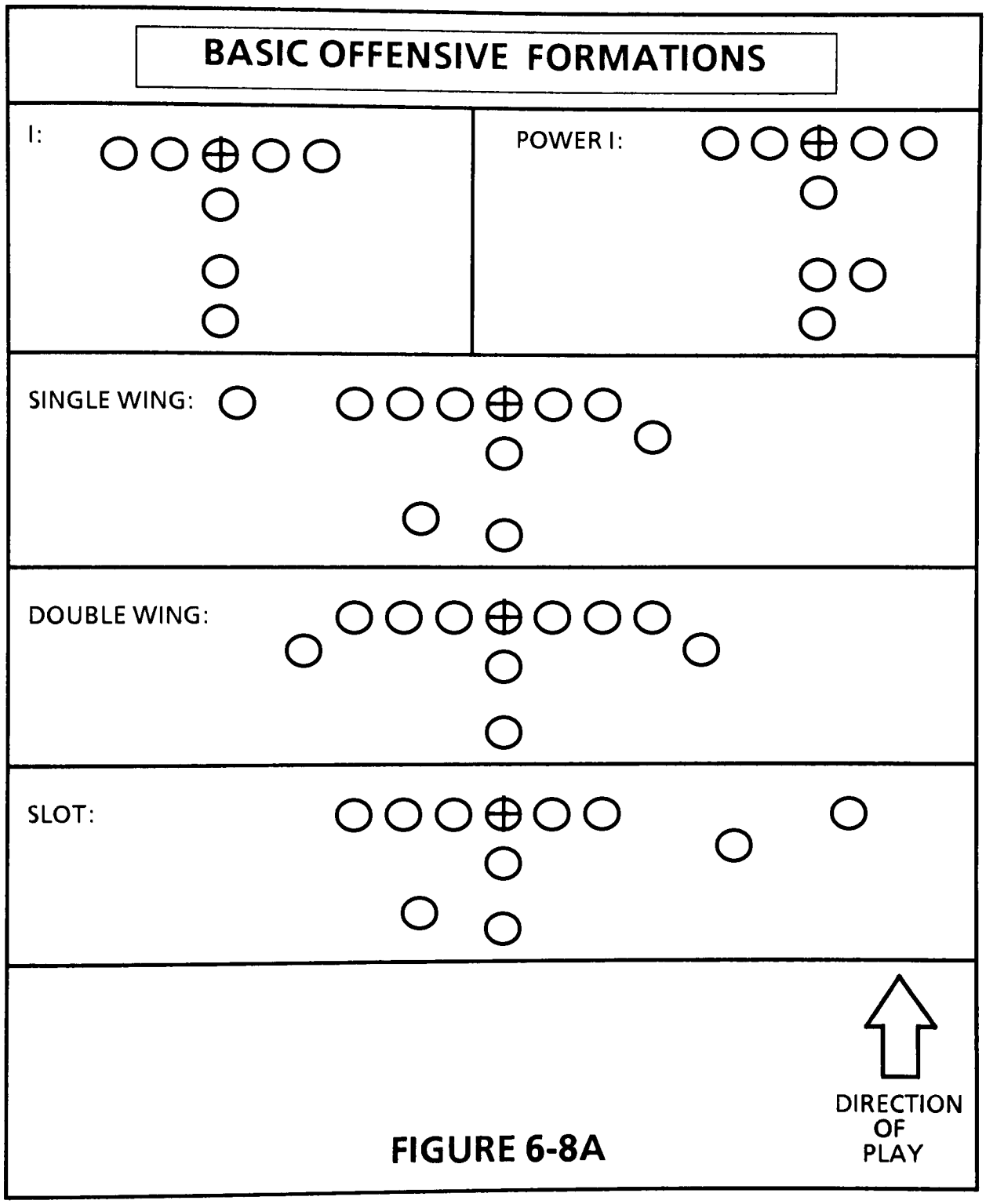

BASIC OFFENSIVE FORMATIONS
I:
POWER I:
SINGLE WING:
DOUBLE WING:
SLOT:
DIRECTION OF PLAY

FIGURE 6-8A

BASIC OFFENSIVE FORMATIONS (CONT)

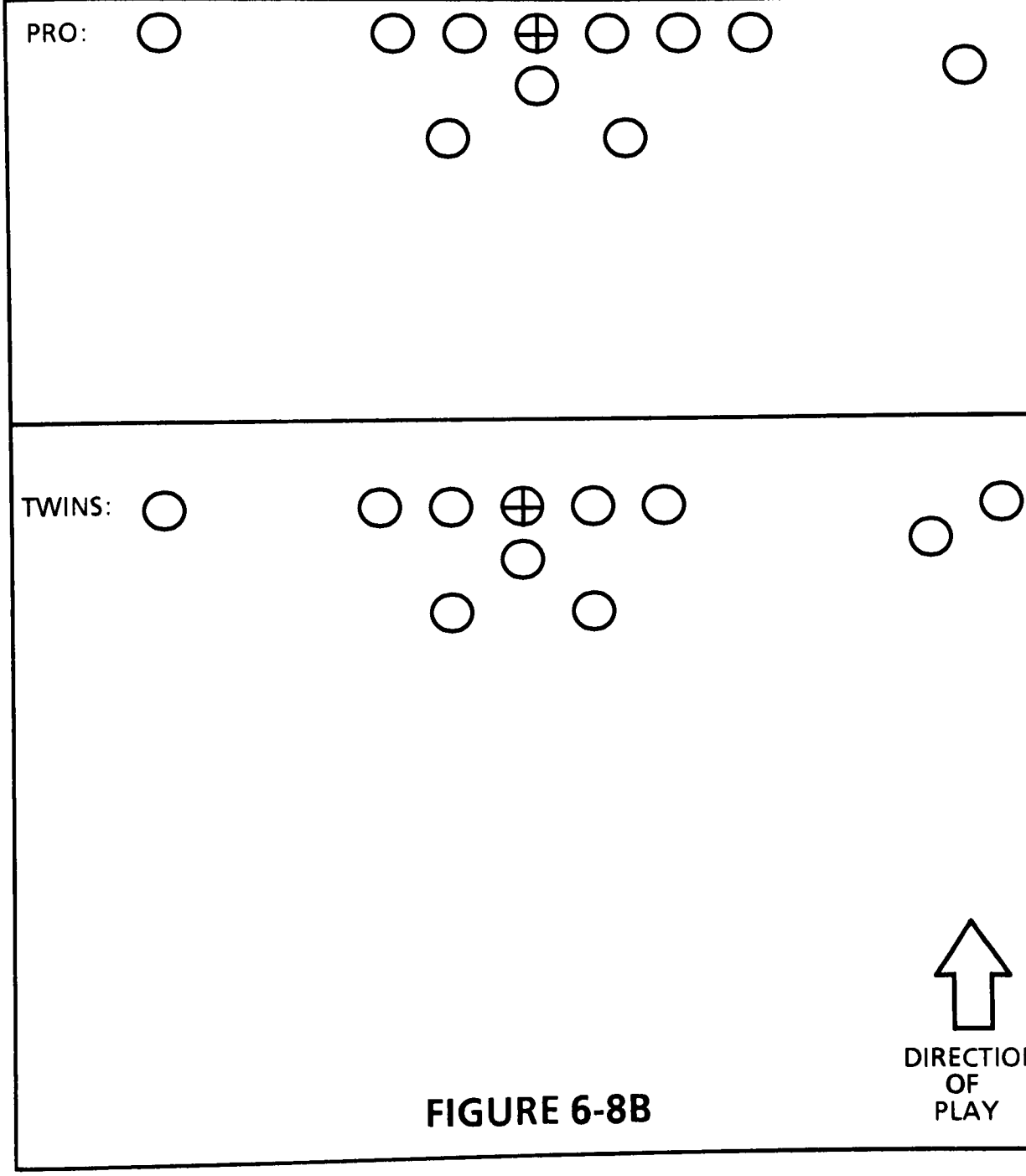


FIGURE 6-8B

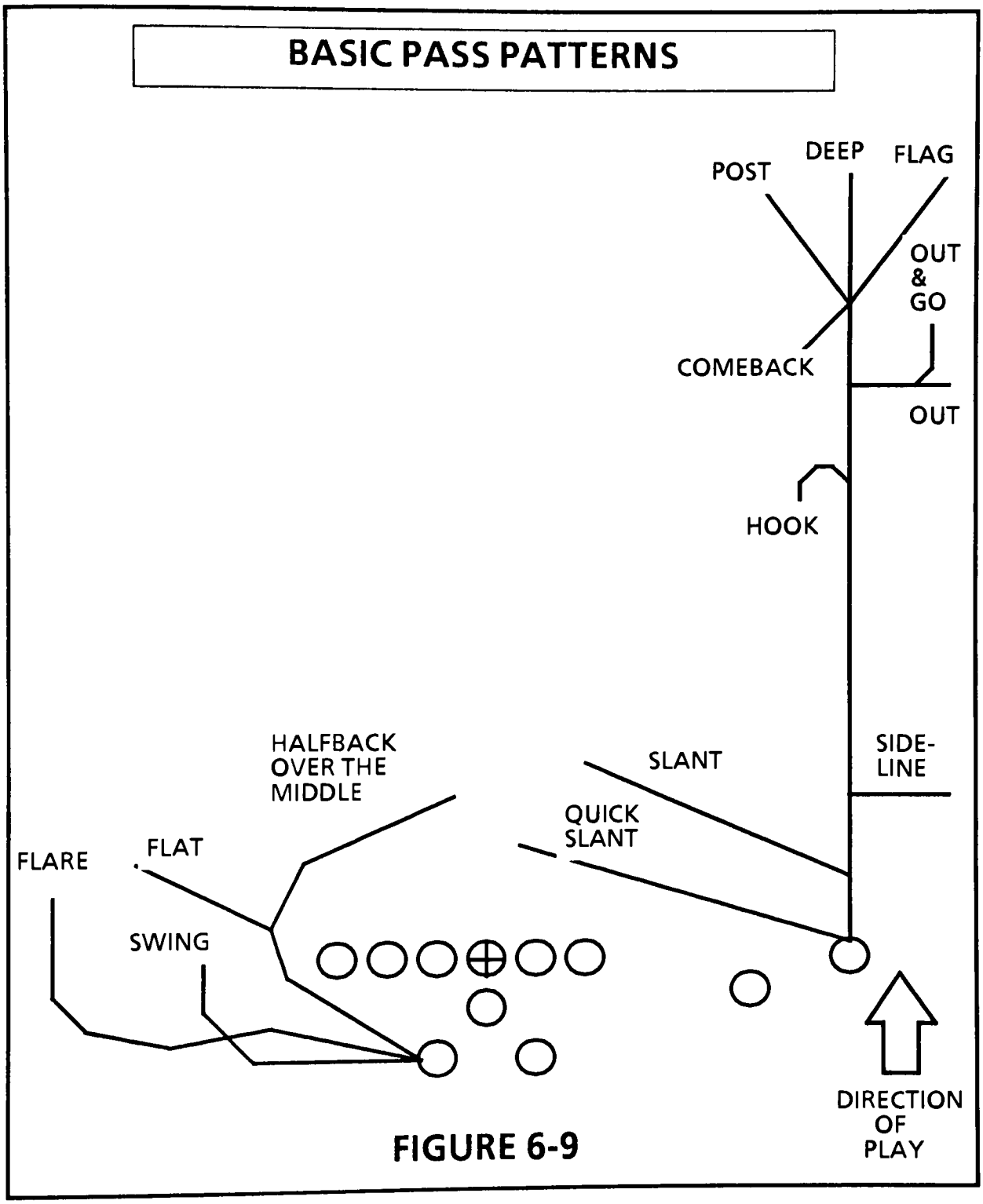
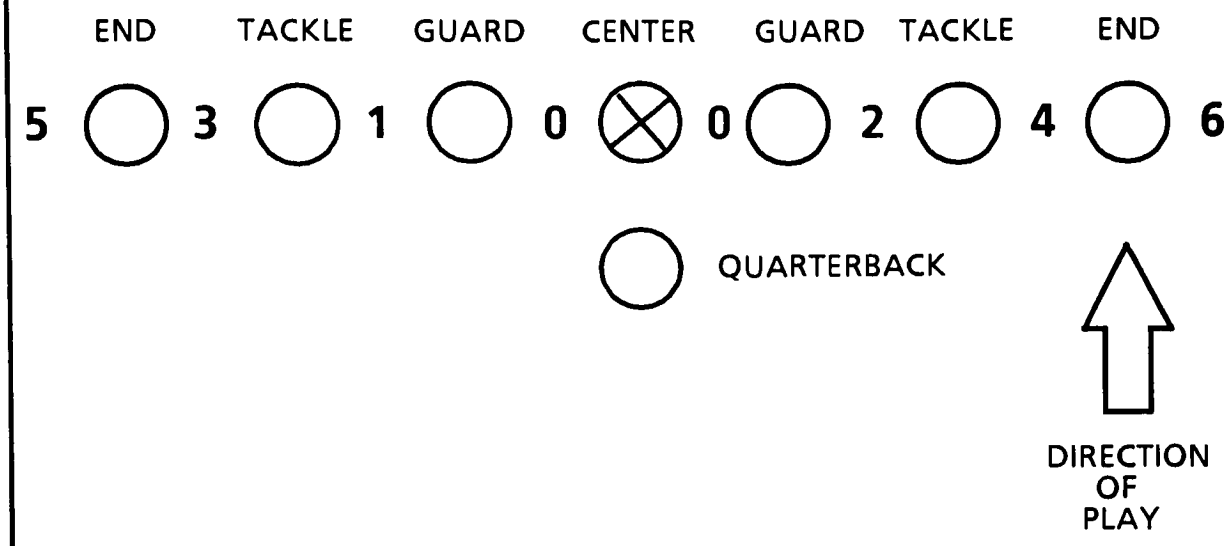

BASIC PASS PATTERNS
POST
DEEP
FLAG
OUT & GO
COMEBACK
OUT
HOOK
HALFBACK OVER THE MIDDLE
SLANT
SIDE-LINE
QUICK SLANT
FLARE
FLAT
SWING
DIRECTION OF PLAY

FIGURE 6-9

HOLE NUMBERING



WHEN A PLAY IS CALLED, THE LAST NUMBER SPOKEN BY THE QUARTERBACK IS THE NUMBER OF THE HOLE THROUGH WHICH THE BALL CARRIER IS SUPPOSED TO GO

FIGURE 6-10

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6.3. Play List.

This is the list of the plays used by COACH. They reside in the six files mentioned in the text of this paper.

fb_in_0
lh_draw
t1
fb_in_1
cc_in_1
t2
fb_in_2
cc_in_2
t3
fl_in_3
t1_give
tb_in_4
belly_4_give
5_pitch
belly_3_keep
reddog_5
belly_4_option
t2_option
flare
sideline_pass
flat_pass
hb_over_middle
box_cut
t2_pass
dump_right
screen_right
slant_pass
qb_option
sprint_draw_1t
hook_&_go

tb_in_0
rh_draw
t1_pitch
tb_in_1
t1_trap
t2_pitch
tb_in_2
t2_trap
tb_in_3
belly_3_give
t4
fl_in_4
t2_give
belly_3_option
t1_option
6_pitch
belly_4_keep
reddog_6
drag
comeback
fb_over_middle
flood
t1_pass
dump_left
screen_middle
screen_left
qb_sneak
sprint_draw_rt
drop_back

6.4. Strategic Level Samples.

This appendix contain sample inputs to the strategic level of COACH with the respective output (the game plan). There is one sample for each of the three major defenses known to the expert system.

6.4.1. Sample for the 5-3 Defense.

6.4.1.1. Inputs.

The following inputs were provided using COACH's menu driven interview process. Numbers in parentheses indicate the number recorded in the data file for each response.

A basic 5-3 defense was expected. (1)

The defensive tackles play inside the offensive tackles. (1)

The noseguard lines up to the right of the center. (2)

The noseguard normally shoots to the left. (2)

The linebackers blitz by looping. (2)

They normally blitz on second down. (2)

The offense normally requires short yardage on this second down. (1)

The offense moves to motion. (1)

The linebackers are the ones who normally follow any motion. (2)

The secondary rotates to motion. (1)

The linebacker covers the split/slot man. (2)

The secondary employs a man-to-man defense. (1)

A 6-5 defense is used in short yardage or goal line situations. (2)

The defensive ends box. (2)

The defensive line penetrates. (1)

Player comparisons show our left tackle to be better than their right defensive tackle. Our center and right tackle are evenly matched with their respective opposing player.

6.4.1.2. Outputs Generated.

COACH initially provided the following general plan of attack against the above expected defensive arrangement.

In general, against t1's 5-3 defense, we should

Throw in the flats

Run straight plays at one man and cut off the loop

Use quick counters, reverses

Pass and run to the outside

Run inside the ends

Run traps, draws, screens

Play-action passes are good

The following is the game plan generated.

1st 15 PLAYS

1. tb_in_3
2. t2_trap
3. screen_left
4. punt/field_goal
5. tb_in_2
6. fl_in_3
7. sideline_pass
8. punt/field_goal
9. sprint_draw_rt
10. cc_in_2
11. fl_in_4
12. 5-pitch
13. t2_pitch
14. t1
15. t2_pass

SPECIAL PLAY

1. t1_specl

GOALLINE

1. t1
2. t1/2 option
3. power_pass

SHORT YARDAGE

1. out_pass
2. sideline_pass
3. t3/4

GOING IN

1. hb_over_middle
2. t3/4
3. belly_3/4_option

COMING OUT

1. t1/2 trap
2. t3/4
3. power_series

THIRD AND (3-5)

1. fl_in_4
2. cc_in_1
3. t1_trap

THIRD AND (6-8)

1. t1
2. screen_left
3. sideline_pass

THIRD AND (9+)

1. flood
2. hook_&_go
3. t2_pass

6.4.2. Sample for the 5-2 Defense.

6.4.2.1. Inputs.

The following inputs were provided using COACH's menu driven interview process. Numbers in parentheses indicate the number recorded in the data file for each response.

A basic 5-2 defense was expected. (2)

The short side defensive tackle plays outside the offensive tackles. (2)

The noseguard lines up directly in front of the center. (3)

The noseguard normally shoots to the left. (2)

The linebackers blitz by shooting into the backfield. (1)

They normally blitz on third down. (3)

The offense normally requires long yardage on this third down. (3)

The offense moves to motion. (1)

The linebackers and the line both follow any motion. (1)

The secondary rotates to motion. (1)

The monster man covers the split/slot man. (0)

The secondary employs a zone defense. (2)

A 8-3 defense is used in short yardage or goal line situations. (1)

The defensive ends wait. (3)

The defensive line penetrates. (1)

The safety usually comes up to bolster the weak side. (y; asked during game plan creation)

Player comparisons show our left tackle to be equal to their right defensive tackle. Our center is better than their noseguard. And our right tackle is weaker than their left defensive tackle.

6.4.2.2. Outputs Generated.

COACH initially provided the following general plan of attack against the above expected defensive arrangement.

In general, against t2's 5-2 defense, we should

Use our short side offense

Keep a split out all the time

Run inside

Throw quick passes over the top

Run power at the ends, quickly fake inside and go outside, or fake outside and go inside

Run traps, draws, screens

Play-action passes are good

The following is the game plan generated.

1st 15 PLAYS	GOALLINE	THIRD AND (3-5)
1. all splits	1. reddog_5/6	1. flat_pass
2. I1/2	2. reddog_pass	2. t2_pitch
3. motion_t3/4	3. flat_pass	3. t1_trap
4. cc_in_1/2		
5. punt/field_goal	SHORT YARDAGE	THIRD AND (6-8)
6. qb_option		
7. tb_in_3/4	1. out_pass	1. sprint_draw_rt
8. flat_pass	2. sideline_pass	2. t1
9. punt/Field_goal	3. sprint_draw_l/r	3. hook_&_go
10. I3/4		
11. t1/2_pass	GOING IN	THIRD AND (9+)
12. sideline_pass		
13. comeback_pass	1. hb_over_middle	1. cc_in_1
14. ----------	2. t3/4	2. t2_trap
15. ----------	3. belly_3/4_option	3. qb_option
SPECIAL PLAY	COMING OUT	
1. slant_pass	1. ISO1/2	
	2. ISO3/4	
	3. ISO_comeback	

6.4.3. Sample for the 4-4 Defense.

6.4.3.1. Inputs.

The following inputs were provided using COACH's menu driven interview process. Numbers in parentheses indicate the number recorded in the data file for each response.

A basic 4-4 defense was expected. (2)

The inside linebackers play inside. (1)

The outside linebackers play stacked. (3)

The defensive tackles play headup on the offensive tackles. (3)

The defense rarley ever blitzes. (3)

The offense moves to motion. (1)

The linebackers follow any motion. (2)

The secondary rotates to motion. (1)

The linebacker covers the split/slot man. (2)

The secondary employs a man-to-man defense. (1)

A 6-5 defense is used in short yardage or goal line situations. (2)

The defensive ends crash. (1)

The defensive line penetrates. (1)

Player comparisons show our left guard to be equal to their right defensive tackle. Our right guard is better than their left defensive tackle.

6.4.3.2. Outputs Generated.

COACH initially provided the following general plan of attack against the above expected defensive arrangement.

In general, against t3's 4-4 defense, we should

Be ready for stunts and fires

Run straight power plays

Run pitchouts and sweeps to the outside

Run traps, draws, screens

Play-action passes are good

The following is the game plan generated.

1st 15 PLAYS	GOALLINE	THIRD AND (3-5)
1. t3/4	1. power1	1. t2_pass
2. power1/2	2. t3/4	2. t1
3. power3/4	3. power_pass	3. sprint_draw_rt
4. punt/field_goal		
5. qb_sneak	SHORT YARDAGE	THIRD AND (6-8)
6. t1/2_pitch		
7. t1/2_outside	1. out_pass	1. fl_in_3
8. punt/field_goal	2. sideline_pass	2. flood
9. flat_pass	3. reddog5/6	3. fl_in_4
10. belly3/4_option		
11. t1/2_pass	GOING IN	THIRD AND (9+)
12. qb_draw		
13. flood_pass	1. hb_over_middle	1. deep_comeback
14. ----------	2. t3/4	2. drags
15. ----------	3. belly_3/4_option	3. deep_hook
SPECIAL PLAY	COMING OUT	
1. flood_pass	1. t3/4	
	2. power3/4	
	3. power1/2	

6.5. Tactical Level Samples.

This appendix contain sample inputs to the tactical level of COACH with the respective output (the plays selected). There is one sample series for each of the three major defenses known to the expert system. The same inputs were provided in each case and are not all the possible inputs as this would prove extremely cumbersome. The inputs are as follows:

6.5.1. Standard Inputs.

Six inputs are in this sample, the first two are numbers of two of the first eight plays. The remaining are four situations each of which is an example of a particular down.

1) Select play 2 of the first eight plays.

2) Select play 7 of the first eight plays.

3-6)

SAMPLE	3	4	5	6
DOWN	1	2	3	4
YARDS TO GO	10	3	7	5
QUARTER	1	1	1	1
YARDLINE	45	45	45	15
WHOSE	o	o	o	t
OUR SCORE	7	7	7	10
THEIR SCORE	6	6	6	7

6.5.2. Outputs Generated.

6.5.2.1. Against the 5-3 Defense.

The following outputs were generated by COACH.

1) **PLAY TO RUN:** t2_trap

2) **PLAY TO RUN:** sideline_pass

3) **Did either of our previous first down plays work well ? [y,n]** n

   I think one of these will get us some yards
   PLAYS TO TRY:
   sprint_draw_rt
   cc_in_2
   fl_in_4

   Would you like some more suggestions ? [y,n] y
   ADDITIONAL PLAYS TO TRY:
   5_pitch
   t2_pitch
   t1

4) **Did either of our previous second down plays work well ? [y,n]** y

   We should be able to get some yards with these
   PLAYS TO TRY:
   t2_trap
   fl_in_3
   sprint_draw_rt

5) **These will get us 6-8 yards**
   PLAYS TO TRY:
   t1
   screen_left
   sideline_pass

6) **Is the opponent expected to move into their goalline defense ? [y.n]** y

   I suggest we attempt one of our goal line plays
   PLAYS TO TRY:

   t1
   t1/2_option
   power_pass

6.5.2.2. Against the 5-2 Defense.

The following outputs were generated by COACH.

1) PLAY TO RUN: I1/2

2) PLAY TO RUN: tb_in_3/4

3) Did either of our previous first down plays work well ? [y,n] n

   I think one of these will get us some yards
   PLAYS TO TRY:
   I3/4
   t1/2_pass
   sideline_pass

   Would you like some more suggestions ? [y,n] y
   ADDITIONAL PLAY TO TRY:
   comeback_pass

4) Did either of our previous second down plays work well ? [y,n] y

   We should be able to get some yards with these
   PLAYS TO TRY:
   motion_t3/4
   tb_in_3/4
   I3/4

5) These will get us 6-8 yards
   PLAYS TO TRY:
   sprint_draw_rt
   t1
   hook_&_go

6) Is the opponent expected to move into their goalline defense ? [y.n] y

   I suggest we attempt one of our goal line plays
   PLAYS TO TRY:
   reddog5/6
   reddog_pass
   flat_pass

6.5.2.3. Against the 4-4 Defense.

The following outputs were generated by COACH.

1) **PLAY TO RUN:** power1/2

2) **PLAY TO RUN:** t1/2_outside

3) **Did either of our previous first down plays work well ? [y,n]** n

   I think one of these will get us some yards
   PLAYS TO TRY:
   flat_pass
   belly3/4_option
   t1/2_pass

   Would you like some more suggestions ? [y,n] y
   ADDITIONAL PLAYS TO TRY:
   qb_draw
   flood_pass
   ----

4) **Did either of our previous second down plays work well ? [y,n]** y

   We should be able to get some yards with these
   PLAYS TO TRY:
   power1/2
   t1/2_pitch
   flat_pass

5) **These will get us 6-8 yards**
   PLAYS TO TRY:
   fl_in_3
   flood
   fl_in_4

6) **Is the opponent expected to move into their goalline defense ? [y.n]** y

   I suggest we attempt one of our goal line plays
   PLAYS TO TRY:
   power1
   t3/4
   power_pass