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Modelling Touch Football (Touch Rugby) as a Markov Process

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Abstract. Touch football is a high profile sport within Australasia, with the potential for large international growth, but a relative absence of research into the sport. The game of touch football was modelled using a series of modified Markov states. The aim of this model was to provide a framework allowing expansion to account for additional game states, time dependence and displacement dependence. The representation was designed to allow adaptation by application of alternative displacement and time dimensional distributions, displacement and time dimensional distribution parameters, and state change probabilities. This would allow adaption to the model according to other various styles of team play and associated levels and composition of teams. Due to the state based nature of the Markov processes involved, the model was planned for more intensive examination in following research focusing on more closely analysing each state in turn. The goal of this paper, however, was to produce the foundation model framework to allow for future development in modelling the sport of touch football.

Keywords: Touch Football, Sport, Modelling, Markov States

1. Introduction

Touch football is one of the most extensively played sports in Australasia. In Australia touch is played by over a quarter of a million registered touch players, half a million school children and up to 100,000 casual players [1,2]. Touch is mainly popular in those states in which rugby league is also popular (Queensland, New South Wales and ACT), which is not surprising given its origins as a training activity for this sport [3]. While New Zealand has less touch players than Australia, it is still the largest participation sport within this country with over 230,000 New Zealanders playing the game. This includes 70,000 under 17 year olds and 160,000 adult players [4]. The running of this sport also involves a vast number of hours devoted by support personnel such as team coaches, team managers, referees, selectors and administrators. Touch is also played in other Australasian countries such as Samoa, Fiji, The Cook Islands, and Papua New Guinea. Countries such as South Africa, England, Wales, Scotland, USA, Japan, amongst others also regularly enter teams in international tournaments, with the 2011 world cup held recently in Edinburgh, Scotland. Much of the touch football within these countries is of a more casual nature or used primarily as a training tool for other sports. Touch as a sport has grown rapidly within Australia [5]. This growth seems to be replicated to some extent in these other countries; however the greatest density of participants is still in Australasia.

Despite the large involvement in touch, very little Australasian sports research has been conducted on this sport when compared to the main professional sports played in Australia and New Zealand. Much work has been done on developing theoretical and practical modelling systems in sports such as AFL, rugby league, rugby union, hockey, cricket, basketball, squash, tennis, golf and others. The majority of published research related to touch football is based on injuries associated with the sport, or use of touch players as a subject group to test some experimental intervention in fairly standard study design. This is not surprising considering the large number of touch players available. However limited published research has been done on the sport itself. One paper that has been published Mathesius and Strand, 1994 (when touch football was called touch rugby in Australia, a name still used for it in many other countries) [3] is now sadly outdated as the game has changed considerably. Due to the immense volume of time devoted to this sport, particularly

by the people of Australasia, there is a need for a basic framework for model development for the sport.

Many invasion type games, in particular sports such as hockey, basketball and football codes can be split into set phases of game play. This is particularly easy for a sport such as gridiron where the very sport is designed around set plays. Most other invasion games can also be split into several distinct components. For example in the game of rugby union different set pieces as well as broken play (i.e. non-set piece play) will have different outcome probabilities for different offensive-defensive team combinations dependant on various factors at any given point in the game, such as for example game score, field position, fatigue and time remaining. In fact a myriad of different factors make modelling of most team sports exceedingly complex and this is particularly so for invasion type sports. Touch football is such a sport and may be modelled as having several components. The first of these components would be a driving phase in which a team aims, amongst other goals (such as gaining a repeat set of touches via an infringement leading to a penalty against the opposition), to gain field position from which to enable both execution of scoring plays and ensuring less probability of their opposition scoring as play is at a larger distance from the scoreline. During this phase, the defensive team has their own corresponding phase of play in which they attempt to both reduce the field possession gained by the attacking team in order to reduce the attacking options of this team and additionally ensure that when they are given their limited touches they are deeper in opposition territory. A secondary, but none the less important goal, for the defending team, within this phase is also to defend against any potential scoring plays the attacking team will attempt to execute, even if far from the try line. The next phase of the game to consider would be line attack. In this phase of the game the attacking team is no longer focused on gaining field possession. They have already reached an appropriate distance from the defensive try line to orchestrate a scoring play. For the defenders this phase of the game would be referred to as line defence. There is also the ability to manage player fatigue and optimal application of personnel via substituting players while simultaneously completing driving plays or the defence to these plays. While touch football is a game where players may be freely substituted during the stoppage time after the scoring of a try, it is also a game where unlimited substitutions (from within a team consisting of a limited number of players and sometimes limited by gender) are allowed. In order to maintain optimal intensity within a game, it is usually necessary to substitute players during various phases of the game whilst minimising disruption of the purposes of these phases. Therefore some phases will represent the switching of players on a team in either attack or defence. In some versions of the game of touch, player fatigue is also managed with a break at half time, while in other tournaments the teams switch ends of the field and restart play at halfway with every touchdown and there is no half time period [6,7]. The version played would affect fatigue management and the importance of substitutions. The half-time break is usually used at higher level tournaments and this half-time period can be considered as another phase of the game. There is also a phase of play following a tap-off to restart the game at half time and a phase of play following a penalty.

A basic skeleton for the various stages of the game of touch was constructed, with built in potential to expand on this system. If it could be shown to be appropriate to model a stage of the game in this way, the prospect of expanding the model with investigation of different stages and looking at other eventualities that present themselves within the sport could thus be realised. If a working model for the stages of this invasion sport could be developed and represented via a Markov Chain then future research could expand this model to other invasion sports mentioned. Many characteristics of the other invasion sports are shared by touch football and this would ease adaption. Certainly these vary across the different sports, but can include limited tackle (touch) counts/plays, one single points scoring method, and a game that is played over a limited time span. Additionally the different offensive and defensive alignments and their preferential defence of certain attacking options or choice of certain offensive methodologies in gridiron closely parallel preferential options and patterns in line attack/line defence in touch football [8]. Other factors include importance of field territory, use of and a limit (either strictly numerical or using conjoint numerical and displacement based systems) to the amount of plays/downs, both games being conducted over a set period of time, scoring by crossing a certain line, requirements of choice of defenders to preferentially defend certain players/zones in man on man, uneven or a compressed defence. By its very nature the sport of Gridiron (and thus logically 'American Touch Football') is highly suited to adaption as a Markov Chain as by its very nature it is split into discrete stand alone plays. Markov Chains have been used to model many different systems in many different academic fields. In sports, they have had particular success for many years in net games, such as squash, badminton and tennis [9-16]. This research has continued progressing over the last 30 years and has been extensively applied to discrete sports such as table tennis [17], tennis [18] carom billards [19] and baseball [20, 21]. However touch football has never been looked at in this manner.

If a Markov model for touch could be designed and shown to represent the probability distribution of any future state given the current state then this could have several practical uses in the future. If the model is sufficiently complex to fit game data well, probabilities of relevance could be simulated as a probability distribution function. This would potentially allow for in-game and pre-game strategic questions to be resolved. There would be many potential applications for such a system. Numerous applications could be used advantageously in order to assist with team coaching and selecting optimal plays. While the application to coaching would be apparent from use of match analysis prevalent in many professional sports, in touch football there are a vast number of participants and potential assistance in selecting representative players at various level could in fact be highly beneficial. In fact teams of selectors must watch all major tournaments in order to establish men's, women's and mixed representative teams at various levels and many different age groups. The potential for future modelling assistance in this talent identification or selection processes was therefore also a consideration. This could be extended in many directions, such as selecting particular players for facing particular opposition as well as for executing or nullifying particular plays. Other interesting uses include estimating in game win and event probabilities as well as points expectation for certain games. These particular points could have potential application for such features as pre-game as well as in-game sports betting, deciding games appropriate for television coverage (issues such as the probability of which games are more likely to be high scoring or exciting games), or allocation of playing areas to different teams during a tournament (tournament control allocating fields with the best spectator viewing areas to those games with higher probability of being both higher scoring and highly competitive games). These latter issues would have particular relevance if such a model was expanded to other sports. Rugby league in particular is similar to touch football in its basic framework of a tackle, as opposed to a touch count. Touch football in fact originally evolved from rugby league [3]. With its high commercial television exposure, in the future it is not inconceivable that some form of statistical modelling or Markov based probability distribution function process could be used for such allocations.

Terminology used in this paper is based around FIT [6] and Touch Football Australia playing rules 7th edition [7]. For the reader unfamiliar with the game the terms: toss, tap, rollball, touch count, ruck, half (player who takes possession of the ball behind the player who performs the rollball), 'period of time' dismissal or 'remainder of the match' dismissal (player sent off temporarily or permanently), drop off, scoreline, touchdown, penalty touchdown, onside, offside, interception, penalty, attacking or defending set and the field dimensions, particularly 5m line and halfway line are defined in these publications and the reader is referred to these compatible publications if definition of these terms is required. These publications also make mention of the variety of different rules used in different competitive environments. The lack of one set system of rules is an interesting feature from a modelling perspective. The term "park touch" is described to refer to the less elite level of touch football, where more rule variations are permitted.

Usually the most common long range attack conducted as a scoring play is the scoop. This is when driving plays (or some other effect) have caused defenders to be in an offside position. The half runs with the ball towards the defending scoreline. This may attract opposing player(s), or attacking players may use agility to escape from their marking defender and the half will attempt to pass to an unmarked player in order that they can score. Both long range and short range scoring plays may be preceded by a play, the emphasis of which is not the scoring of points or advancing the ball towards the opposition line, but engineering circumstances such as particular opposition movements or ball placement to enhance the probability of scoring on the follow play. In order to simplify the nomenclature (for this and future papers), we will refer to this play as the "strike dump". Another concept to consider is second phase attacks. If an attack is conducted, but is unsuccessful at scoring, it may still have forced the defending players to be in a poor position for defence. A situation that can be capitalised on by launching a quick attack designed to take advantage of this misalignment. Such a rapid attack following, but dependant on, the misalignment caused by the previous unsuccessful attack is referred to as a second phase attack. A further attack aimed at exploiting the defensive structure adopted as a result of this secondary attack would be referred to as a third phase attack. Hypothetically there could exist fourth and fifth phase attacks, though the difficultly in maintaining momentum and coordinating these across the attacking team according to the hypothetical structure changes of the defensive teams, as well as the chance of a touchdown or stoppage on an earlier play makes these highly unlikely (P~0).

Another concept relevant to the model is a player's games sense [22]. The ability to make correct tactical decisions based on the many variables they observe during play. If elite players tactically change their actions according to the previous interactions with opponents, then this has obvious implications for

stationarity within the model.

2. Methods

It was first necessary to define the game states required in order to model a match. State 0 is logically the determination of the team to start off via a coin toss. The winning team captain receives possession for the commencement of the first half, the choice of direction for the first half and the choice of interchange areas for the duration of the game. Many assumptions are made in this model and the first of these is that the choice of interchange areas and choice of direction for the first half do not adversely influence the states model. If a situation arises for which some environmental or psychological factor influences the model due to these choices, then this can later be factored in as an additional parameter. At a competitive level, fields should be situated and both marked and illuminated in a manner that such a choice should not influence play for reasons of field location. However certain environmental factors such as for example sun and wind are more difficult to control, so it is feasible that such an arrangement could have a small influence on the game in certain circumstances. Notwithstanding this approximation is still a reasonable one for the purposes of creating a skeletal framework from which to develop a working model for the sport. Additionally similar assumptions are commonly made in other many examples of sports modelling and yet produce reliable working models [17].

State 1 was designated as one of two possible states of equal likelihood with one of the two teams taking a tap off play. This could have several outcomes, the most likely being that the defending players effect a touch on an attacking player in possession and a rollball must be affected with a touch count advanced by 1. This is the most likely state transition, however other possibilities are that one of the teams might make a error leading to the touch count being restarted with a rollball for the attacking team, a penalty for either team, a turnover resulting in a rollball with a restarted touch count for the team that was defending, an interception by the team that was defending or a try for the attacking team. While many of these state changes are unlikely they were still considered. In fact we can consider that during the driving phase of play, any of these options can occur as well as after a tap off or penalty play. The driving phase of play was therefore modelled as having 6 states within a Markov process representing the touch count for all six touches. The first driving state "rollball T0" (with the number next to T indicating that zero touches had been made by the opposition in this particular touch count) was considered replaceable by one of two alternative states representing a tap from either a penalty or restart from the halfway line. Both of these states differed from a conventional rollball in the distance the defence must retreat from the position at which play is restarted, therefore the metres play is advanced may be distributed differently. Both of these states have the same outcome options as the first rollball state, though the outcome probabilities may slightly differ.

As the touch count progresses, the attacking team has two primary effective options namely to attempt to continue to focus on territorial advantage or attempt to score a touchdown (which may also lead to some advancement of territorial position even if unsuccessful). This leads to the introduction of several additional possible states, namely states representing an attempt at a long range attack, a short range or line attack provided field position is appropriate, a touch deliberately allowed to be executed by the defending players in order to set up a more promising line or long range attacking option (the strike dump) and lastly a second, or later phase attack after an initial unsuccessful line attack (the first phase attacking option). This leads to two categories of line attack, those based from a deliberately engineered platform and those not set up in this way. The probabilities of successful execution will depend on the particular attack used and the appropriate nature of the platform used for any particular combination of attacking and defending teams. We have also explained the concept of second (and later) phase attacking play. As these later phase options are conducted under alternative circumstances, logically the probabilities of success will be different to a conventionally attacking option. Therefore this stage of the model will require a unique state and such a logical argument follows for the prospective extended stage attacks if these are attempted (or even possible). These probabilities will also be affected by the actual attacking option chosen requiring either further sub-states or additional parameters in the probability density function for this particular state as the model expands.

For each team there is an optimal position to initiate a particular line attack. While short range attacks will need to be conducted 5-7m or very close to this distance from the touch line, some attacks such as a scoop can potentially be initiated from anywhere on the field. The probabilities of success depend on acceleration, top end speed, avoidance of deceleration after attaining maximum speed by the scooper and support players (if sufficient distance is covered to attain top end speed) and coordination of the attack across the team. The primary determinant however will be the distance from the opposition scoreline and the point

when the attack is initiated. As the distance increases, the probabilities of success will converge towards zero, as the likelihood of successful execution reduces dramatically with significant distance from the scoreline. This particular category of attack could be executed as a long range attack as opposed to those that must only be initiated closer to the opponents score line, namely short range attacks.

In this paper an approximation was made. During the driving phase teams have the ability to attempt to score at any time in their attacking set, though most usually, as field possession is not optimal and a successful score is improbable without field position, this option will be taken on the last, or sometimes second last, touch of the attacking set. These attacks were classified as long range line attacks. Teams also have a range of short range line attacks. In order to initiate these attacks certain conditions must be met and these will vary from team to team. The successful execution of a line attack will be a function of the distance from the scoreline at both the touch it is initiated on and the previous touch. As the model evolves, the time and distance between these touches being executed will also need to be factored into the distribution function. This will reflect the ability of the defence to return to an onside position and make any other necessary adjustments. Both the time dependence and displacement dependence of this function will have a different effect on the probability density distribution for different attacking plays. For some teams and some moves a second phase attack may be launched in some circumstances provided possession is retained and the touch is made with the attacking players in a suitable position. Some defending teams may be more susceptible to such an attack than others.

Each driving or line attack state requires 6 sub-states to represent the touch count. Each strike dump or second phase state requires 5 sub-states to represent the touch count. The need for only 5 is due to the need for a following line attack or a preceding line attack state. Those states that result in the resetting of the touch count or a change of possession do not require additional sub-states within the current model.

The state model in the results section was thus developed (Figure 1). The transition between states is represented by an arbitrary probability or a probability density function according to the transition involved.

Assuming an error is made, we can assume possible results are: a recount (i.e. play continues and the touch count is restarted), penalty, turn over, intercept, send off or player sent for time (we assumed the probability of these last two options as being equal to zero in this simple model, but this can be expanded in future work). Other than these changes of state, teams have the option to execute an attacking play such as a long range attack. We must also consider the possibility of entering into this state at any phase of play and consider that for tactical reasons this is most likely after the 4^{th} or 5^{th} touches have been made (a play such as a scoop is a high risk play, but there is less at risk as possession will most likely be lost anyway).

In the event that the line attack is unsuccessful and assuming the touch count has not expired nor some other event requiring a turnover of possession, there is a possibility that the attacking team will use the following play to execute a second phase attacking option. The alternative to this is to set up an attacking option for the following play or alternatively attempt an attack that does not capitalize on the disarray in defence caused by the preceding attack; however this is a low probability option and therefore an unlikely choice. This last option, while a poor choice earlier in the touch count may however be the only option if no second phase option is available and the 5^{th} touch has been made.

This model makes the following assumptions: no substitution is conducted, no players are sent off or sent for time, there is no drop-off, there are no injuries, fatigue is not considered (i.e. no players fatigue) and all players are identical within a team (which is certainly not the case). While this is imperfect, it was necessary first to generate a basic framework for the game. This framework was designed such that it could easily be expanded in future work.

3. Results

The state transition diagram (Figure 1) was obtained. Arrows and diodes (selected due to the intuitive nature of the symbol) were used to indicate direction of possible state change. This diagram relied on the assumptions detailed in the methods section. The model was a framework allowing easy addition or modification of states. State transfer probability was in most cases dependant on displacement functions planned for expression during model expansion in future work. Some state transfers were deemed to have near zero probability. States that were not included in the diagram (For clarity as these states could be transferred into from most of the other states) were a half-time (where applicable with rule variations) and a full-time state. Similarly a touch count expired state was also kept as a hidden state due to the number of states from which this state could be transitioned to. A symmetrical state system exists for the opposing

team, for presentation purposes, only one team's states were shown. The teams were labelled Team A and Team B. The state diagram shown is for state transitions when Team A is in possession of the ball. Certain states would lead to a change in possession as indicated in Table 1 below. In this case the states based model would continue, but in a symmetrical set of states for Team B.

Table 1: States which result in a change of possession from Team A to Team B.

Previous State in Team A's Markov State System	**Future State in Team B's Markov State System**	**Notes**
Touchdown Scored Offense	Tap off Restart Team B	
Interception	Turnover of Possession T1	Other possibilities for state change exist for interception
T5 Team A	T0 Team B	Touch count expired, not shown in diagram.
Stoppage due to Error by Offense	Turnover of Possession T0	Other Possible State "Penalty Awarded to Defense"
Penalty Awarded to Defense	Turnover of Possession Penalty	
State zero, the coin toss	Tap off Restart Team B	P=0.5
Touch count expired	Roll ball T0	Not shown on the states diagram, transfer after state T5 if touch is made.

State transfer was dependant on the touch count T0-T5, displacement from the opposition score line and time. Provisional transfer probability functions were developed for state transfers and these were planned for investigation in future work.

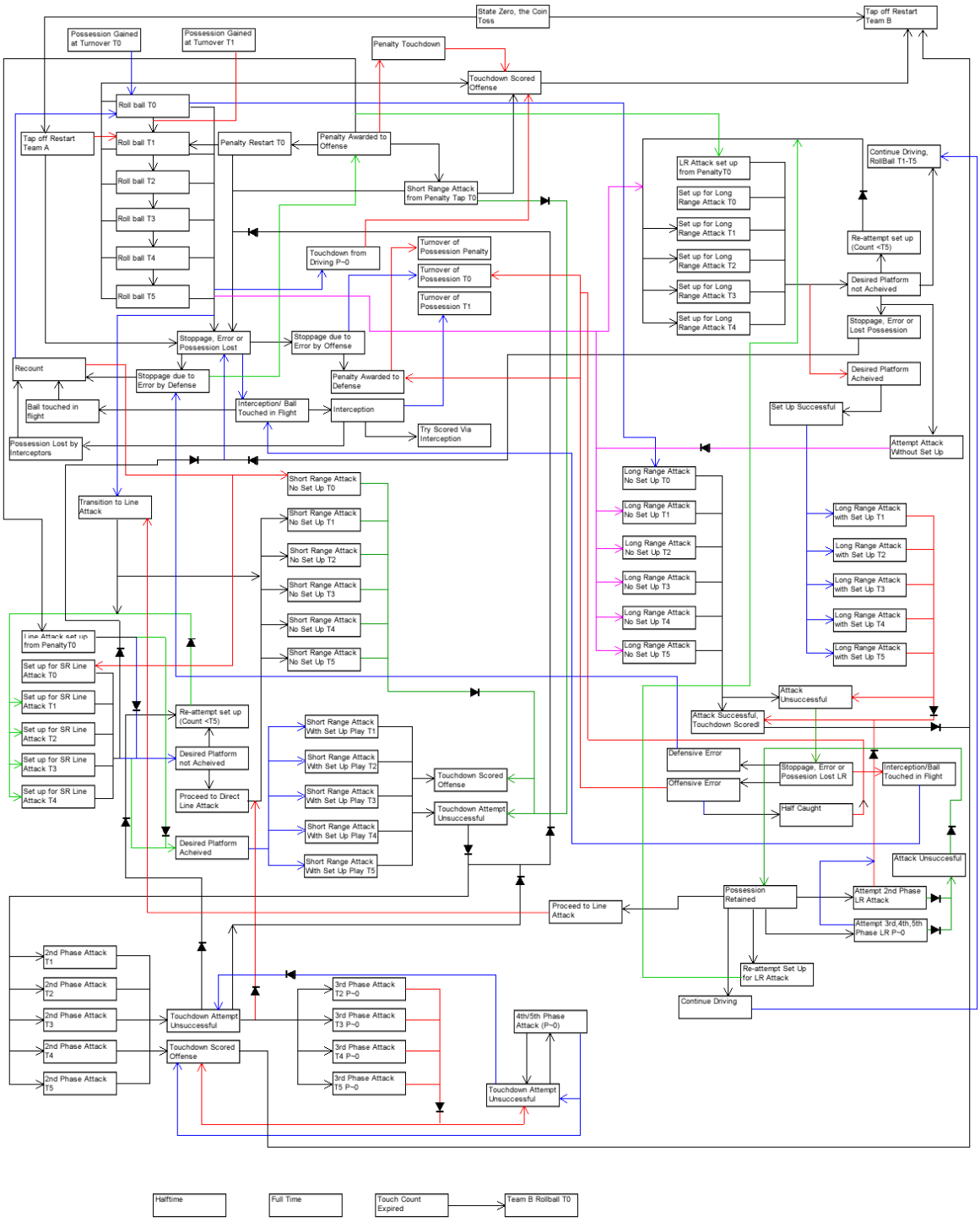

Fig. 1: A Markov States Model for the Game of Touch Football. Arrows and Diodes indicate direction of flow. Several state transitions have been coloured in this diagram for clarity.

4. Discussion

This was a theoretical study designed to form the backbone for further, progressively more cogent, work modelling invasion type games. Certainly there are a myriad of different effects which need to be acknowledged, but that were approximated either as being zero, or as being implicitly included in the probabilities within the model or as being equal for all teams involved. For the purpose of future expansions to this model consideration of whether a team is winning or losing and its effect on morale and motivation

could be added. If one team is winning or losing, either by a great deal or a small amount or the game is close the probabilities of success may well change due to psychological reasons. These probabilities may also change due to the importance of the game. This was hard to represent using a simple base model; however it was an area in which the model could be further expanded. Hypothetically this could be represented using an extra construct representing the effect motivation and morale of the different teams has to alter performance in each of these: situations. It would be recommended to use an adaptation of the surrender parameter, λ [21] for psychological issues such as these. Player fatigue was also a factor that this model did not consider. It is something that is very relevant to the coach who wishes to optimally manage fatigue while ensuring the best players are in the key field positions at the appropriate time and for as long as they will continue to perform more optimally than their non-fatigued replacements. The differences between different players themselves and their abilities to execute certain key plays represent another factor for future expansions to the model.

The model can be adapted for the rule changes in "park touch" or another tournament if rule variations are used by adding additional states. The adaption to the basic framework of the model may not however be necessary for most rule variations however as they do not change the categorization of states. The change would most likely be implemented by minor alteration to the probability function representing transfer between states. Potentially this could also be used for modelling the implications of rule variations, should changes be considered in the future.

A match of many sports is not strictly a Markov Chain. This is because in executing a particular move or action, the reaction/response of the opposition will be influenced by the previous actions of both teams in that position and their outcomes. This is something attacking teams are aware of and purposefully incorporate into their tactics. An example would be conditioning a defence to react to a particular action with a particular response and to begin anticipating that they must respond in a certain way. Once this is achieved the same action is executed by the attacker, but altered at the critical moment in the hope that it is too late for the defender to change his anticipated response. For teams that have played extensively against each other or reviewed each other's performances extensively, this may then not apply to the same extent as in the situation where they have no prior experience of the way the other team plays. In the situation where the team has a set structure that must be followed at all times by the players and provided that this system is not altered in the game as a response to the actions of the opponents or their own failed actions, then this game can be modelled as a Markov Chain. This would also entitle modelling as a Markov Chain a game for a team which had a set structural policy to follow, a policy, which would only be reviewed after the game or a game conducted amongst players with too limited games sense [22] in order to make tactical changes throughout the game as play progressed. At a higher level it is presumed that leading players and/or coaching staff would possess sufficient ability to make such tactical changes. However, if the optimal offensive and defensive patterns had been selected against a particular opponent then a run of unlikely plays, resulting in a sequence of play which was a low probability outcome, might not result in the changing of playing patterns; for a highly astute coach may identify this for what it is, namely a highly unlikely sequence of events. Therefore, in this case the use of a Markov Chain based methodology would still hold as valid.

Further consideration needs to be given to the distance required for a successful attack. Consideration needs to be made of scoops, which are longer range attacks and one might model these using the probability of gaining a given number of metres and successfully off-loading which can be treated similarly to a new type of scoring play with a corresponding defence score for each team. For an attack from a dynamic platform this requires far less distance from the score line. Further work needs to evaluate the probability changes caused by preceding attacks with strike dumps as a component of the attacking structure. Particularly focus should be placed on attack types as there is the possibility of attacking several times from some sets of six provided that the first attacks retain the ball if unsuccessful (e.g. quick release plays as opposed to some failed long ball plays which may result in a turn-over due to a failure to deliver the ball appropriately to the receiving player.). Therefore different teams, but particularly different attack types will have different probability outcome functions requiring further state divisions to account for several attacks a team possesses. At the moment however, the model views the outcomes as probabilities given a short or long range attack, so this is not incorrect, just a more macroscopic view. As field position develops, teams can structure an attack using one of these three methods as is relevant: a scoop, a strike dump or primary attack followed by a second phase attack, or an attack from a dynamic driving platform.

Stationarity is challenged under certain conditions in the game of touch. For example a team that has just been scored against at the start of a game is unlikely to change its game plan, however a team losing by 1

touchdown with one minute left of the game would likely play a more high risk form of game in order to try and score on its next set of touches. This singularity is also challenged due to the half and full time state changes, however by consideration of these as special situations and keeping track of time as part of the model (effectively time and displacement are further parallel sub-states) this can be accommodated within the parameters of the model. Eventually it is hoped that GPS data combined with real time video analysis could be used for conjoint theoretical and practical future development of the model.

5. Conclusions

Due to the large number of touch players in Australasia, the potential international growth of the sport and the relative absence of research, especially mathematical modelling of this sport, there are numerous reasons for developing this particular study. This paper provides a basic framework for modelling touch football as a Markov Chain. Due to the absence of previous work in this area, the focus has been entirely on developing a framework for this model, without specifically detailing transition probabilities. This however will be the next stage in the process of building a workable and practical model. A simple score by score workable method could easily be developed, however it is hoped that this model, while requiring further work and less approximations will eventually be more insightful due to the more intensive nature of transitions.

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