Extending Handivote to Handle Digital Economic Decisions

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There is a growing realisation that the populace need to be consulted on a more regular basis about issues that concern them. We address a particular economic problem, that of national budgeting, and show how digital technology can be applied in an understandable way in this domain. The current situation is that governments are reluctant to conduct plebiscites due to the expenses inherent in the traditional voting model. Handivote is a system which allows maximal participation, using a ubiquitous input mechanism, the mobile phone, to support decision-making. In this paper we show how the Handivote system could be extended to invite voter input into national economic decisions. Our proposal includes an algorithm which maximises voter satisfaction in the presence of budgetary constraints, and the preferences revealed by the vote.

Handivote, Electronic Voting, Digital Economy

1. INTRODUCTION

National Government constitutes roughly 35% of the economy in the UK (Dye & Sosimi (2009)) . Most research into digital economy focuses on the e-commerce sector which constitutes only 7% of the UK economy (WebDezign (2009)). There is clearly a need to start considering how to apply digital technology to the relationship between citizens and the government, which constitutes such a large slice of the economy.

In previous papers (Renaud & Cockshott (2009b,a)) we have shown how it is possible to organise secure and anonymous electronic voting. The voters register their plebiscite votes by mobile or landline phone. The plebiscites we've focused on generally have yes/no alternatives such as:

- Should smoking in public be banned?
- Should the UK get out of the Afghan war?
- Should Scotland be independent?

In this paper we extend the analysis to the more complex issues that arise with complex and conflicting demands on budgetary policy. We will show that it is possible to set up electronic voting systems that allow the public to make decisions on issues of tax and public expenditure, even though they perhaps do not understand the minutiae of the dependencies and conflicts that are involved in making these decisions. Such plebiscites differ from the classical subjects of plebiscites in that:

1. The decisions to be made are not binary but involve a range of possible options. For example, should public library expenditure go up by 1%, 2%, ..., 6% etc. This means that the results of the vote have to be expressed in numeric terms rather than as just a majority based "yes" or "no".
2. There are multiple different issues to be decided on. For example, they could be items of public expenditure which require adjusting and balancing: schools, hospitals, the Navy, pensions, etc. This means that the decision problem is multi-dimensional in the strict sense. This implies that the result of the decision must not only be numerical but must be a vector of numbers.
3. There are functional dependencies between items that can be voted on. Suppose the topics to be decided on are the public expenditure headings given above along with the tax rates for VAT, basic income tax, higher rate income tax and tobacco tax. This is not only a multidimensional problem, but it must be ensured that the change in taxes is sufficient to finance the change in expenditure.

Each of these problems will be considered in turn, resulting in the proposal of a model that can handle all of them.

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2. THE HANDIVOTE SYSTEM

We first proposed a procedure for electronic plebiscites in Renaud & Cockshott (2007). A summary of the procedure is included here for the sake of clarity. The voting takes place in three distinct stages: registration, voting and verification.

1. Voters register, in person, presenting a recognised form of identification to the registration officers. A record of their registration is taken to ensure they do not register multiple times.
2. They then choose a sealed envelope from a jar. The envelope contains a voter card that looks like a credit card. The voter card contains a SIM chip, and has printed on it two numbers, a voter ID number and a PIN. Note that only the voter him or herself will know which voter ID number is associated to him or her.
3. When the voting period commences, the citizen can use this card to place a vote. The vote can be placed either at the polls, or via a number of electronic channels. In all cases the voter ID number and the PIN have to be used, either manually or by automatic readout from the SIM, to tag the vote. Only correct combinations of ID and PIN will be registered as valid votes. Note that since only the citizen him or herself knows which ID number is on the card, the voting process remains anonymous until voting has concluded.
4. Votes are counted electronically and the final result published. After the voting has closed, the voter is able to verify that his or her vote has been recorded correctly, Because the entire list of voter ID numbers registered for the YES and NO alternatives is published (on the web and in the press). This allows:
   - Citizens to check that their vote was correctly registered.
   - Anyone with access to the published list of votes can verify that the count was correctly performed.

The procedure we proposed had a number of checks and balances to ensure that votes were counted correctly and that the entire process was as transparent as possible.

To summarise, the principles of our voting process are:

1. Voters shall choose a random voter card when they present their identification to the electoral office and this identification matches the name on the voters roll. This ensures that only eligible voters vote and that they can vote anonymously.
2. Voters may place their vote using a variety of devices including mobile phones, landline phones, public phones and the polling booths. This lowers barriers to participation and mobility of voters.
3. An electronic re-vote on a particular voter card number will void the previous vote if it is different from the original vote. This discourages voter card theft.
4. Lists of voter cards together with votes cast are made publicly available once the election period has concluded. This provides the transparency often lacking in current e-voting processes. It is also possible for any voter to check the accuracy of the count. It also ensures that no person or group will know the intermediate outcome and have time to mount a massive coercion-based attack to swing the outcome of the plebiscite. Lauer argues that having a voter verified audit trail is the only effective countermeasure against a number of electronic voting threats Lauer (2005).
5. Finally, our system is characterised by the simplicity of the voting process. Voters either put the voter card into a voting machine and choose an option from the display, or contact the voting line by phone, provide their card number and PIN, and choose an option. There are no complicated extra steps involved as is the case for other e-voting schemes.

The Rowntree Reform Trust's report Purity of Elections in the UK: Causes for Concern Wilks-Heeg (2008) stated that: "e-voting pilots have proved extremely expensive and there is no evidence to suggest that e-voting offers any significant scope for turnout to be increased by this means. At the same time, serious concerns persist about the security and transparency of e-voting systems and their vulnerability to organised fraud"

Concerns were particularly raised about e-counting: "Not only has e-counting frequently failed to improve on the estimated time required for a manual count, it has also highlighted the lack of transparency in such a system". Furthermore, they point out that there were 42 convictions for electoral fraud between 2000 and 2007. Moreover, every English police force except the City of London has investigated electoral malpractice allegations since the year 2000. Finally, there were concerns about the credibility of the voters roll, with many voters not being registered and postal voting has been shown to be open to wide-spread abuse.

Does Handivote offer a viable alternative to existing systems? We believe that it does. Let us consider the problems highlighted by this report:

Increasing turnout By offering voters an opportunity to vote from their phone, mobile phone or public phone, we lower the bar. It makes voting as convenient as placing a phone call, and removes the need for voters to visit polling stations.

Transparency The verification phase included in our proposal allows voters to verify that their vote was recorded correctly, from the comfort of their own homes; either on the TV or via the Web.

Expense Our scheme requires voters' cards to be produced. Once this is done, existing devices will be able to read the embedded chip, removing the need for expensive devices to be purchased.

Coercion If a voter is coerced to place a vote which was not intended, he or she can simply visit the polling stations and vote there. This vote replaces the earlier vote.

Vulnerability to organised fraud Our system is able to provide some resistance. If two votes are cast using the same voter card number, the original vote is voided, hence the person who has attempted to break into the system will not have his or her vote counted.

E-counting problems Problems in the Scottish elections of 2007 occurred because votes were recorded manually and then scanned into a system to be electronically counted. This was bound to be a problem since people became confused and recorded their votes incorrectly. Furthermore, handwriting variety led to the software being unable to recognise numerals.

Handivote, as it stands, caters for standard plebiscites. The following section outlines the proposed extension of Handivote to support voter input on multidimensional issues.

3. NUMERIC OUTCOMES

In a standard plebiscite people vote "yes" or "no" and whichever gets the greater number of votes triumphs. We have shown how this schema could be securely mapped onto a procedure involving sending text messages to a single number. There is another way of viewing this procedure as one which first computes a rational number and then thresholds it. Suppose we have yes$= +1$ and no $= -1$, then the total vote V is calculated as:

$$V = \frac{\sum_{i=1}^{n} v_i}{n} \tag{1}$$

Where n is the number of votes cast and v_i ranges over the individual votes. This number V is in the range $-1..1$and we declare the result a yes vote if $V > 0$.

It is clear that one can extend this view of standard plebiscites to obtain numerical outcomes from a vote. Suppose there are 3 telephone numbers that you can text for a vote on library expenditure:

- xxx xxx0 means reduce it by 5%,
- xxx xxx1 means leave it unchanged and
- xxx xxx2 means increase it by 5%

It is clear that by applying the method in Equation 1 we can obtain a value of V that is a numeric percentage change in library expenditure. The result is the average of what the voters want. This will, in our case, be bounded by -5% to +5%, but these bounds could be varied by those setting the vote, and, at the cost of some slight increase in complexity, a broader range of numbers to dial could be provided without changing the basic procedure.

4. MULTIDIMENSIONAL OUTCOMES

Now suppose that there are three items to be decided on: local council tax, school expenditure and library expenditure. A simple extension would be to set up phone numbers for voting as follows:

Phone number	*Topic*	*Change*
xxx xx00	Council tax	down 5%
xxx xx01	Council tax	leave as is
xxx xx02	Council tax	up 5%
xxx xx10	Libraries	down 5%
xxx xx11	Libraries	leave as is
xxx xx12	Libraries	up 5%
xxx xx20	Schools	down 5%
xxx xx21	Schools	leave as is
xxx xx22	Schools	up 5%

People could then text in to express their personal decisions. The result of applying the procedure in equation 1 to this would be to obtain a vector result $\mathbf{V}$ each of whose elements was a numerical outcome for a particular topic $\mathbf{V}_o$ the vote on council tax, $\mathbf{V}_1$ on libraries etc.

It should not be necessary for voters to express their opinion on all possible issues under consideration. They should be allowed to vote only on those issues that they are most concerned about or those that affect them. As long as sufficient people vote on each individual issue, the law of large numbers means that will get a reasonably accurate estimate of public opinion on that topic. Surowiechi (2005) shows that an opinion aggregated from many non-experts is usually superior to that of a few experts.

5. FUNCTIONAL DEPENDENCIES

If we consider the example given in section 4, there is no guarantee that the proposed changes to tax and expenditure would be compatible. It is likely that people will vote for increases in expenditure but not vote sufficient tax increases to cover this. How can this be handled?

Let us first consider a simple case in which there are only two topics being voted: schools and taxes. Suppose that the vote was [4, 2] indicating a 4% increase in school expenditure and only a 2% increase in taxes to cover it (let us make the simplifying assumption for now that schools are the sole form of expenditure). Figure 1 shows the average vote at position [4,2] and also a diagonal line representing the feasible combinations of expenditure and tax. The best choice given the constraints is labeled 'compromise'. This is the point on the feasible set closest to the selected vote: expenditure is a little lower and tax has risen a little more than people chose in the absence of the functional dependency. In our practical example this will be the point [3,3] which is a 3% increase in tax and a similar increase in expenditure. Whilst this might seem an obvious averaging compromise, it can be obtained by the following geometric steps:

1. Obtain the unit vector in the direction of the feasibility set. In our case since we have a 45 degree line as the feasibility set, the unit vector will be $[\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}]$.
2. Project the point chosen by the voters onto this unit vector, obtaining the distance along the unit vector at which a line normal from it will pass through the vote point. This projection can be done using an inner product operation $[\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}].[4, 2]$ which gives $\frac{4}{\sqrt{2}} + \frac{2}{\sqrt{2}} = \frac{6}{\sqrt{2}}$.
3. Convert from a distance along the vector to a position in the original coordinate space by multiplying the unit 45 degree vector by the distance $[\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}] \times \frac{6}{\sqrt{2}} = [3, 3]$.

We illustrated this using a two dimensional system, but for a general n dimensional case were there are l taxes an m expenditure items, and $n = m + l$ there will be a linear constraint of the form

$$\sum_{i=1}^{m} \mathbf{V}_i a_i = \sum_{j=1}^{l} \mathbf{V}_j b_j \quad (2)$$

where the a_i represent share of total expenditure going on item i and b_j is the share of total income obtained by tax j. This constraint defines an $n - 1$ dimensional sub manifold F that constitutes the feasible set. The best compromise, given the vote will be the point of intersection between F and the line normal to F passing through $\mathbf{V}$.

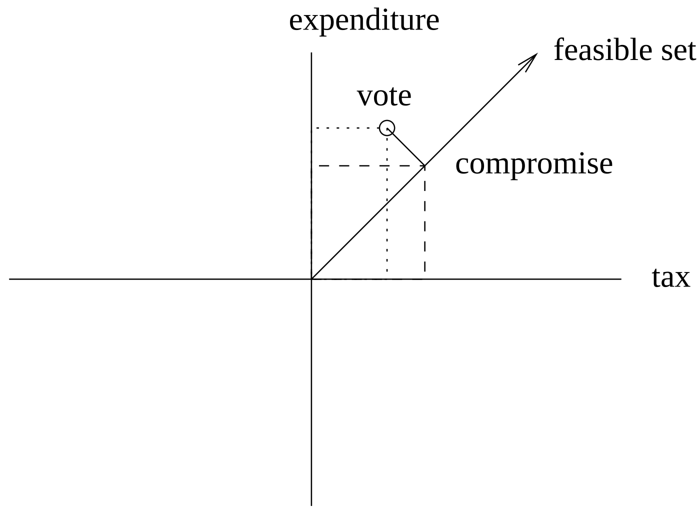

Figure 1: *Choosing between two functionally constrained options.*

We can extend the 2D method of finding the closest point for the general case of budgetary constraints as follows. Given an equation for the plane of the form $a_1x_1 + a_2x_2 + ... + a_nx_n = 0$ (we have combined the a_is and b_is in equation 2). We define the normal vector

$$N = [a_1, a_2, ..., a_n] \quad (3)$$

and let $\mathbf{V}$ be the vote point. We wish to find the compromise point C on the feasibility set closest to the vote point.

Let **n** be the normalised version of N, i.e., the vector of unit length going in the same direction as N. The closest point in the plane to the given point $\mathbf{V}$ is on the line which passes through $\mathbf{V}$ and which is perpendicular to the plane. Since the line is perpendicular to the plane, the normal vector of the plane gives the directional vector of the line. The equation of the line must thus be :

$$L(k) = \mathbf{V} + k\mathbf{n} \quad (4)$$

for some real parameter k. We find k by doing a dot product with the normal unit vector thus : $k = \mathbf{V}.\mathbf{n}$. Then subtract $k\mathbf{n}$ from $\mathbf{V}$ to obtain the point on the plane.

$$C = \mathbf{V} - k\mathbf{n} \quad (5)$$

C is then the best compromise vote given the budgetary constraints.

It should be noted that our optimisation procedure implicitly uses a Euclidean metric, by virtue of its use of inner product operator. It could be questioned whether a Euclidean metric is appropriate in this economic context Cockshott (2009). It is possible that some sort of L1 or Minkowski metric is strictly more appropriate. However, this is a rather abstruse mathematical point and is unlikely to give radically different results from the more familiar Euclidean metric. One has to bear in mind that if experiments with this sort of voting are carried out, it will be necessary to explain to politicians and to voters how the compromise mechanism works. This can be done relatively easily with the sort of example shown in Figure 1 which uses simple planar geometry of the sort an educated non-mathematician can understand. Attempting to explain Minkowski metrics to politicians is probably best avoided.

6. SOCIAL ASPECTS

One of the most basic requirements of any voting system is that it should be understandable by all sectors of the population. Paper-based voting has this understandability and electronic voting proposals struggle to meet this requirement. The one aspect of multidimensional voting that will be core to its success is its understandability and acceptability to the public at large. No politician will undersign any voting system that could cost them votes.

The Scottish elections of 2007 are a prime example of a too-complicated system. Voters were given two sheets: on one they were requested to place a cross next to only one candidate. On the other they had to rate various candidates. The result was a fiasco, with 140 000 votes being discarded.

Some researchers mention the acceptability aspect in their publications. Costa et al. (2005) argue that acceptability will be based on the usability and trust the populace place in the system. Xenakis & Macintosh (2005) argue that if security is enhanced then acceptance will result. Other researchers are more concerned with the acceptability of the scheme to the public body than to the individual voter (Bouras et al. (2003)).

Schaupp & Carter (2005) carried out a study to determine which factors did influence acceptability of electronic voting systems. The factors they identified included the trust aspect, as argued by Costa *et al.*, but also highlighted the influence of *perceived usefulness* and *compatibility*. The former relates to the extent to which the individual voter believes that the use of the electronic voting system will allow them to participate in the election process more efficiently. Compatibility relates to the person's previous experiences. For example, if the system in question were an online voting system, then previous use of the Web for e-commerce or other tasks would pre-dispose the person to use the same mechanism for voting. Schaupp and Carter's model did not list ease of use as one of the influential factors but they admit that their sample was composed of relatively expert computer users and that this factor was unlikely to be relevant for such a population Indeed Carter & Belanger (2005) did identify ease of use as being an influential factor, also confirming the roles of trustworthiness and compatibility. Storer *et al.* Storer et al. (2006) found that convenience, mobility and verification were important to voters. The first two could arguably be classified as being related to usefulness and the latter is directly related to trust.

These, then, are the aspects we need to focus on to maximise acceptability of multidimensional voting:

- Trust — this has two aspects: trust in the government and trust in the voting system. The former is not a function of the voting system and so we need to ensure that the voting system itself engenders sufficient trust. However, if voters are concerned that the way they voted could be held against them at a later date, the Handivote system becomes particularly attractive since there is no link between the voter and the vote. Handivote has been designed with specific features to provide feedback throughout the process specifically to show concerned voters exactly what the underlying processes are, and how their votes have been stored and counted.
- Ease of use — we have to ensure that the casting of a vote is as simple as possible. The requirements for interacting with the system will have to be very clear. However, multidimensional voting is clearly different from the way many voters will have voted in the past and there is no track record which could be consulted to guide our efforts. Therefore we will have to carry out a number of pilot studies to uncover the problems and work towards addressing them in order to make the process as usable as possible.
- Usefulness — facilitating voting by mobile phone ensures that voters are no longer bound by geographical or time constraints so the usefulness of this system should be obvious to voters.
- Compatibility — in the UK mobile phone saturation is over 100% (Deans (2008)) so there should not be any resistance to the use of the phone based on people's familiarity with the device.

7. SECURITY ISSUES

This proposal raises the issue of whether a person should indeed be allowed to vote for more than one topic?

One alternative would be that individual voters should be able to cast as many votes as there topics being decided, so they would have 3 in our example. Another alternative would be that each voter should have only one vote which they cast on the single topic that most concerns them.

Whichever alternative is chosen, the voting software is going to have to tally up how many votes each voter has cast. It is obvious that no voter can be allowed to register multiple votes on the same topic. A parent should not be able to vote 3 times to raise school expenditure by 5%. One could either invalidate any subsequent votes cast on topic x by voter $yyyyy$, or take the last vote cast as final, but this may raise interesting issues relating to stolen card numbers. We have previously argued that in an ordinary plebiscite the best option is to invalidate any vote that is part of a set of inconsistent votes cast using the same registration number. This both allows a voter to partially correct a mistake in voting the first time, and also provides an deterrent against stealing card numbers. Any attempt to use a stolen card number which clashes with the original decision of the voter will be invalidated, thus limiting the gain to be made from attempting to cast duplicate votes. We think that the same argument applies to multi-dimensional referenda.

7.1. Incorrect tax or expenditure data

The proposal to take a vote on budgetary issues and then move to a compromise position compatible with a balanced budget is open to a subtle form of manipulation. If we assume that it is unlikely that the popular vote will be exactly on the feasible hyperplane, and that it will have to be nudged over onto the hyperplane, then the chancellor of the exchequer could in principle manipulate the outcome of the vote by misreporting the share of government revenue raised by various taxes.

Suppose people can vote on 2 taxes: VAT, income tax. Suppose that in fact VAT raises 25% of govt revenue and income tax 75%. If the electorate votes for a 4% rise in expenditure and a 1% rise in VAT and a 3% rise in income tax, then the compromise position by equation 5 should be :

VAT	Income Tax	Expenditure
1.23%	3.69%	3.08%

But suppose that the chancellor dishonestly states that VAT raises 50% of revenue, and the voters make the same choice, then the compromise position will be worked out at:

VAT	Income Tax	Expenditure
1.67%	3.67%	2.67%

In other words the increase in expenditure will be smaller because he has overstated the share of revenue raised by an unpopular tax. Thus manipulation of data on tax returns could enable the government to tailor the result of a vote. Effectively what they would be doing is adjusting the slope of the hyperplane representing the balanced budget. This sort of manipulation shades off into the general question of the reliability and honesty of official statistics and whether these are subject to political manipulation.

7.2. Non-linearities

Our model implicitly assumes a linear response of tax income to changes in rates. This assumption is probably false for real economies Gruber & Saez (2002); Giavazzi et al. (2000). However a non-linear function can usually be approximated reasonably well by locally linear segments. If the marginal changes made to taxation as the result of a vote are relatively small, the locally linear approximation is likely to be good enough. One should also consider that the existing process by which the treasury arrives at tax and expenditure levels will itself be based on similar approximations.

8. CONCLUSION

This paper has described the extension of the Handivote system to facilitate a new kind of social decision making, where multidimensional issues are involved. We have described the mechanism and detailed algorithms for supporting this. This potentially allows the extension of democratic participation by means of the latest informatics technologies.

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