17.1-01 PATTERSON SEARCH AND DIRECT METHODS - A COMBINED APPROACH TO STRUCTURE SOLUTION

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Although direct methods have proved very powerful in solving difficult crystal structures, some problems resist even the most sophisticated attempts. In these cases, a combination of Patterson search techniques and direct methods can lead to a rapid structure solution, if part of the chemical structure is known. We have combined the Patterson search program of Hornstra (1) with the tangent expansion of Karle & Karle (2) to solve two structures, which could not be solved by direct methods alone, using chemically similar structures as a starting model. In one ideal case, the structure of a bridged steroid with 47 atoms was obtained by successfully searching for a 25 atom fragment of a diastereoisomer. In a second problem, a terpene derivative with 20 atoms was solved using a tetrasubstituted cyclohexane ring as model. In both cases, the best solution after the Patterson search corresponded to the correct position of the fragment, although atomic shifts of up to 0.2 Å were observed during the successive tangent expansion with one misplaced atom disappearing.

This procedure, which is at least as fast as the available direct methods program packages, provides a reliable starting point for the successful application of the tangent formula. It could have considerable potential as a structure solution strategy utilizing known chemical structure with the currently available stores of atomic coordinates and search retrieval facilities contained in the Cambridge Data Base.

(1) P.B.Braun, J. Hornstra and J.I. Leenhouts, Philips Res. Repts. 42, 85 (1969)
(2) J. Karle and I.L. Karle, Acta Cryst. 21, 849 (1966)

17.1-02 ON THE INTERPRETATION OF THE PATTERSON SYNTHESIS. By P. Engel, Laboratory of Crystallography, University of Berne, Freiestrasse 3, CH-3012 Berne, Switzerland.

The phase problem of the crystal structure analysis can best be explained in the Patterson space. Assuming complete separation in the Patterson synthesis it is possible to state two theorems about the uniqueness of the crystal structure analysis (Engel, Chimia (1979) 33, 317).

For small molecular structures the Patterson synthesis is separated into finite domains which comprise one or several convolution molecules. For each domain the convolution integral is solved through the calculation of the moments (Engel, Z. Kristallogr. (1973) 137, 433). The following theorem can be proven (Engel, Z. Kristallogr. (1980) 151, 217):

Theorem 1: For non-polar space groups the crystal structure is uniquely determined if the Patterson synthesis can be separated in a singular, non-equivalent way into finite domains.

Theorem 1 requires that the scattering density is concentrated on small molecular domains. The empty space between these domains then determines uniquely the phases of the structure amplitudes. In order to calculate the phases the M-function can be applied in an iterative procedure (Engel, Z. Kristallogr. (1981), in press). As a reliable fit of goodness the remaining density between the molecular domains can be determined. Under the premises of the above theorem homometric structures of the first kind occur in polar space groups, if the molecule itself is a convolution of some prime structures. Homometric structures of the second kind only occur if the overlap of the domains in the Patterson synthesis is too excessive.

In coordination structures with few heavy atoms only the interatomic vectors between the heavy atoms can often be made out and it is appropriate to assume point atoms. Centrosymmetric space groups generate the characteristic vector set which systematically can be searched for (Engel, Z. Kristallogr. (1980) 151, 203). The following theorem can be proven (Engel, Z. Kristallogr. (1980) 151, 217):

Theorem 2: For centrosymmetric space groups the set of point atoms is uniquely determined if the characteristic vector set can be separated in a singular, non-equivalent way.

Different vector sets usually interpenetrate the characteristic vector set and therefore only a point solution can be obtained. For point sets of atoms phases can only be calculated assuming atomic scattering factors. These phases are then determined only within the scope of the assumed model. In non-centrosymmetric structures or if interatomic vectors systematically coincide homometric point sets of the second kind may occur.

17.2-01 FORMULAS FOR THE CALCULATION OF n-TET PHASE INVARIANTS AND EMBEDDED SEMINVARIANTS FOR ALL SPACE GROUPS. By Jerome Karle, Laboratory for the Structure of Matter, Naval Research Laboratory, Washington, D. C. 20375, U.S.A.

Formulas have been developed for the computation of phase invariants of any order that can be applied to any space group. On the assumption that decreases in the accuracy with which it is possible to compute increasingly higher order phase invariants are not so pervasive as to preclude significant applicability of this theory, certain characteristics are worth mentioning. It is readily possible to use these formulas to calculate embedded seminvariants by making use of special relationships among the phases that are characteristic of the various space groups. It is not necessary to introduce "neighborhood" theory or "representation theory" in order to determine which of the structure factor magnitudes provide the strongest contributions to the evaluation of the phase invariants. Such information is already contained in the formulas. There is also no need to derive a special joint probability distribution for each invariant and each embedding and associated neighborhood since the formulas include these matters. The development of the theoretical basis for the formulas was particularly facilitated by the application of the general (not conditional) determinantal form of the joint probability distribution (Karle, J. (1978). Proc. Natl. Acad. Sci. USA 75, 2545-2548).

Questions arise concerning the possible utility of formulas derived from joint probability distributions. On the theoretical side, they concern the applicability of joint distributions, derived on the basis of restricted structural models, to the highly regular structures encountered in practice. The questions also concern whether the formulas used in practice have captured the essence of the joint distribution sufficiently well. On the practical side, there are questions concerning the accuracy and range of data, the increase of complexity, the enhanced computing requirements and the lower probabilities associated with the higher order phase invariants. We ask finally whether the strongest indications will, at least, be reliable and to what extent they can impact on a phase determination. Can they afford a facility in structure determination that is not otherwise readily accessible? Such questions have not yet been answered. There are a myriad of varieties of formulas for phase invariants and embeddings associated with the many space groups which are directly accessible and may well require prolonged investigation before evaluations and judgements of utility can be made. It is planned to describe the formulas, discuss how they are to be used, make some comparisons with the existing formulas for computing phase invariants, present some initial calculations and, perhaps, attempt to formulate some ideas concerning future developments.

17.2-02 THE USE OF QUARTETS AND QUINTETS IN RANDOM PHASING PROCEDURES. By A.A. Freer and C.J. Gilmore, Department of Chemistry, University of Glasgow, Scotland.

The use of random phasing procedures coupled with least-squares refinement has been developed (Baggio et al. Acta Cryst. (1978) A34, 883-893) into an important tool in the application of direct methods to difficult structures. As an extension of our work on utilising higher invariants in the MULTAN computer program, (Acta Cryst. (1980) A36, 470-475) we have applied negative quartets and quintets to the random phasing method in the following ways:

(a) As figures of merit to decide when to stop the least-squares (or steepest descents) refinement procedure.

(b) As figures of merit to filter out unpromising solutions so that they are not passed to the weighted tangent refinement procedure.

(c) In an active mode, whereby these invariants are themselves used in the refinement calculations.

The use of (a) and (b) can reduce the computer time needed on a typical computer run by as much as 30%. Most successful solutions show a clear minimum in these figures of merit. In this context they are more useful than the conventional reliability indices.

The use of (c) somewhat weakens (a) and (b) since the figures of merit are no longer independent of the phasing method, but the radius of convergence and the stability of refinement can sometimes be increased.

17.2-03 THE SIR PROJECT: A GENERAL PROBABILISTIC APPROACH TO THE PHASE PROBLEM. By C. Giacovazzo & G.Cascarano, Ist. Mineralogia, Università, Bari, Italy; M.C. Burla, A. Nunzi & G. Polidori, Ist. Mineralogia, Università, Perugia, Italy; B. Busetta, Lab. de Cristallographie, Université de Bordeaux, Talence, France; R. Spagna, Lab. di Strutturistica Chimica, CNR, Monterotondo Stazione (Roma), Italy; I. Vicković, University Computing Centre, Zagreb, Yugoslavia; D. Viterbo, Ist. Chimica-Fisica, Università, Torino, Italy.

In 1977 Giacovazzo (Acta Cryst. A33, 933) introduced the idea of representation of a structure invariant (si) or seminvariant (ss). This idea proved to be a very general way of defining the normalized magnitudes which are most effective, in a statistical sense, in the evaluation of si or ss quantities. A very important feature of the representation method is its capability of making full use of symmetry in a general way.

The SIR (Semi Invariant Representation) project is a joint effort aiming both to the theoretical development and to the practical application of this new approach to the estimation of si's and ss's.

In its present state the SIR computer program includes the following features:

1) Evaluation of one-phase ss's and their optimization via special two-phase ss's.
2) Evaluation of two-phase ss's.
3) Generation of triplets and their evaluation by means of Busetta's (Acta Cryst. A32, 359, 1976) modified MDKS formula.
4) Estimation of negative quartets using the first representation (full use of symmetry) and their strenghtening by the second representation.
5) Convergence procedure using all relations and eliminating redundant information.
6) Phase extension and refinement by tangent formula.
7) Use of several figures of merit.

This is by no means the final stage of the program. The development and testing of new formulae for the estimation of other types of si's and ss's or for improving the evaluation of those already used, is in progress and will be continued in the future. We are also developing and testing new techniques for phase extension and refinement.