GR9

Volume 1

Abstracts of Contributed Papers for the Discussion Groups

9th International Conference on General Relativity and Gravitation

July 14–19, 1980

Friedrich Schiller University, Jena

German Democratic Republic

Under the auspices of the:
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International Union of Pure and Applied Physics,
Friedrich Schiller University, Jena

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ORTOCARTAN - A COMPUTER PROGRAM FOR CALCULATING CURVATURE TENSORS

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The program is called ORTOCARTAN since it performs the calculation on the components of the orthonormal tetrad of Cartan forms representing the metric tensor. Its input data are the components of the forms, and its output are the tetrad components of all the quantities that are calculated on the way to the Weyl tensor, and, on request, of the Einstein tensor. On special request the program can also calculate the coordinate components of all these quantities, including the Christoffel symbols and the metric tensor (the latter just as a check on the input data).

The program is directed towards calculating the curvature tensors in the sense that for this purpose it can be used by an inexperienced user with only minimal introductory learning (a detailed user's manual of 52 standard manuscript pages is available [1]). However, the program contains several subprograms which can be assembled into packages performing many other types of symbolic calculations. The subprograms perform: algebraic simplification, differentiation, calculating inverse arrays, and printing the results in the standard mathematical format. Also, our scheme of the user-program interface is easy for the programmer, convenient for the user, and liable to modifications. At present, the projects are under way to generate from ORTOCARTAN the programs for the algebra of large matrices, processing truncated power series and manipulating rational functions.

ORTOCARTAN was created and implemented in the LISP programming language (UT version 4.1) on a CDC Cyber 73 computer under the operating system SCOPE 3.4.4. Copies of the program may be obtained from the authors of this note as magnetic tape records or boxes of punched cards. The listing, together with a detailed description of the code, is also available.

The notation for data used on input follows the standard mathematical format as closely as possible, with deviations to the FORTRAN-like infix notation where necessary, e.g. in the case of exponentiations. The output is printed in the standard mathematical format. The user has the possibility to introduce large amounts of substitutions into the expressions processed, at any stage of the calculations. However, since the program works in the batch mode, no interaction is possible and the substitutions have to be planned all in advance.

ORTOCARTAN is far from the fastest programs existing, but the possibilities to make it a few times faster are still open. At present, the program calculates the Einstein tensor for the Bondi-van der Burg-Metzner metric in 536 sec. at 53000 (decimal) words of core. This is to be compared with 856 sec. for one of the slower systems (REDUCE) and 33 sec. for one of the fastest ones (CLAM). The technical features of ORTOCARTAN are discussed in more detail in another publication [2].

The program was tested on about 30 metrics of various degrees of complexity, taken from the published literature, ranging from the simplest de Sitter metric to the more complicated metrics of Bondi-van der Burg-Metzner and Robinson-Trautman. In each case the expected final result was indeed obtained. This fact, together with more than 2 years of careful debugging, testing and improving yields a reasonable degree of reliability for the potential users. A new solution reported in this volume [3] was obtained with the help of ORTOCARTAN which has then proved fully useful.

Our program has no unique superiority over any of the others existing, since each of its advantages can be found in at least one of the other well known algebraic computer systems, like e.g. CLAM, ALTRAN, FORMAC, REDUCE, SAC-1, SYMBAL and SHEEP. Nevertheless, we think we have achieved a convenient combination of useful features which makes ORTOCARTAN very easy to use even for a layman in computers. Therefore we would like to invite and encourage all the potential new users to make use of our program what will help us to improve and extend it further.

As an illustration we reproduce here the ORTOCARTAN's input data and short pieces of its output in the case of the simple and well known Robertson-Walker metric:

$$ds^2 = dt^2 - R^2(t)\left[dr^2/(1 - kr^2) + \right.$$
$$\left. + r^2(d\vartheta^2 + \sin^2\vartheta\, d\varphi^2)\right]$$

where k = const. See next page.

References:

[1] A. Krasiński, M. Perkowski, The system ORTOCARTAN - user's manual. Preprint N. Copernicus Astr. Center (1980).

[2] A. Krasiński, M. Perkowski, submitted to Journal of Gen. Rel. Grav.

[3] A. Krasiński, Spacetimes with intrinsic spherical symmetry. See this volume.

```
ORTOCARTAN ((
           01
  (ROBERTSON WALKER METRIC)
  2                        2
  (COORDINATES T R THETA PHI)
  2                         2
  (FUNCTIONS CAPR (T) )
  2                 3 3 2
  (CONSTANTS K)
  2         2
  (EMATRIX 1 0 0 0 0 (CAPR / (1 - K * R ** 2) ** (1 2)) 0 0 0 0
  2                 3        4            4    4   43
          (CAPR * R) 0 0 0 0 (CAPR * R * (SIN THETA))   )
          3         3        3          4          43  2
   ))
   10


(ROBERTSON WALKER METRIC)

          0
> EMATRIX  . = 1
           0

          1                  2 (-1/2)
> EMATRIX  . = CAPR (1 - K R )
           1

          2
> EMATRIX  . = R CAPR
           2

          3
> EMATRIX  . = R CAPR SIN (THETA)
           3


                       -1
> RICCI    = - 3 CAPR    CAPR,
       0 0                   T T

                       -2          -2        2       -1
> RICCI    = 2 K CAPR    + 2 CAPR    CAPR,     + CAPR    CAPR,
       1 1                               T                  T T

                       -2          -2        2       -1
> RICCI    = 2 K CAPR    + 2 CAPR    CAPR,     + CAPR    CAPR,
       2 2                               T                  T T

                       -2          -2        2       -1
> RICCI    = 2 K CAPR    + 2 CAPR    CAPR,     + CAPR    CAPR,
       3 3                               T                  T T


                                         -2          -2         2           -1
> CURVATURE INVARIANT = - 6 K CAPR    - 6 CAPR    CAPR,     - 6 CAPR    CAPR,
                                                         T                   T T


(ALL COMPONENTS OF THE WEYL TENSOR ARE ZERO)


(IT HAS BEEN A REAL FUN TO WORK FOR YOU. COME TO SEE ME AGAIN)
END OF WORK
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