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GIS and the geography of politics

M HORN

This chapter is concerned with geographical aspects of electoral systems, and in particular with the challenges that arise in the delineation of electoral districts. A brief outline of the various types of electoral framework provides the starting point for a discussion of the principles that are applied in electoral districting. Those principles have often been violated through the abuses of gerrymandering and malapportionment, and districting plans can become objects of contention even where there is no deliberate bias. It is pertinent therefore to consider analytical measures and procedures that can help to ensure the fairness of districting outcomes. This discussion is followed by a survey of districting applications for GIS, with respect to both specialised analyses and the more 'generic' GIS facilities. These technical issues are illustrated with reference to recent Australian experience.

1 INTRODUCTION

A lively branch of political geography is concerned with the use of local districts as bases for electing representatives to public bodies at local, regional, and national levels. District boundaries can have decisive impacts on the composition and behaviour of political institutions, and the task of delineating those boundaries raises significant theoretical and technical challenges for geographical practitioners. This chapter focuses on political districting under systems of representative democracy, of which the following characteristics are of particular relevance:

- Democracy involves the principle of fairness and the associated idea that all citizens should be treated as equals: for electoral systems, this implies that everyone's vote should have equal value.
- In modern democracies the principles of fairness and equality are deeply entangled in party and interest-group politics: so, for example, established parties often demand for themselves 'fair and equal treatment' analogous to that pertaining to individual citizens.

A geographical extension of these principles is necessary to justify locally-based representation, especially under systems based on single-member constituencies, as in the US House of Representatives and the British House of Commons. Implicit in such systems is an assumption that common interests can be defined fundamentally in geographical terms, rather than (for example) on a vocational or party-political basis. This must be regarded as dubious in view of the removal of barriers to transportation and communication over the past 150 years, and the accompanying increase in residential mobility (e.g. see Wild 1985).

Even so, the identification of representatives at a local level does provide effective channels for dealing with local issues, and helps to maintain contact between politicians and citizens. It is perhaps most effective when complemented by an alternative form of constituency definition, for example in bicameral parliaments where the chambers have different electoral bases, and in bodies constituted as mixtures of at-large and locally-elected members (e.g. the German Bundestag and some city councils in the USA).

Most constitutional landscapes comprise a combination of national and local representation, and of political and administrative subdivisions. Thus in countries governed on federal lines, the local

government areas with their component districts (e.g. wards) generally are nested within state or provincial boundaries, which in turn nest within national boundaries; similarly, constituency areas for the European parliament are overlaid upon the political maps of the member countries. In order to give some coherence to this account, a *districting plan* is defined here as a division of a high-level spatial entity or region into electoral *districts*, so as to provide a localised basis for political representation. The aggregate of people officially represented in a district is a *constituency*, each constituency having a total residential or electoral population relevant to an apportionment criterion, as discussed later in this chapter. The districting plan used for federal elections in New South Wales, Australia, is shown in Plate 57.

1.1 Electoral systems

Electoral systems based primarily on single-member districts are now confined mainly to France and the English-speaking countries (Butler and McLean 1996). Apart from the doubts referred to earlier, a major criticism of such systems is their failure to guarantee that the balance of forces in a legislative chamber will match the aggregate proportions of votes won by the various parties. This deficiency has motivated the development of systems under which voters select several candidates simultaneously in each electoral district, the districts being delimited especially for the purpose or else pre-defined (e.g. as provinces or states, or an entire country). Such systems are of two main types:

- Under a simple method of *proportional representation* (PR), voters choose from among lists of candidates submitted by the parties. The numbers of seats awarded to the parties are determined in approximate proportion to their total votes, and for each party the winning candidates (if any) are then read off sequentially from the top of its list. There are many variants on this scheme involving different methods of converting proportions of the total vote to integral numbers of candidates (i.e. *allocative methods* as discussed in section 2.1 below), thresholds that in effect discriminate against small parties, options for individually-directed votes, and geographical elaborations as discussed below.
- Systems of *single transferable voting* (STV) are used in Ireland, Malta, and Australia. Here electors indicate a numerical order of preference among the candidates or (as an option in the Australian Senate elections) among the parties. The result is determined by distributing the first-preference votes among the candidates, followed by successive redistributions of next-preference votes (those for the least successful, and the surplus from already elected candidates) until a minimum quota has been achieved by the required number of candidates. Essentially the same method, called *preferential voting* or *instant run-off*, is used in Australia for elections in single-member districts, where it allows voters to indicate their views in a nuanced way, and eliminates the 'spoiler' role that plurality election forces upon minor party candidates.

Apart from a few strictly 'at-large' cases (e.g. Israel and the Netherlands), multi-member electoral systems generally involve multiple districts. District-based and at-large elements are frequently combined, under three main variants (Blais and Massicotte 1996):

- In the two-vote *corrective* PR systems used in Germany, New Zealand, and Venezuela, a citizen can vote both for a candidate in his or her local district and for a national party list. A representative is chosen in each district by a plurality of the local votes, then additional seats (e.g. half of the German Bundestag) are allocated so that each party's representation in the chamber as a whole is proportional to their shares of the list votes.
- The two-vote *combination* systems adopted recently in Japan and Russia also provide a mixture of PR and district-based representation, but differ from the German model in that the PR seats (at-large in Russia, and based on multi-member districts in Japan) are allocated without reference to the results of the local district elections. The Hungarian system is a hybrid of corrective and combinative elements.
- In single-vote *tiered* systems, PR is applied in a geographical hierarchy. Three tiers are used in Greece, and two in Belgium, Austria, the Czech Republic, and the Scandinavian countries. Under a two-tiered system, representatives are elected

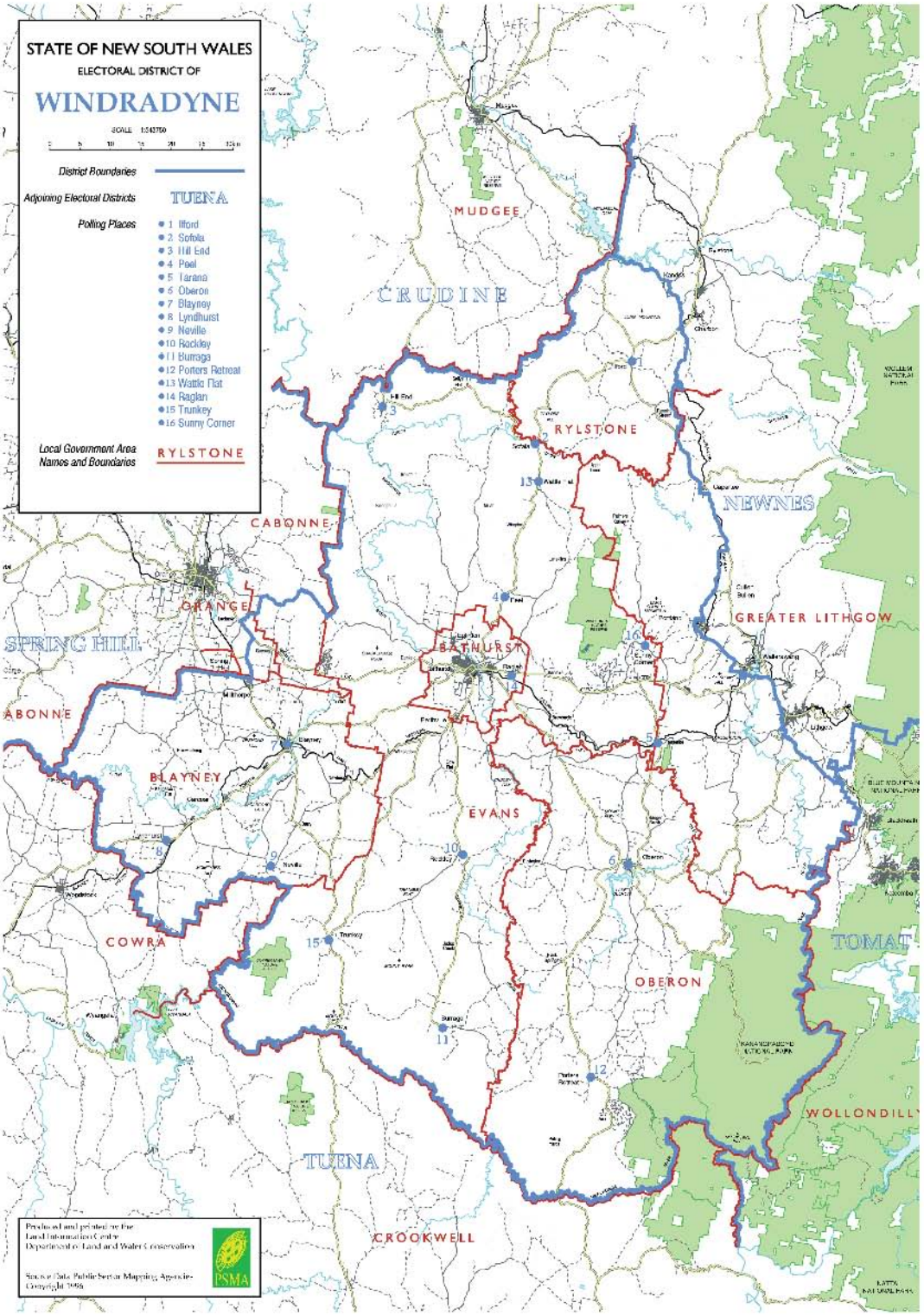

Plate 57 Sample electoral district of Windrayne, New South Wales, produced using Electoral Distribution and Mapping System (EDAMS).

first from multi-member districts, and the district level votes are then re-applied (under a variety of formulae) to select an additional set of representatives at the national level.

2 DISTRICTING CRITERIA

Districting remains an important task under single-member systems and (to a lesser degree) under PR and STV. Clearly it is desirable at least that districting plans should achieve public acceptance in terms of the geographical concerns outlined at the beginning of this chapter, besides conforming with rules established in electoral legislation or (as in the USA) legal precedent.

The Australian Electoral Act illustrates how districting criteria are expressed in legislation. It sets out explicit requirements (see section 5.1 below) regarding equality of electoral populations in House of Representatives Electoral Divisions (single-member districts), with five further factors to be considered in relation to each division:

- community of interests within the division, including economic, social, and regional interests;
- means of travel and communication within the proposed electoral division;
- the trend of population changes;
- the physical features and area of the proposed electoral division;
- the boundaries of existing divisions.

The complexity of districting tasks arises largely from the multiplicity of ways in which such criteria can come into play. This is illustrated in a hypothetical example. Suppose that ten parliamentary districts are to be delineated in a state with a voting population of a million people, 60 per cent of whom reside in ten urban centres of nearly equal size, the remainder being dispersed in surrounding agricultural areas. Here the equal representation principle clearly demands that each district should have a population of around 100 000, and this (we suppose) is easily satisfied by drawing the electoral boundaries more or less midway between the urban centres, like Thiessen polygons (see Boots, Chapter 36), so that the ratio between rural and urban populations in each district is similar to the state-wide ratio. Such a plan may well accord with people's understanding of local geography, but it forces any 'farmers' candidate' to stand in a predominantly urban constituency. In numerical terms, fairness would suggest that four of the ten parliamentary representatives should speak for rural interests, yet it is likely that those interests will find no clear voice at all.

An alternative to the approach outlined above would be to carve out a number of agricultural districts from the spaces between the cities, so as to ensure rural representation while still satisfying the principle of population equality. Yet this may require district boundaries to transgress the physiographic and institutional lines that demarcate the cities' recognised 'natural' hinterlands: a rural district for instance may have to straddle several counties, crossing natural boundaries such as mountain ranges or unbridged rivers. A plan made on such lines is likely to be regarded as unnatural or artificial and is vulnerable to suspicions of gerrymandering.

The following sections discuss how the most widely-recognised districting criteria are justified and applied, but it should be noted that the relative importance of these criteria is often difficult to assess. Such difficulties are especially prevalent in the USA, where although districting for Congressional seats is carried out by the state legislatures (or by more or less independent bodies appointed by them), the operative criteria are defined in the series of judgements arising from challenges to districting plans in the federal courts since the beginning of the 'apportionment revolution' in the early 1960s. The primacy of constitutional concerns and the special circumstances of American political life make the USA in some ways a special case, but experience there can still be very instructive in other contexts.

2.1 Equality of representation

The principle of equal representation is concerned with the *apportionment* of voters among electoral districts, and implies that every vote should have equal weight. It follows that the population covered by each representative should be approximately equal to the average or *quota*, calculated by dividing the total population by the number of representatives. This can be applied in three different ways, depending on the electoral framework.

First, where there is one representative (or an equal number of representatives) for each district, the equality principle requires that the populations of all districts should be approximately the same.

The degree of approximation may be specified in electoral laws as a permissible deviation from the quota (e.g. as much as 25 per cent in Canada). The alternative is to provide only a verbal formulation, as in India, the UK, and the USA, although this can lead to significant difficulties of definition. For example, the US Supreme Court's ruling in Reynolds v. Sims (1964) stated:

'Whatever the means of accomplishment, the overriding objective must be substantial equality of population among the various districts, so that the vote of any citizen is approximately equal in weight to that of any other citizen in the state . . . So long as the divergences from a strict population standard are based on legitimate considerations incident to the effectuation of a rational state policy, some deviations from the equal population principle are constitutionally permissible . . .'

This left undefined the concepts of 'substantial equality' and 'rational state policy': in the aftermath, the courts came close to a principle of *strict* equality, since equality was easier to measure than 'rational state policy' (Dixon 1982; Morrill 1987: 248). Similar issues have arisen with respect to the English electoral laws (McLean and Butler 1996).

An extension of the formulations discussed above applies in multi-member systems that allow the delineation of districts with different numbers of representatives (e.g. in Ireland and in the Australian Capital Territory). Here the apportionment quota can be treated as a notional module in building districts: although this entails some of the 'lumpiness' of single-member systems, it allows greater flexibility in tailoring districts to the varying scales of human settlement.

A third application of the equality principle arises in the allocation of representative numbers among pre-defined districts. Actually this is not a geographical task at all, but it affects apportionment in political landscapes where legislative seats are nested within state or provincial boundaries. The aim again is to provide a uniform ratio of representatives to population; thus in a federal legislative assembly the equality principle typically is applied in two stages: first in determining the allocation of a total number of legislative seats *among* the states, and then in the districting task itself *within* each state. In such cases equality can be compromised by the enforced rounding-off of representative numbers (Ibaraki and Katoh 1989, McLean and Mortimore 1992). A much more severe malapportionment is endemic in bodies (e.g. the US and Australian Senates) that are constituted with an equal number of representatives for each state.

2.1.1 Population

For apportionment purposes, population is usually defined as the number of residents eligible to vote (UK and Australia), or as the total number of residents (USA). The sum of the two (plus a small area allowance) is used in Denmark. In Australia total population is used for the statewise allocation of seats and voters for the delineation of electoral districts.

Where apportionment is based on residential population, the political complexion of a districting plan can be affected by demographic irregularities such as large concentrations of childless voters (e.g. military bases), or conversely of non-voters such as non-citizens and children in young families. For these reasons the accuracy of census counts can become a focus of political contention, notably in the USA, where some localities have large transient and alien populations that tend to be under-counted in conventional census practice, thus potentially compromising the strength of their political representation (Harvison et al 1985). A fair apportionment also requires that the population data on which a districting plan is based should be accurate during the life of the plan, given the impact over time of migratory and other demographic trends – as we shall see below in section 5.1.

2.2 Community of interest

Community of interest involves at least a commonality of substantive economic or cultural interests. A criterion of this kind may be justified as follows: geographical clusterings of local association correspond with clusterings of common political interest, and those local interests in turn deserve representation as primary components of the larger constitutional mosaic (see the discussion in the introduction to this chapter). This seems clear enough in the case of 'active' communities based on densely interwoven clusters of local affiliation, but such patterns are not always well-defined, especially in the suburban areas of large cities. It is therefore often more productive to define community in terms of intra-district affinity or homogeneity, as indicated by demographic measures such as household income,

occupation, family profile, religious affiliation, and ethnic classification (see Morrill 1991; Walmsley 1985).

Community of interest entails two additional difficulties. First, because the spatial distributions of the demographic indicators mentioned above can differ markedly, a districting plan that takes cognisance of one indicator can be unsatisfactory with respect to others. Second, even well-demarcated local communities vary in population and spatial distribution, and there is no reason to expect that they will neatly match the average-population quota mandated by the equal population principle: thus for example when a small community has to be grouped with others to make up the district population quota, its political strength may be fatally diluted.

2.3 Physical and behavioural criteria

Several further geographical criteria are related in various ways to the community concerns discussed above. Although they appear in some electoral laws and as points of reference in debate over districting plans, their application has sometimes been challenged by political scientists and (in the USA) the courts.

2.3.1 Physical geography

Physiographical conditions often concur with patterns of human settlement, and consequently may be important also in assuring political legitimacy; indeed an important strand of geographical scholarship has focused upon concurrences of this sort (Macdonald Holmes 1944). But as the USA Supreme Court has said 'legislators represent people, not trees or acres' (Reynolds v. Sims 1964).

2.3.2 Accessibility, transport, and communications

Patterns of travel and communication can be useful in identifying communities of interest, while the infrastructure sustaining those patterns has a similar if less direct role (see section 4 below). Accessibility as such may be thought of as a distinct concern underlying the argument for geographical area as a districting criterion.

2.3.3 Area

Where human settlement is sparse, political districts must be correspondingly large in area if they are to satisfy the equal population criterion. For example, the electorate of Kalgoorlie – represented by a single member in the Australian House of Representatives – has an area (2 265 050 km^2) larger than that of western continental Europe. It is often argued that in such cases a district population substantially less than the quota should be permitted, so that interaction between the constituency and its representative should not be too arduous. Such reasoning has produced some notable malapportionments (see section 3 below), and its force has faded considerably in the face of improvements to travel and communication.

2.3.4 Geometry

Attributes of shape such as the spatial cohesion or compactness of individual districts have sometimes been specified as districting criteria (e.g. in the UK and some States of the USA), and compactness measures have been widely discussed by scholars (Dixon 1982; Johnston and Rossiter 1981; Young 1988). Such measures are usually regarded as elementary safeguards against gerrymandering, but they are also susceptible to a more analytical interpretation (see section 3.1 below).

2.3.5 Existing boundaries

The conventional view of districting is in terms of more or less small modifications to an existing set of boundaries: the point here is that once established, electoral districts themselves are influential in consolidating patterns of political and other local interests (see the discussion of continuity in the next section). In addition, districting guidelines usually call for attention to be given to the boundaries of other political units, such as local government areas. Apart from the possible administrative advantages, this can be desirable as a means of promoting public understanding and acceptance, and because government areas often reflect patterns of local interest (see Dixon 1982).

2.4 Political criteria

The criteria discussed below are concerned explicitly with the impacts of districting plans on the membership of representative bodies, and especially with the positions to be obtained in those bodies by parties and interest groups. They are akin to the equal representation and community of interest criteria discussed earlier, but differ in their attention to probable voting patterns in each district, based for example on previous election results or ethnic composition.

2.4.1 Neutrality

A principle of political neutrality states that the parties' relative success in the electorate at large should be reflected in the proportions of their candidates elected to office, so that the ratios of votes to seats won are nearly the same for all parties. Thus in a simple two-party case, a party should gain a majority of seats only if it has won more than half of the aggregate vote. The situation is more complex with respect to minority parties and ethnic groups. In the USA it has been a contentious question whether a districting plan should deliberately seek to give representation to such groups (Morrill 1981); by contrast, countries such as New Zealand and Taiwan have set aside seats to represent their indigenous populations.

Neutrality raises fundamental difficulties under single-member systems of representation, in that where support for parties and interest groups has a near-uniform spatial distribution, such systems tend to exaggerate the gains of a winning party, and to under-represent minorities (for detailed analyses of neutrality and competitiveness see the references in Blais and Massicotte 1996: 69–70). Neutrality is precisely what PR systems are designed to achieve – and can achieve easily provided that the number of members in a district is not too small. Indeed the initial impetus for PR was a desire to establish a broadly-accepted political mode of operation in countries (Belgium and Switzerland) marked by religious and linguistic divisions (Carstairs 1980; Farrell 1997).

2.4.2 Competitiveness

A political party's interest in 'winnability' implies a view of a districting plan as a frequency-distribution of districts ranging from 'safe', through 'marginal', to 'unwinnable' from the party's point of view. An extension of the neutrality principle states that these distributions should be approximately the same for all parties (for a mathematical elaboration see Blais and Massicotte 1996). It is notable also that the distribution of competitiveness as such implies an overall susceptibility to political change (Morrill 1987; Niemi 1982). A further concern is that because campaign spending tends to focus on marginal or 'competitive' districts, a plan with many such districts will unfairly favour wealthy candidates and parties (Cain 1984).

2.4.3 Continuity over time

Changes to electoral boundaries from one districting plan to another can upset citizens' connections with their political representatives, and conversely they require politicians to reconstruct their local support networks. Furious contention can arise over a proposal that splits apart a district represented by a veteran incumbent, or changes a district's political complexion from safe to marginal. A broader issue here concerns the development of legislative experience amongst political practitioners, as against providing opportunities to inject 'new blood' into a legislature.

3 ABUSES AND DISTORTIONS

Systematic violations of districting principles can occur when a governing party has unchecked control over the processes by which districting is carried out. The two main forms of abuse in single-member electoral systems are malapportionment and gerrymandering.

Malapportionment involves a substantial deviation from the equal population requirement. To bias the value of votes in its favour, an entrenched party will delineate under-populated districts where its support is strong, and over-populated districts where its support is weak. Until the 1960s this was common in the USA as a means of over-valuing rural votes: its scale is indicated by the case of Colgrove v. Green (1946), which concerned a Congressional district in Chicago with more than seven times the population of a rural district (Morrill 1981).

Malapportionment at times has been institutionalised by legislatures in several Canadian and Australian states, in the form of 'zoned' systems that (it is argued) address the difficulties faced by representatives in sparsely-populated areas. The idea is to divide a state into a small number of zones, assigning to each a different population quota for districting purposes. Queensland for example until recently had four zones, with average electoral populations in 1989 differing by more than 100 per cent between the metropolitan and remote-areas zones. Although the zoned system has since been abolished in Queensland, a 'rural weighting' has been retained for districts more than 100 000 km^2 in area.

Another type of malapportionment is achieved merely by neglecting to revise boundaries in the light of changing settlement patterns. This is typified in the electoral map of England before the Reform Bill of 1832, with the depopulated 'rotten boroughs' providing

a continuing political base for rural interests, while many of the new industrial cities went entirely unrepresented. The rural malapportionments in the USA operated in a similar way (Morrill 1981). In France, a set of district boundaries drawn in 1958 persisted until 1985: during that period the range of electoral populations expanded from 1:1.6 in 1958 to almost 1:6 in 1979 (Butler and McLean 1996; Hand et al 1979).

The word '*gerrymander'* was coined in response to a redistricting bill signed by the Governor of Massachusetts, Governor Elbridge Gerry, in 1812: a newspaper cartoonist drew the map of one very oddly shaped electoral district in the form of a monstrous animal or salamander, and included for good measure against its hindquarters a profile of Gerry's face (Butler and McLean 1996). While it is true that odd shapes and strange discontinuities are characteristic of many gerrymanders, the word now refers more precisely to a districting plan drawn in violation of the principles of neutrality and competitiveness, so as to distort the likely outcome of an election. A party can achieve this without malapportionment by *packing* putative opposition votes into districts where they are wasted in excessive majorities, or *splitting* localities of opposition strength and allocating the ineffectual fragments to adjacent districts (Morrill 1981).

There is a rich 'American tradition' of gerrymandering directed against both opposition parties and ethnic minorities (Taylor and Johnston 1979, with examples also of French gerrymanders). The US Supreme Court has been reluctant to overturn even fairly blatant partisan gerrymanders, but has been more forthcoming with respect to minority groups, even permitting in some circumstances what might be regarded as a gerrymander in favour of such groups. A limit to this trend is indicated in Shaw v. Reno (1993), in which the Court rejected (by a bare majority) a districting plan for North Carolina that sought to increase black representation in Congress by means of a district strung tenuously some 160 miles along the I85 highway corridor.

PR makes gerrymandering more difficult in principle, but that by no means excludes the possibility of abuse under such a system. Clogg (1983), for example, describes a Greek electoral law of 1955 as of 'truly Byzantine complexity'. Multi-member districts returned representatives by three different methods (plurality, 'majority/semi-PR', and two-party PR), the methods and the districts strategically combined so as to exaggerate the strength of the ruling party. This was replaced shortly afterwards by a system of 'reinforced PR' (involving high thresholds for minor party representation) combined with an apportionment based not on the then recent (1951) census but on that of 1940. Yet in the 1961 elections these manipulations failed so badly (according to widespread allegations) that the ruling party engaged in outright and large-scale vote-rigging!

3.1 Detecting abuses

Detecting malapportionment is a straightforward task when district population figures are available and apportionment requirements are precisely defined. Measures indicating the degree of malapportionment in a districting plan include the proportion of an electoral population that could control a majority of seats (e.g. for n districts, this is the ratio of population in the $(n/2) + 1$ least-populous districts to the total population); and distributional measures such as the Gini index (Taylor and Johnston 1979).

Detecting gerrymanders is complicated by the role of voting patterns, since political bias in a districting plan may not become evident until after an election. Similarly, electoral authorities and courts have been reluctant to entertain objections to districting plans based on predicted voting patterns, on the grounds that prediction of this sort is beyond the scope of their responsibilities: examples include the US Supreme Court as mentioned earlier, and electoral commissions in South Australia and New Zealand. A distinction can be drawn between a deliberate gerrymander and unintentional bias, since with the best will in the world it may be impossible to provide a completely neutral footing for all parties and interest groups while at the same time satisfying other districting criteria (Johnston and Hughes 1979; Lijphart 1982).

Some gerrymanders however are quite blatant, especially where districts are internally disconnected or perforated (e.g. the 'packing' of small minority communities into districts with which they have no physical connection). As such cases suggest, measures of compactness and contiguity can be useful in warning of likely gerrymanders (Morrill 1981, 1987). The geometric measures alone cannot, however, provide a definitive verdict (Dixon 1982; Taylor and Johnston 1979). Other techniques based on statistical regression are described by Kousser (1996).

4 OPTIMISATION PROCEDURES

Automated districting techniques have been used both in adversarial settings and by independent districting authorities, sometimes in order to ease technical difficulties, but often also in the hope of avoiding political bias. That hope was high in the USA during the 1960s and 1970s, when the Supreme Court presided over extensive reforms of electoral practices, but it has faded considerably since then in the face of experience with both computer-based techniques and analogous 'politically blind' districting panels. The main stumbling block in this respect has been, and continues to be, the fact that ignoring political realities when making a districting plan provides no guarantee that the outcome will be fair with respect to the political criteria outlined earlier in this chapter (Dixon 1982; Cain 1984). Given that there is little prospect of capturing all conceivable political and geographical realities in legible mathematical terms, districting algorithms and procedures must be regarded mainly as tools for use in exploring the possibilities of districting situations, and in suggesting useful starting points for further refinement by human planners (Horn 1995; MacMillan and Pierce 1996).

A useful survey of automated procedures by Williams (1995) confirms that nearly all the published automated procedures were developed in the USA during the 1960s and 1970s. (For a discussion of similar underlying principles see Openshaw and Alvanides, Chapter 18.) The following account does not attempt to describe how the procedures work, and omits some interesting alternative approaches, the emphasis being rather on the rationale for what appear to be the most productive lines of attack. These can be characterised generally as aiming to produce districting plans that are in some sense optimal, or at least close to optimal, with respect to apportionment and compactness (or compactness-related) criteria. This is realistic in the overriding importance given to the principle of population equality, while compactness provides at least *prima facie* credibility with respect to geographical criteria, with possible substantive extensions as discussed below.

There are two main ways of combining apportionment and compactness criteria for optimisation. One line of research involves maximising apportionment equality subject to compactness and contiguity constraints; the more usual alternative however is to maximise compactness while satisfying apportionment conditions such as a maximum permitted deviation from the quota. Further alternatives are available for the definition of compactness itself: for the sake of clarity, they are discussed below with reference only to the compactness-maximising view of the optimisation task. It is assumed that a region is divided in advance into small-area units or *zones*, which are to be the building blocks for districts.

Radial compactness is defined in terms of distance or interaction costs, weighted by zonal populations, between the zones in each district and a district centre. The optimisation task then is to assign the zones to the centres – and to select the centres – so as to minimise the sum of these costs for all districts while satisfying the apportionment constraints. This approach has found a place in districting analysis due to its operational flexibility and its amenability to well-established location–allocation techniques (see Church, Chapter 20; Cova, Chapter 60, for examples in the context of emergency planning). It is attractive also because in principle it allows clusters to be defined in behavioural terms such as volumes of spatial interaction, possibly weighted by measures of 'social distance' (Morrill 1991). Yet because the centres themselves have no special significance, the compactness achieved is somewhat arbitrary, and involves an inbuilt bias against the formation of 'multi-nucleated' districts.

Procedures based on *circumferential* compactness seek to assign zones to districts so that the sum of interdistrict boundary lengths is minimised, subject to apportionment constraints and a requirement that each district should be contiguous (i.e. spatially connected). An effective procedure for this purpose has been developed by the author (Horn 1995) using a Kaiser–Nagel type of heuristic (Williams 1995), with provision for several additional conditions to be applied to an optimisation, as discussed below in section 5.1. The circumferential compactness formulation was first enunciated by Johnston and Rossiter (1981) in the purely geometric terms given above. A major deficiency of this approach is its sensitivity to irregularity in the definition of zone edges, and the consequent inbuilt bias against convoluted natural boundaries such as winding rivers (Morrill 1987). As an alternative however the edge lengths could be defined in terms of transportation infrastructure (e.g. road lanes) or spatial interaction (e.g. volumes of traffic) crossing each edge.

Minimising such a measure would have the effect of delineating clusters of zones with high levels of internal spatial interaction, which in turn would have some credibility as a proxy for the community of interest criterion.

5 GIS APPLICATIONS

A spatially-based approach to information management is clearly relevant to districting tasks, and the availability of powerful, well-structured GIS toolkits in recent years has made possible the development of software packages that are in effect tailor-made for districting. Such packages indeed are now available from most of the leading GIS vendors and a number of specialist companies (Hughes 1991); by contrast, it appears that the automated procedures mentioned in the preceding section have had a more limited commercial dissemination. Rather than enumerate the features of individual packages and procedures, the focus here is on the circumstances in which they are used, and on architectural and data requirements.

The coverage of districting in GIS journals and magazines makes it clear that the attention of technical staff in this area is very much taken up with data acquisition and preparation: for this purpose the full 'generic' range of GIS functionality is quite appropriate. By contrast, the making of districting plans involves specialised requirements and is normally carried out as a distinct activity. That activity moreover is often carried out under conditions of confidentiality by senior public officials or politicians with little technical knowledge, and so demands a more focused functional range than is provided in conventional GIS practice. It is therefore useful to distinguish between two categories of GIS application:

- Decision support, to provide assistance in making districting plans and investigating how well they satisfy relevant criteria (see Shiffer, Chapter 52).
- Support for data preparation, and for the production of maps and other publications that describe districting plans, including materials for electronic dissemination.

This suggests a configuration in which decision support and data management subsystems share access to a common database, and are built using a common kit of GIS tools. For example, MacMillan and Pierce (1996) describe how a key element in an optimisation procedure was implemented using an ARC/INFO Macro Language (AML) procedure. Relevant types of data include:

- spatially-disaggregated electoral enrolment or population data relevant to apportionment criteria;
- spatially-disaggregated data on socioeconomic, occupational, and other demographic attributes relevant to the community of interest criterion;
- voting information from previous elections, if this lies within the scope of the districting process (see section 3.1 above);
- spatial definitions for the small-area units from which the above three were collected;
- existing electoral and administrative boundaries, transportation networks, and other topographical data.

The main requirement is that electoral enrolment and (if possible) other demographic data should be available at a level of spatial detail consonant with the detail at which districting boundaries are drawn. In practice this is satisfied by data aggregated at the level of discrete small-area units, such as census enumeration districts: the fully-disaggregated alternative – with each person or household recorded and located separately – may be technically feasible, but is likely to come into conflict with privacy rules pertaining to such information. The main challenge with respect to voting statistics is to distribute this information spatially from its sources (i.e. polling stations) to the small-area units mentioned earlier, in order to provide a common basis for analysis and reporting. Attention may need to be given here to concerns over voting privacy, although inferred statistics are surely far less offensive in this respect than address-matched voting records under a full-blown 'electronic democracy'.

5.1 Australian experience

An account of Australian experience over the past decade will illustrate some of the issues discussed above, notably the coordination of different forms of spatial data and the directions in which districting support software may be expected to evolve. The requirements and GIS strategies of large public-sector GIS users may also be of interest here.

The Australian Electoral Commission (AEC) is the statutory authority responsible for managing the proceedings that define electoral districts for seats in

the Australian House of Representatives. Those proceedings are conducted separately in each state by a Redistribution Committee comprising the Electoral Commissioner, the state's Surveyor-General, and other senior public officials. The most important districting requirements in practice refer to community of interest and apportionment. With respect to the latter, the electoral law allows deviations from the state quota of ±10 per cent at the time of redistribution, and ±2 per cent halfway through the normal life of the redistribution, three and a half years later. The force of the narrower margin lies in the requirement for a new redistribution at the halfway point if at that time more than a quarter of seats in the state are malapportioned by the 2 per cent standard (some further conditions are omitted here for simplicity).

The AEC became interested in computer-based systems to aid districting processes during the late 1980s, partly in order to avoid the 'forced redistributions' mentioned above, partly to make effective use of the spatially-disaggregated demographic data which the Australian Bureau of Statistics (ABS) was then beginning to make available, and partly also to ease the cartographic burden which districting imposed on the staffs of the Surveyors-General. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), a national research organisation, was interested in technical implications of these issues, and in 1988 the Commission and CSIRO initiated a research project focused on the Interactive Territory Assignment (ITA) system, a spatial decision-support system that had been developed originally for related location-planning applications (Horn et al 1988).

ITA was attractive by comparison with the commercial GIS available at the time in two respects. First, it provided a graphical user interface and functional schematic directly orientated to districting needs, so that users of the system quickly became adept at building and modifying districting plans using very simple point-and-click operations. These basic manipulations were supported by map-viewing and data-enquiry functions related directly to the districting task, including for example the maintenance of histograms and demographic totals for the plan currently under development. ITA's second main strength lay in its incorporation of the automated districting procedure mentioned in section 4, which could be used in conjunction with the 'manual' functions to modify plans wholly or in part, at the user's discretion. A variety of conditions could be applied to an optimisation, including weightings on existing political or administrative boundaries, relaxation of the contiguity constraint (e.g. for archipelagos), and pre-defined clusterings of small area units (see Horn 1995).

The plan-making capabilities outlined above were underpinned by a spatial schematic based on small-area units called census collector districts (CCDs). By the late 1980s the ABS had recognised the possibility that these could have analytical as well as operational value, and had begun to define larger spatial entities such as local government areas as aggregations of CCDs. In a similar spirit the AEC had redefined the 'habitation walks' used for its electoral censuses in conformity with CCDs. The main benefits of these rationalisations so far as districting was concerned lay in the availability of electoral and demographic data under a common spatial referencing system, and in the use of the CCDs as building blocks for electoral districts. The latter did impose limitations on districting flexibility (especially in the case of large CCDs in remote areas), and the Redistribution Committees in several instances saw no alternative to splitting CCDs, reverting here (as still in map production tasks) to manual methodologies. Overall however the Committees found the new system very convenient in comparison with their previous experience with hand-made boundaries and hand-calculated apportionments.

The AEC and several of its counterparts at state government level made extensive use of the ITA over several years, and the system was also installed in the Australian Parliament for the use and edification of politicians. It was always recognised however that ITA's functional range was far from comprehensive, its main limitations lying in its rudimentary cartographic outputs, the absence of a CCD-splitting capability, and difficulties in database maintenance. For these reasons (most critically the last), the electoral authorities have ceased to keep ITA databases up to date with respect to newly-released demographic and geographical data, and for districting tasks have turned to general-purpose GIS such as ARC/INFO and MapInfo.

A new districting system called EDAMS promises a more comprehensive synthesis of GIS and decision-support functionality (Clifford 1996); see also the EDAMS output reproduced here as Figure 1 and Plate 57. EDAMS is being developed by the New

South Wales Land Information Centre, a leading provider of geographical data which has important support roles in electoral districting at both state and national levels. The new system incorporates an Oracle database and Microstation graphics engine, and borrows ideas from ITA and from software developed by the ABS for the 1996 census. It provides cartographic output of extremely high quality, ITA-like manual districting capabilities, and facilities for splitting small area units, as discussed earlier. The intention is to include automated districting and other features in the next stage of development, under an architectural scheme like that outlined in section 5.

6 FURTHER FIELDS IN POLITICAL GEOGRAPHY

Although this chapter has looked at technical and analytical challenges in political geography primarily from a public policy perspective, it is notable that (at least in the USA) political parties have been active users of GIS for many years. Two strands of interest can be distinguished in this respect. First, even under well-regulated districting processes a party will naturally try to see at least that it is not treated unfairly with respect to the political criteria outlined earlier, and will therefore have an interest in the development of alternative proposals, using perhaps the same tools as those employed by public agencies. The second strand is concerned with devising strategies and plans for electioneering, which involves a style of GIS analysis similar to that used in geographically-orientated marketing work (e.g. see Hagens and Fairfax 1996).

Some broader concerns of political geography deserve mention also. A country's territorial scope is a primary determinant of its citizenry, jurisdiction, and material resources, and the definition of

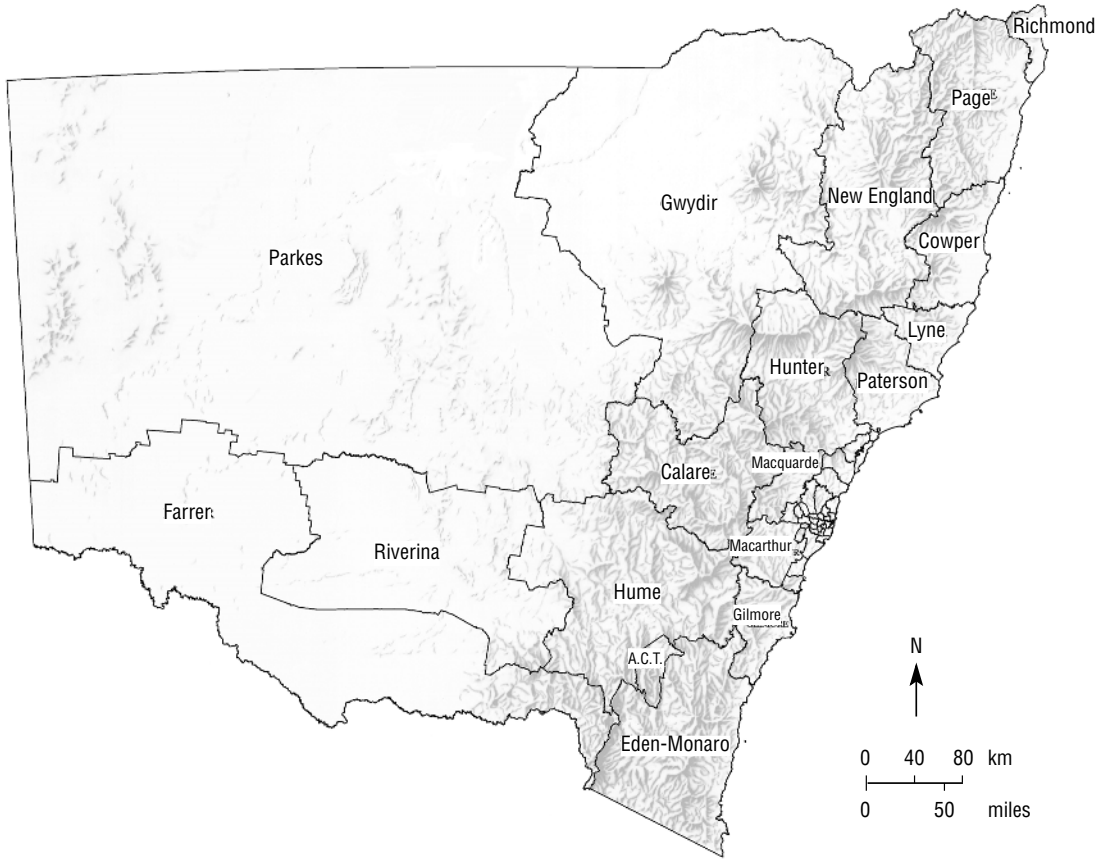

Fig 1. Map of New South Wales showing Australian House of Representatives electoral districts. Each federal electorate has about 70 000 electors.

international frontiers has often been the subject of catastrophic contention, for example in the former territories of the Austrian and Ottoman empires. Although they tend to be played out in a much more violent manner, these contentions often echo concerns (such as community of interest) that are encountered in drawing intra-national political boundaries.

Another area of analysis has to do with governmental decisions whose impacts have non-uniform geographical distributions. Such decisions sometimes are guided overtly by motives of political gain, as in 'pork-barrel politics', but even altruistic public policies have spatially-differentiated outcomes. Of particular interest here are policies concerned with the location of facilities such as schools and hospitals, and the provision of infrastructure for transport, communications, water supply, and so on. In such cases political analysis has similar objectives to the substantive analyses carried out by planners and policy makers, since in each case a major concern is with distributional impacts, summarised in the question: *Cui bono*? Who are the beneficiaries? And by extension, who are the losers?

Finally, it is interesting to consider how geography is treated in political discourse. Maps have played an important part in political propaganda, notably in graphic depictions of purported threats to national sovereignty. During the war in Vietnam, for example, posters and leaflets distributed by proponents of Australian involvement in that conflict included maps showing a red stain seeping southwards through southeast Asia, 'downward' towards Australia. Political cartoons also often use cartographic imagery by distorting or embellishing a map to make a telling image, as in the original 'gerrymander' mentioned in this chapter. Associated with these graphical figures are emotionally-charged geographical terms used in political speech, such as 'ghetto', 'homeland', 'sagebrush country, and 'small-town America'.

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