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RAPID SEARCH AND SELECTION OF PATH GENERATING MECHANISMS FROM A LIBRARY

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Abstract—Using an harmonic analysis, the coupler curve of any mechanism may be stored as a series of coefficients independent of mechanism type. A process of normalization can be applied to the coefficients. By storing the normalized coefficients and associated dimensions of a large number of dimensional variants for one particular mechanism type, a catalogue can be created. Catalogues for a wide variety of different mechanism types are combined together in a library. A method whereby this library can be created and searched to find the best "seed" mechanisms for subsequent optimization as a path generator is discussed.

BACKGROUND

The selection of a mechanism as a path generator is traditionally carried out by means of firstly a process of "type" synthesis followed by "dimensional" synthesis. Type synthesis is the process of choosing the kind of mechanism from the diversity of possible types, e.g. the use of a crank-slider as opposed to the use of a four-bar-linkage. Dimensional synthesis is the modification of the kinematic parameters associated with the chosen mechanism to give the desired performance.

The constraints or rules governing the choice of mechanism type are normally an initial subset of those used during the final dimensional synthesis. The greater care that is taken during the initial selection, the more likely the final mechanism synthesized will meet all the constraints. It is therefore desirable to have as many of the rules governing the final performance requirements of the mechanism available to the designer during the selection of the mechanism type. Great care should thus be taken in the initial selections, as a poor choice can severely limit the possibility of meeting all the constraints applied to the final mechanism.

At present there is great difficulty for the inexperienced designer in finding a mechanism to undertake a particular path generation problem. The wealth of kinematics analysis packages on the market encourages experimentation and trial-and-error approaches to finding a suitable mechanism. Sometimes more complex cam mechanisms are used simply because less well known linkage solutions have not been considered. Similarly, lower quality solutions to the problem may become acceptable since more complex linkage types could not be investigated fully. Where extensive atlases of mechanisms [1] are available to the designer, the process of finding a useful "seed" is time consuming and prone to human error, since scaling, translation, and rotation of curves appearing in the presented solutions must take place in the mind.

HARMONIC ANALYSIS

Many other methods of mechanism classification are possibly based on output function [2], however there appears to be no method of mathematically quantifying this function in a non-dimensional general description. Broad titles of "motion intermittent rectilinear", "straight-line mechanisms" are fine for texts but do not allow for rapid selection of mechanism type via digital computers. Expert systems perhaps represent the only technique for looking at this kind of problem.

Harmonic analysis has been used successfully in the past for synthesis of mechanisms both type and dimensionally. Using harmonic analysis the performance of the mechanism is described using a set of Fourier coefficients.

The TADSOL paper by Rankers *et al.* is a major reference[3]. Here Fourier series models of a desired task are matched against a number of models each for a different mechanism, stored in a catalogue. Choices are made from the catalogue of the mechanisms which are most able to emulate each of the harmonics. The theory also allows the dimensionless synthesis of the selected types of mechanism using the values of the Fourier coefficients of the goal function. The technique is used only for problems of function generation. The cataloguing system contains the Fourier configurations and shift criteria for each mechanism along with the required analysis routines. In this theory there is an explicit relationship between the Fourier coefficients and the mechanism parameters. The CADOM project of the Delft University of Technology utilizes this technique as part of an overall approach to mechanism design [4].

Bogdan and Larionescu [5], used complex harmonic analysis as an aid to synthesis of timing dependent path generators. The technique was useful in that synthesis was undertaken on binary structure groups (consisting of two links connected together) rather than the entire mechanism itself. The methodology began by determining the desired set of Fourier coefficients. After this a process of qualitative synthesis could be undertaken. This determined whether the proposed arrangement of binary groups would meet the desired set of coefficients. If this was not the case then another arrangement could be proposed. In the final stage of dimensional synthesis, equations relating the Fourier coefficients produced by the binary group itself were created. Using a considerable amount of algebraic manipulation, an infinite system of non-linear equations was generated. It was found that this could be readily solved by successive elimination of a series of variables. Some examples of the use of this methodology in the synthesis of four and five bar mechanisms are given in another paper [6].

Research undertaken at Brunel University [7] has shown that Fourier series approximations provide a compact and useful way of representing closed curves. The theory differs from the classical approaches of Bogdan and Rankers in that there is no explicit relationship developed between the Fourier coefficients describing the curve and the mechanism parameters. Firstly the mechanism is analysed by means of constraint modelling to determine a series of points on the coupler curve [9]. This stage of the analysis is not covered here since essentially any kinematics analysis package can easily generate a series of points on the coupler curve. A numerical technique is then applied to evaluate the complex Fourier coefficients of the curve. These coefficients are generated independently of mechanism type and a secondary process of normalization removes the effect of scale, translation, rotation, and input-crank start angle. The mechanism catalogue is then created using a wide range these normalized coefficients and associated dimensions.

THEORY

A typical point on the plane curve is specified by coordinates x and y which are functions of some parameter t. If the curve is closed then these functions are periodic and here the period is unity. If the curve lies in the complex plane, we specify the coordinates by a single complex function

$$z(t) = x(t) + iy(t)$$

where

$$i = \sqrt{-1}.$$

For a closed curve, z is also periodic and so

$$z(t+1) = z(t)$$

$z(t)$ can be expanded in a Fourier series [8]

$$z(t) = \sum_{m=0}^{\infty} a_m \exp(2\pi imt).$$

The coefficients are non-real and are given by

$$a_m = \int_0^1 \exp(-2\pi imt) z(t)\, dt.$$

The derivation of this relates back to the orthogonality condition defined in following integral [8]

$$I_{m,n} = \int_0^1 \exp(2\pi imt)\exp(2\pi int)\,\mathrm{d}t = \begin{cases} 0 \text{ if } m = -n \\ 1 \text{ otherwise} \end{cases}$$

Among the coefficients, a_0 is regarded as belonging to the *fundamental*, coefficients a_1 and a_{-1} as specifying the *first harmonic*, a_2 and a_{-2} the *second harmonic*, and so on.

If a coupler curve is given, not as a function of mechanism parameters, but as a sequence of points around the curve, the integrations can be numerically calculated. Suppose there are N points

$$z_0, z_1, \ldots, z_{N-1}.$$

This sequence is circular; i.e. if a subscript does not lie between 0 and $(N-1)$, it is reduced modulo N. Generally, the points are for equally spaced values of the parameter t, so that the step length in t between them is $1/N$. The trapezium rule applied to the integral defining each Fourier coefficient yields the following approximation.

$$a_m = (1/N)\sum_{k=0}^{N-1} z_k \exp(-2\pi imk/N).$$

If $m = 0$, it is seen that the fundamental coefficient is simply the average of the points. That is, it represents their centroid. This is true also for the integral representation.

Now consider the contribution made to the Fourier series by the two first harmonic terms, that is by the following function.

$$z_1(t) = a_1\exp(2\pi it) + a_{-1}\exp(-2\pi it).$$

Each Fourier coefficient can be written in complex exponential form

$$a_m = r_m \exp(i\phi_m)$$

where

$$r_m = |a_m| \quad \text{and} \quad \phi_m = \arg(a_m).$$

Hence

$$z_1(t) = r_1\exp[i(2\pi t + \phi_1)] + r_{-1}\exp[i(-2\pi t + \phi_{-1})]$$

and this can be rearranged in the form

$$z_1(t) = \exp(i\alpha)\{r_1\exp[i(2\pi t + \beta)] + r_{-1}\exp[i(-2\pi t - \beta)]\}$$

where

$$\alpha = (\phi_1 + \phi_{-1})/2 \quad \text{and} \quad \beta = (\phi_1 - \phi_{-1})/2.$$

Expansion of the complex exponentials inside the square brackets yields

$$z_1(t) = \exp(i\alpha)[(r_1 + r_{-1})\cos(2\pi t + \beta) + i(r_1 - r_{-1})\sin(2\pi t + \beta)].$$

The term inside the square brackets represents an ellipse whose centre is at the origin and whose semi-major and semi-minor axes are $(r_1 + r_{-1})$ and $(r_1 - r_{-1})$. The major axis is along the real axis. The effect of the complex exponential is to rotate the shape through an anticlockwise angle α.

Provided $r_1 > r_{-1}$, the semi-minor axis has positive length and the ellipse is traced out anticlockwise as t increases from 0 to 1. If $r_1 < r_{-1}$, the curve is traced out clockwise. In the case when $r_1 = r_{-1}$, the ellipse collapses to the straight line segment at angle α to the real axis.

NORMALIZATION

For most practical purposes the first five harmonics give a good approximation of a mechanism coupler curve. A process of the normalization may then be applied in order to eliminate the effects of scale, translation, and rotation and input-crank start angle in both the set of Fourier coefficients and the dimensions of the original mechanism.

The translation of the curve is carried out by making the coefficient a_0 zero. $[z(t) - a_0]$ represents a closed curve in the complex plane whose centroid is at the origin.

The major axis of the coupler curve is at an angle $\alpha = (\phi_1 - \phi_{-1})/2$ to the x-axis. Normalization proceeds by rotating it through an angle $-\alpha$ about its centroid. The effect on the Fourier coefficients is to multiply each by $\exp(-i\alpha)$, i.e. to subtract α from each argument.

The ellipse for the first harmonic is traced out anticlockwise if $|a_1| > |a_{-1}|$. Standardization on the direction around the original curve is achieved by specifying that if this inequality does not hold then the direction is reversed (equivalent to changing the direction of the input crank). The effect that this has on the Fourier coefficients is simply to interchange a_m and a_{-m} for each m.

The length of the major axis of the ellipse for the first harmonic has length $|a_1| + |a_{-1}|$. The normalization of scale proceeds by making the magnitude of a_1 unity by dividing all the Fourier coefficients (all points on the original curve) by $|a_1|$. (It is assumed here that this value is non-zero; care is required in the exceptional cases).

The normalization carried out so far has reduced the first harmonic coefficients and their ellipse to the following forms.

$$a_1 = \exp(i\beta)$$

$$a_{-1} = r_{-1}\exp(-i\beta)$$

$$z_1 = \exp[i(2\pi t + \beta)] + r_{-1}\exp[i(2\pi t - \beta)]$$

where

$$0 \leqslant r_{-1} \leqslant 1$$

and

$$\beta = (\phi_1 - \phi_{-1})/2$$

(which gives the modification necessary to input-crank start angle).

We now change the parameter from t to s where

$$s = t + \beta/2\pi.$$

As s varies between 0 and 1, the same closed curve is traced out. All that changes is the position where plotting starts. This is at the point where the original parameter t is $-\beta/2\pi$.

Noting,

$$\exp(2\pi imt) = \exp(2\pi ims)\exp(-im\beta)$$

the effect on the Fourier coefficients is to replace a_m by

$$a_m \exp(-im\beta).$$

This means that the first harmonic terms, a_1 and a_{-1}, become purely real; in fact a_1 is now unity, and a_{-1} is r_{-1}.

By storing the performance information (in this case the coupler curve) of the mechanism in terms of its normalized Fourier coefficients it then becomes readily possible to compare the set of normalized coefficients with a set of coefficients derived from any arbitrary curve.

In Fig. 1, a four-bar-linkage mechanism undergoes harmonic analysis. The coefficients for the first five harmonics are given in Table 1.

After normalization the Fourier coefficients become those in Table 2 and application of the normalization transforms gives the mechanism shown in Fig. 2. The mechanism has been translated 1.3966 units horizontally, -1.5316 units vertically, the rotation is $-76.924°$ overall. A scaling factor of 0.9147 is applied and modification of 64.3584° to the crank start angle is given. Finally the mechanism is reflected in the x-axis to ensure that the modulus of the imaginary part of the coefficient a_{-2} is greater than zero (reflecting a curve in the x-axis has the effect of negating the imaginary parts of the coefficients).

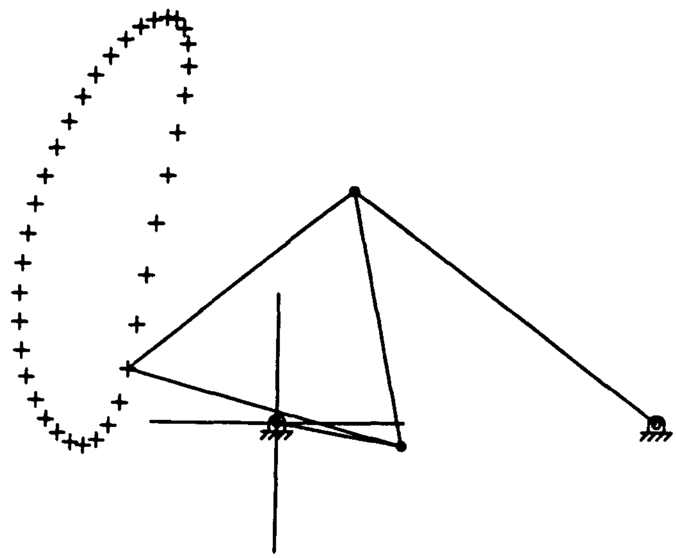


Fig. 1

TIME INDEPENDENCE

In the harmonic analysis of the original set of points which describe the curve, it may be necessary to include or exclude the timing information relating to the velocity of the coupler point around the curve. Obviously, with the timing independent approach, only the shape of the coupler curve is of importance. This choice is included in the original Fourier analysis.

In the previous sections, the coordinates of a given point are determined as functions of a parameter t. The parameter does not actually affect the shape of the curve produced.

The effect of changing the parameterization is to alter the speed at which the curve is traced out as t varies steadily. In this sense, t represents time. If interested only in analysing the shape of the curve itself it is necessary to be independent of this time factor. The procedure now described produces reasonable results.

The curve is parameterized differently, this time in terms of chord length. Firstly a set of points around the curve are evaluated as usual from kinematic analysis. This is generally undertaken using equally spaced values of the original parameter t (except in the case of four-bar linkages which do not satisfy Grashof's conditions of assembly—here the crank direction is reversed twice throughout kinematic analysis). The distance between consecutive pairs of points is taken. Then the value of the new parameter at any one of the points is the sum of these distances for points between the start point and the required one.

If the trapezium rule is applied to evaluate a Fourier coefficient, the summation used needs to be revised as follows.

$$a_m = (1/N) \sum_{k=0}^{N-1} (1/2)(t_{k+1} - t_k)\{z_{k+1} \exp(-2\pi i m t_{k+1}) + z_k \exp(-2\pi i t_k)\}.$$

Table 1

	Real	Imaginary
−5	0.003831	0.000633
−4	0.008201	0.008759
−3	0.005862	0.038328
−2	−0.059161	0.113159
−1	−0.446741	0.358131
0	−1.396631	1.531649
1	1.067099	0.237849
2	0.039487	0.078974
3	−0.002570	0.007710
4	−0.002390	0.001195
5	−0.000560	−0.000187

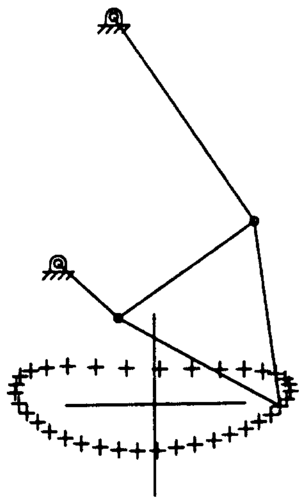


Fig. 2

Table 2

	Real	Imaginary
−5	0.003096	0.001740
−4	0.003296	−0.010469
−3	−0.035058	−0.005362
−2	0.003995	0.116727
−1	0.523715	0
0	0	0
1	1.0	0
2	−0.034423	−0.073059
3	−0.005294	0.005218
4	0.002196	0.001074
5	0.000063	−0.000536

Note that the same normalization procedures may be used on coefficients with time independence.

PROGRAMMING PLATFORM

The technique of constraint modelling has been used successfully at Brunel University and several companies for a wide variety of mechanism problems. RASOR [9] is the name of the constraint modeller which is in its simplest form a programming language, but with the ability to solve a series of implicit rules or constraints which the user may specify on any problem. By electing variables within the system with which to solve these rules, the system can optimize a particular design (which may be a mechanism problem). Using the constraint modeller mechanisms can be analysed fairly easily using only a small amount of coding. Where the closure of the mechanism cannot be solved easily using explicit equations, the constraint modeller allows them to be solved implicitly. These factors provide a useful framework for kinematic analysis and dimensional synthesis of path generating mechanisms.

Inbuilt functions in the RASOR programming language allow the Fourier analysis and normalization procedures to be carried out quickly and simply.

The constraint modelling technique employs Powell's [10] method of optimization for resolution of the constraints. It has been found that for highly non-linear applications, such as the optimization of mechanisms, better results can be achieved when a starting from a good seed. Arising from this need prototype programs on RASOR now allow the user to select a mechanism type as well as a basic set of dimensions for the mechanism prior to optimization.

THE METHODOLOGY

The new methodology makes it possible to select from a library a series of mechanisms which will execute a given motion and use one or more of these "seeds" for subsequent optimization. (This higher level optimization is not covered in this paper.)

A library has been created consisting of a number of catalogues. The catalogues are files containing a large selection of variants of one particular mechanism type. These contain the Fourier coefficients of the closed curve traced by some point on the mechanism as well as the mechanism dimensions and other parameters for each individual linkage. The stored Fourier coefficients are normalized dimensionally so that the curves are completely independent of scale translation, and rotation. The normalized kinematic parameters of the linkage required to give this normalized curve are stored in the file associated with the set of Fourier coefficients. Normalized mechanism parameters can be obtained directly by applying the normalization transforms obtained during the normalization of the coupler curve to the mechanism model.

CREATION OF THE CATALOGUES

Each catalogue is intended to give a broad selection of the "coupler point" paths that can be achieved for a particular mechanism type. Thus, the range of variables held for each mechanism type must firstly be limited both in range and incremental variations. Obviously, if the step size is small over the range of each variable than a vast amount of information will be stored in the catalogue. With a large amount of independent variables required to describe a mechanism there is a danger of running into storage problems for that mechanism type.

Because the mechanisms are stored in normalized form, the number of required variables for description is reduced. We are therfore more interested in link length ratios, rather than a value for the length of each member.

During the creation of the catalogue any combination of link length ratios that do not allow the mechanism to assemble over the full range of rotation for the crank are rejected. In addition, coupler paths which form a circle, or an arc are of less interest and may be rejected at this stage. The same principle applies to more complicated linkages which are effectively giving the same performance as types comprising fewer members.

The way in which a catalogue for a particular mechanism type has been written is shown in the block diagram of Fig. 3. The Fourier analysis will either be time dependent or time independent. When using time independent analysis it is possible to analyse coupler curves of mechanisms such as four-bar double rocker linkage etc.

Prior to creation of the catalogue a list of mechanism dimensions which are to be tested in the program which writes the catalogue are put into a separate file. In the case of a four-bar chain values are chosen for the five design parameters by means of a series of nested loops. Each combination of values is written to the list file. If the length of the crank is taken to be unity, then the list of possible values for the coupler link, driven link, the distance between the pivot points, the local x and y coordinates of the coupler point are created using the nested loops. Some initial screening of the dimension list may take place at this stage to eliminate undesirable combinations.

Once the list file has been created it is then possible to assemble a mechanism using these kinematic parameters and analyse it to obtain the set of points forming the coupler curve. This is done by calling the appropriate analysis routines within the RASOR constraint modeller. These points (which must form a closed curve) are then passed to the Fourier analysis functions in RASOR which will return the required number of coefficients. Usually no more than five harmonics are required. These coefficients may then be passed to the normalization function which will give the normalized values of these coefficients as well as a series of transforms for scaling, rotation, and translation which must be applied to the mechanism to ensure that its dimensions are also normalized.

Assuming that all the conditions of assembly and performance have been met, then the Fourier coefficients and associated mechanism dimensions are written as an entry into the catalogue file. The results from timing dependent and timing independent analyses are written into separate catalogue files along with the appropriate normalised mechanism dimensions.

The catalogues contain a broad selection of mechanism dimensions alongside the Fourier series coefficients describing the coupler path of each mechanism. To date, catalogues for the four-bar-linkage (crank-rocker, double-crank, and double-rocker), the slider-crank mechanism, the symmetrical geared-five-bar-mechanism, and four different arrangements of the six-bar-linkage have been created. Timing dependent and timing independent results are stored in separate catalogues (there is no timing dependent catalogue for the double-rocker four-bar-mechanism because of the need for crank direction reversal during the cycle).

SEARCHING THE CATALOGUES

The process used to search the library for a particular curve is shown as a block diagram in Fig. 4.

Firstly there must be a performance requirement for the design under consideration. Generally this will be a set of points forming a closed curve, for which we wish to find a mechanism that can reproduce the same curve. A RASOR program has been set up which allows the user to define a set of points by hand, almost as a sort of sketch-pad. The sketch-pad allows straight line segments,

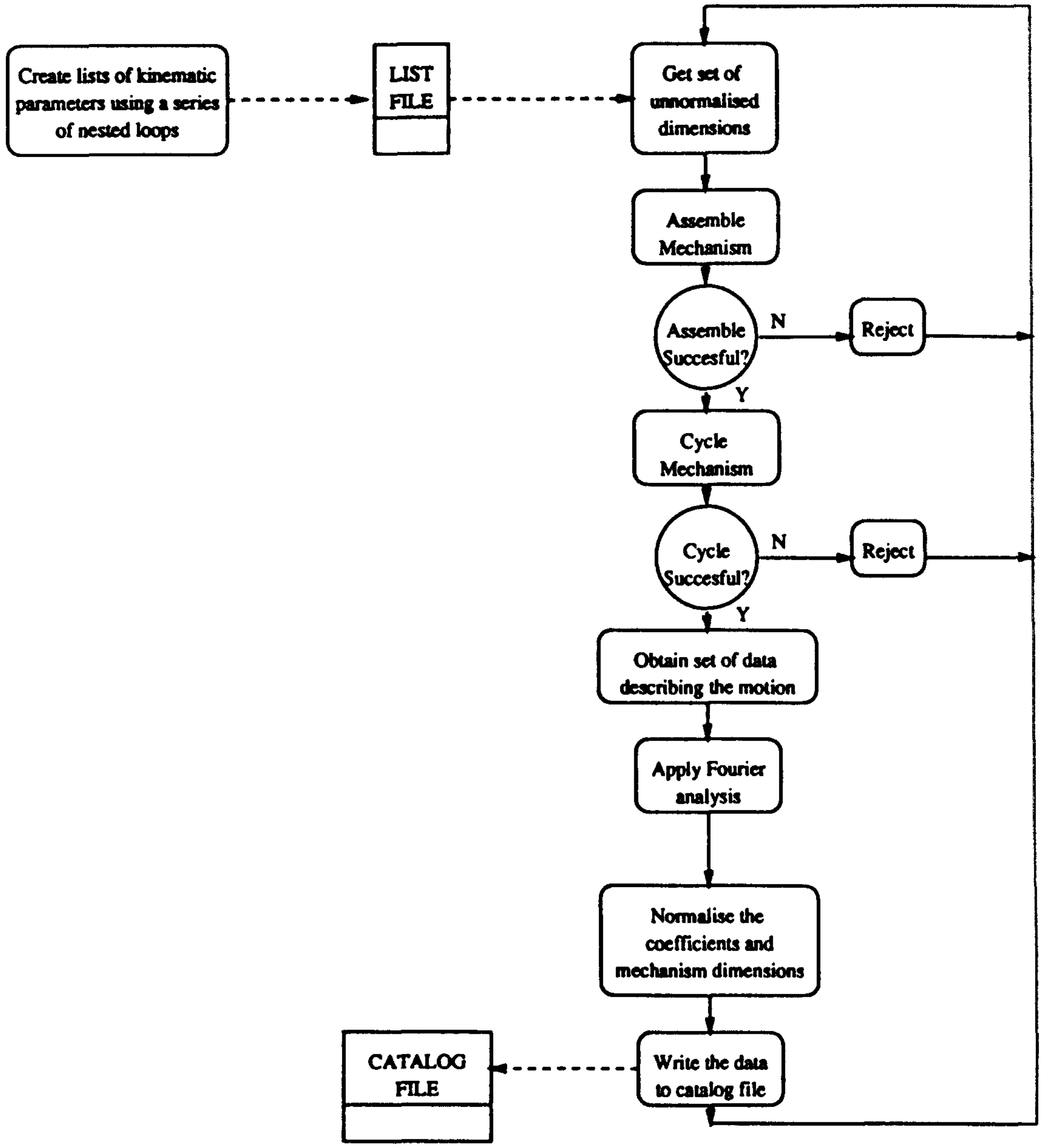


Fig. 3

digitized locations and exact coordinates to be entered. The set of points may be saved in a file for future use. Alternatively a set of data may be imported from the analysis of some existing mechanism.

Having obtained the desired curve in the form of a set of points the next stage is to perform an harmonic analysis on them. Again we may elect a timing dependent or timing independent approach during the Fourier analysis. We must then obtain the set of normalized Fourier coefficients.

Note also that the values of scale, translation, and rotation obtained from the normalization transform are very important. They will be used to de-scale, de-translate, and de-rotate any mechanism picked out of the catalogue.

The selection process from the catalogue has been incorporated into a single function in RASOR to make things easier for the programmer. This function takes four arguments. The first two are the arrays of real and imaginary parts of the coefficients obtained from the normalization process. The third argument is the name of the catalogue file to be searched. The fourth argument is the number of choices, N, which are to be returned from the catalogue. (Note that these will be ordered

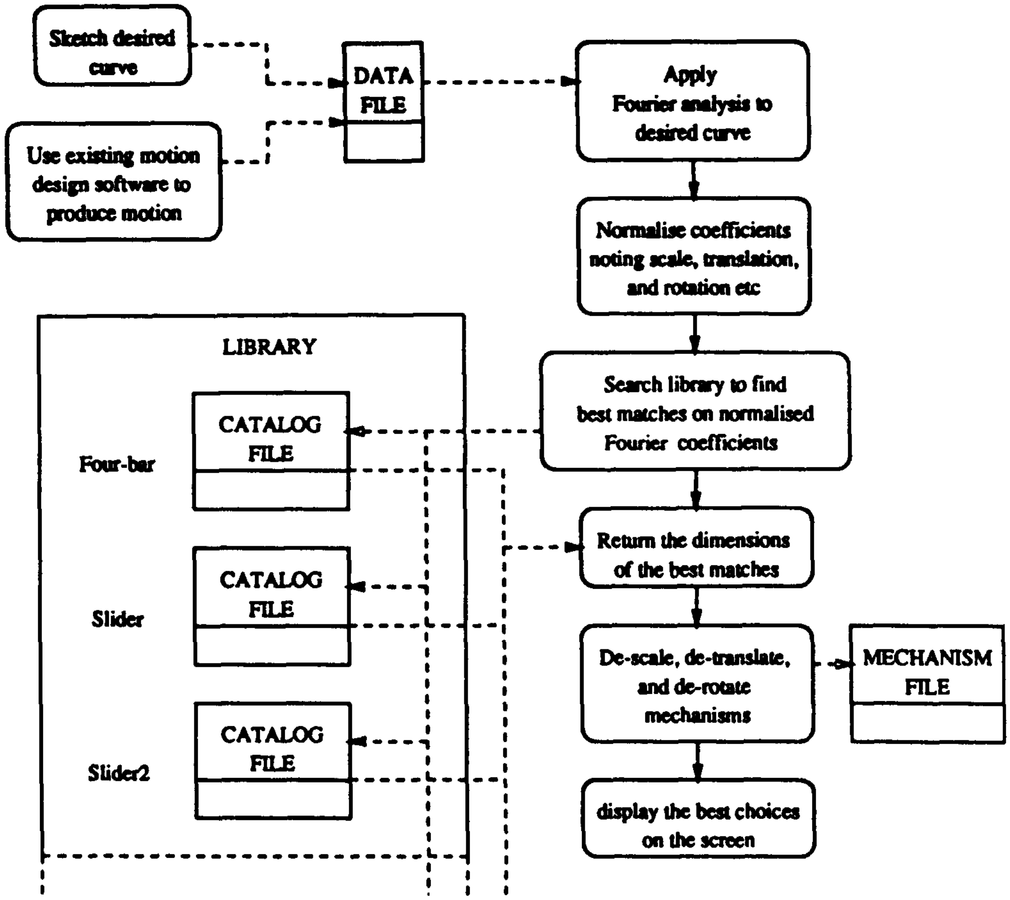


Fig. 4

such that number 1 is the best and N is likely to be the least useful from the N selected.) At this stage the user may also eliminate some of the presented solutions due to other considerations such as the mechanism orientation and position in respect to other parts of machinery which may be known to clash.

The method of comparison relies on the fact that similar curves have similar Fourier coefficients, and a measure of this "closeness" is obtained by taking the cumulative sum of the squares of the difference between the set of desired coefficients and the sets of coefficients in the catalogues. If the desired coefficients are given by the real and imaginary parts A_i and B_i and the current coefficients from the catalog by A_i' and B_i', a measure of the error, E, between the two is given by

$$E = \sum_{i=-M}^{M} (A_i - A_i')^2 + (B_i - B_i')^2$$

where M is the number of harmonics we wish to take into consideration in the comparison. The number of coefficients that we compare against in the desired set of points may be less than or equal to the number of coefficients present in the catalogue file. This allows a search to be performed on the comparison of a variable number of harmonics. For example, a rough match may be obtained by restricting the search to only the first two harmonics. Any coefficients pertaining to the higher harmonics in the catalogue file will be ignored. To increase the potential accuracy of the catalogue selections, a greater number of harmonics may be used, however increasing the accuracy much beyond four harmonics seems unlikely to be worthwhile as the degree of fit would be of secondary importance when practical considerations of the design and subsequent optimization activities are undertaken.

The returns from the catalogue function in the RASOR are the N sets of kinematic parameters which, for whatever mechanism type was under investigation, represent the best matches. These values are stored as scalars in arrays. To make use of these numbers we must have a series of routines which will extract the dimensional information and display the appropriate type of mechanism allowing the user to animate it etc. Once the basic mechanism has been assembled the values returned from the normalization of the desired set of points can be used in reverse to produce the correctly scaled rotated and translated mechanism on the screen. The proximity of the coupler curve of the chosen mechanism to the original set of points can be seen as a superimposed image on the set of points.

If, at any stage, a mechanism of significant interest is selected, all the correctly scaled, translated, and rotated dimensional information may be exported to a mechanism file immediately. Standardized data structures for each mechanism type allow the values to be read intelligently by other analysis and synthesis programs within RASOR.

EXAMPLE

An example of the use of the rapid search and selection technique is given in Fig. 5. Here the desired set of points forms a path required for a particular piece of packaging machinery. The selection is carried out on a time independent basis, so that timing around the curve is not critical. Figure 5 also shows a variety of four-bar-linkages, slider-cranks, geared-five-bar-mechanisms, and six-bar-linkages extracted from their respective catalogues. Note that some of the selections from the library would provide a poor seed for further optimization due to poor transmission angle etc., although they do follow the original path well.

CONCLUSIONS

The design of mechanisms to generate on arbitrary path is a complex problem. Fourier coefficients can be used to describe such output functions numerically. A technique for normalizing the coefficients has been presented. This technique eliminates the effects of scale, translation, and rotation.

The methodology enables a library of mechanisms of variable types to be generated and stored in terms of the normalized Fourier coefficients of the path they generate. This process may be carried out with or without regard to the timing of the coupler point around the curve. The catalogues making up the library can be created and accessed using a computer system called RASOR. To use the library the user firstly specifies the desired motion. The system finds the normalized coefficients, obtains the nearest matches from the appropriate catalogue and then transforms the generating mechanism appropriately.

By using RASOR to search the library, with and without timing dependency, it is soon established that a much better match on shape only is obtained using the timing independent catalogues. Where timing around the curve is not important the time dependent method of analysis represents unnecessary over-constraining of the problem.

It is also found that by searching through different catalogues, an elementary form of type synthesis can be undertaken. It can fairly rapidly be established which mechanism type is most suitable for the task at hand.

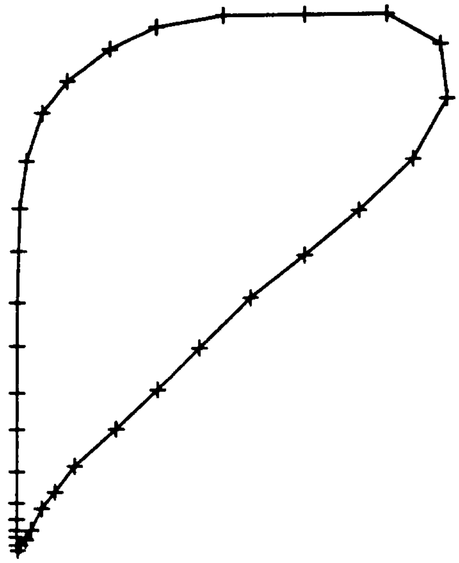
It is anticipated that the main benefit of this system is the speed with which a series of useful seed mechanisms can be found for a path generation problem. The time taken to search through a catalogue of approx. 1300 slider-crank mechanisms returning the best six matches is in the order of 10 s on a SUN Sparc-1. Subsequent optimisation using RASOR is likely to be much more fruitful using these mechanisms selected from the library of catalogues as "seeds".

FUTURE

Work is currently being undertaken to implement a much greater number of mechanism types into the library. The implementation of all types of six-bar mechanisms is expected to be of great use to the designer, although the quantity of data associated with each type of six-bar will be enormous.

Tools are also under development to allow users to write their own catalogues of mechanisms which are of interest to them. These should help large companies to classify all path generating mechanisms which are currently in use within their respective organisations, as well as mechanisms

(a)



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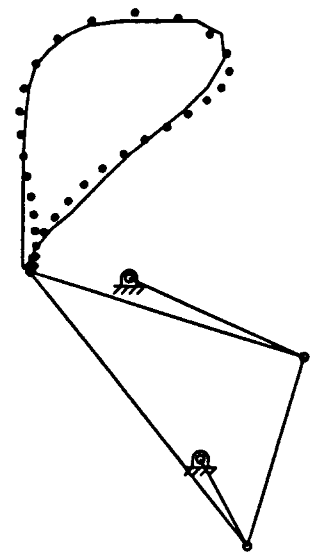

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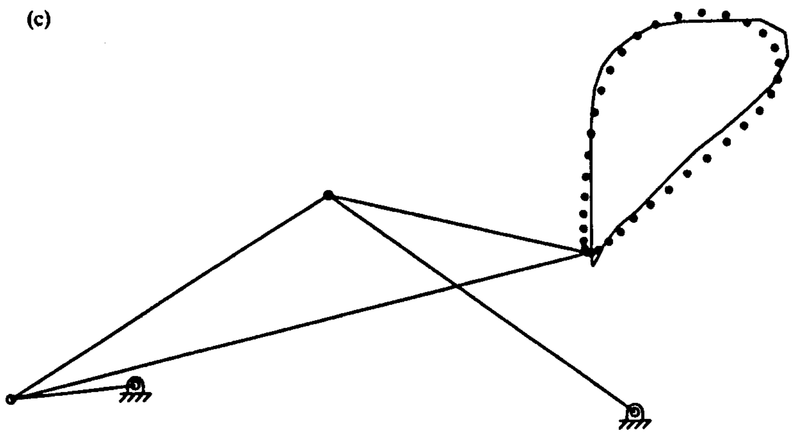

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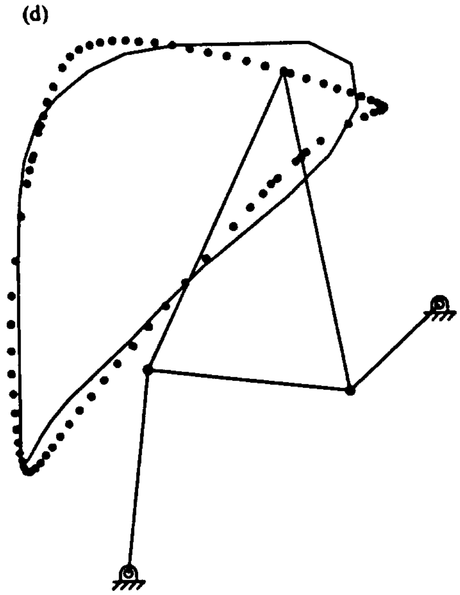

Fig. 5(a–d) *continued overleaf*

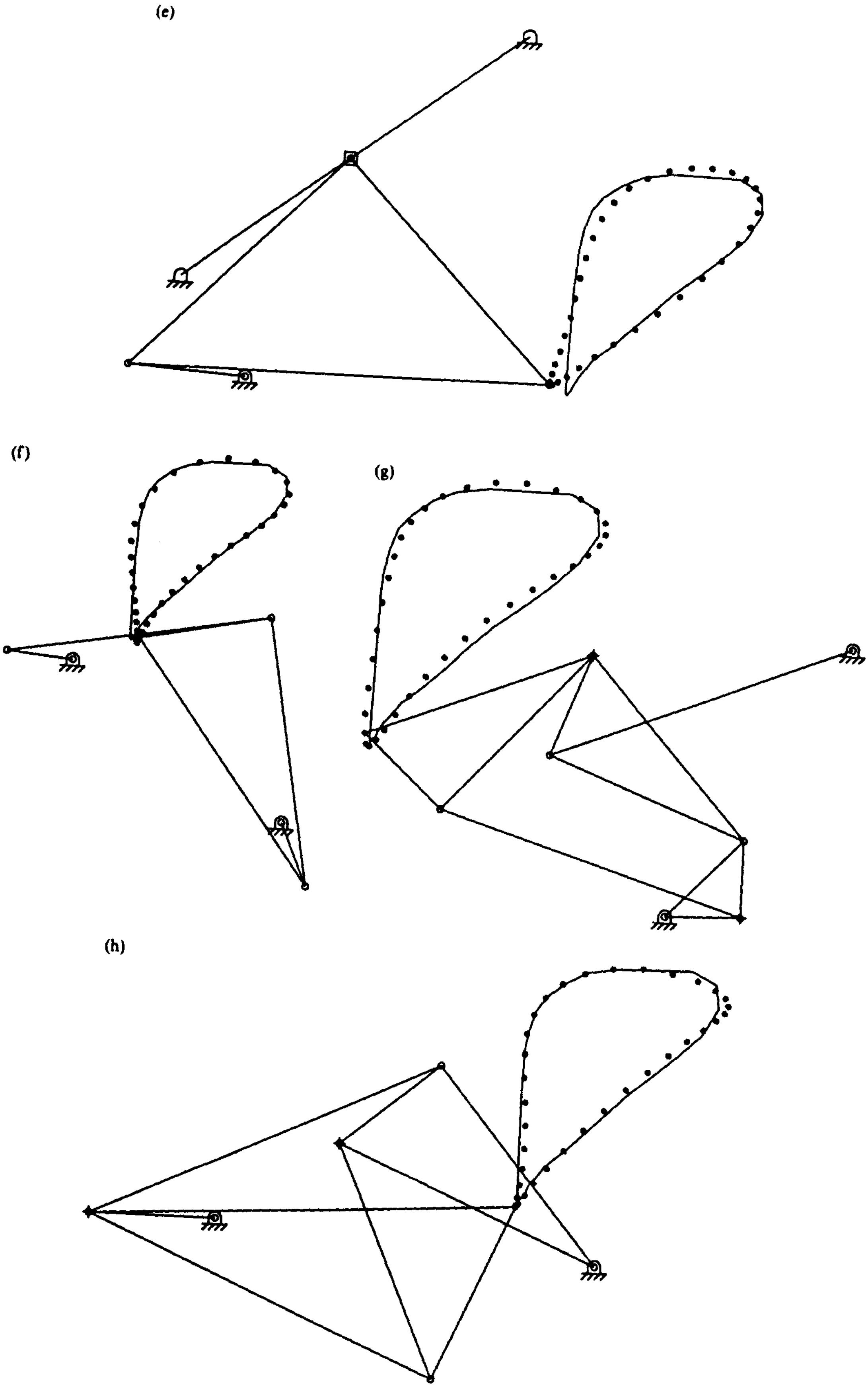

Fig. 5(e–h)

whose dimensions have only a slight variation from the original. Extending the research to cover the area of function generation is also under consideration.

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SCHNELLSUCHE UND AUSWAHL VON KURVENERZEUGENDEN MECHANISMEN AUS EINER DATENSAMMLUNG.

Zusammenfassung—Die harmonische Analyse erlaubt es, die Koppelkurven von beliebigen Mechanismen als eine Folge von Fourier Koeffizienten zu speichern. Diese Koeffizienten sind unabhaengig vom Typ des Mechanismus und koennen verallgemeinert werden, um die Einfluesse von Massstab, Translation und Rotation auszuschalten. Durch Speichern dieser Koeffizienten und der zugehoerigen normierten Parmeter des Mechanismus wird ein Katalog erstellt werden. Jeder Katalog enthaelt eine grosse Anzahl Variationen eines besonderen Mechanismustypes. Wenn man diesen Gedanken weiterfuehrt, koennen Kataloge fuer ein weites Spektrum moeglicher Mechanismen in einer Datensammlung gasammelt werden. Prototyp Programme auf Basis des RASOR Constraint Modeller erlauben dem Benutzer, einen Mechanismus und bestimmte geometrische Anfangswerte aus der Library auszusuchen. Eine Bedingung fuer den Mechanismus ist durch eine Reihe von Punkten gegeben, die eine geschlossene Kurve bilden. Wenn man die harmonische Analyse auf diese Punkte anwendet, erhaelt man bestimmte Kooeffizienten, die dann mit den Fourier Koeffizienten der Librarymechanismen verglichen werden koennen, um die genaueste Auswahl aus der Library zu bestimmen. Erneut werden der Massstabs, die Translation und die Rotation des ausgewaehlten Mechanisms (entnommen aus den jeweiligen Katalog) auf der Grundlage der urspruenglichen harmonischen Analyse der gewuenschten Punktkonstellation definiert. Als Beispiel fur die Andendung dieser Technik ist die Suche nach einem Ursprungmechanismus fuer das Design von Komponenten einer Verpackungsmaschine beschrieben.