Sophisticated momenta mapping with DIANA

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Details of recent developments of the Feynman diagram analyzer DIANA (DIagram ANAlyser) are presented. Apart from some discussion about QGRAF and new plotting features, we concentrate on a new sophisticated mechanism of momenta mapping.

1. Compatibility with current QGRAF versions

DIANA uses QGRAF \cite{QGRAF2} as diagram generator. By now there exist several QGRAF versions which, however, have incompatible syntax of their input files. In most cases the user does not need or does not want to know which version of QGRAF is in use. DIANA takes care of this. It automatically investigates which version of QGRAF is in use. Starting from version 2.37 it also provides the user with information about the version used for the diagram generation. At present, all QGRAF versions 2.\ldots\ and 3.\ldots\ are supported. From the DIANA point of view there is no difference between them; the differences concern only syntax.

2. New plotting features

QGRAF cannot generate two-line vertices. This causes problems when DIANA is requested to introduce counterterms. In this case it produces three-line vertices but does not show one of them, i.e. in this case DIANA skips the image of the “spurious” line in the diagram. Another new feature is introduced to suppress labels. In version 2.35 of DIANA and later ones these options (changing the model extensions \cite{model_extensions}) are taken into account in terms of “optional extensions” in the propagators of the model file, e.g. in

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[le,Le;1; FF(num,fnum,vec, mle)*i_;
    mmle; nothing,0,0;]
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the last two extensions ;nothing,0,0; (separated by :) have the following meaning:
1. the new line type of the propagator “nothing” means that this line will not be drawn. The two following parameters in general stand for line characterizations and must be included in any case.
2. the second “extension” apparently is empty, which means that no label will be drawn - in previous versions this meant the “default image” (in the above example: le)

3. Automation of momenta distribution

Again, starting from version 2.25, momenta can be introduced automatically. There are several different approaches \cite{momenta_distribution}.

As “standard” way of attributing momenta, we consider the possibility to calculate, e.g., from external momenta the so called “chords”, characterizing the virtual lines apart from the integration momenta.
A more specific problem is the following: occasionally topologies have to be generated from more complicated ones by scratching lines and one may want to stick to the momenta introduced for the lines which are kept. This option was described in [5].

A new and more difficult situation occurs when the user wants to “scratch” some external lines. Consider e.g. the Anomalous Magnetic Moment; this is a 3-point function of the type fermion – fermion with an external photon of zero momentum. Performing a necessary differentiation and putting the photon momentum to zero, the resulting graph appears to be a 2-point function with higher powers of scalar propagators. In this case we need to map the momenta of the 3-point function to the corresponding momenta of a 2-point function, putting one external momentum to zero.

At present, DIANA is able to map momenta from \( n \)-point functions to \( m \)-point functions \( (m < n) \). Here we provide some details.

Let us consider one of the diagrams relevant for \( g - 2 \) in two loop approximation, Fig.1.

After differentiation w.r.t. to the photon momentum \( q \), we have to put \( q = 0 \) and evaluate the resulting propagator with the only one momentum \( p \).

To perform the differentiation w.r.t. \( q \) we formally consider at first a diagram with the only nonvanishing momentum \( q \), all others zero. In a FORM program the differentiation is then per-

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**Figure 1.** A typical diagram for the two-loop Anomalous Magnetic Moment. Arrows indicate the direction of momenta.

**Figure 2.** Momenta decomposition. The initial momentum flow is a “sum” of a three-point momentum flow a) and a two-point momentum flow b).
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formed w.r.t. $q$ and after that for zero momentum $q$, momenta fitting to the three-point function are introduced, see Fig. 2.

In a first step we generate the FORM input with momenta as in Fig. 2a). After differentiation w.r.t. $q$, we look (e.g. in another program like MINCER [7]) for the corresponding two-point topology (Fig. 2b), add for technical reasons all momenta from the two-point topology [2b)] to the current three-point topology [2a]), put $q = 0$ and generate the FORM input for further evaluation.

The main problem here is to determine which two-point topology corresponds to the current three-point topology. In DIANA topologies are represented [1] in terms of ordered pairs of numbers like (fromvertex, tovertex) (see Fig. 3).

All external legs have negative numbers. The momenta distribution according to Fig. 3, e.g., is added like

$$\text{topology } A = (-2,2)(-1,1)(1,3)(4,1)(2,4)(3,2)(3,4): \ k_1+p, k_1, k_2, k_2+p, k_1-k_2;$$

This fixes directions and values of all momenta on the internal lines. External lines must be known from the process definition.

A special TM\(^2\) operator was introduced:

\begin{verbatim}
\amputateTopology(varname, tablename)
\end{verbatim}

It tries to find an amputated topology for the diagram under consideration (e.g. 2a, taking off $q$) in the table “tablename” (e.g. from MINCER) and returns this topology (e.g. 2b). It adds all momenta from the table topology to momenta of the current (2a) topology and saves the resulting momenta to the local variable $<\text{varname}>_M$.

On failure this TM operator returns an empty string. If it can’t load the table it halts the program.

Apart from $<\text{varname}>_M$, the operator creates several other variables:

- $<\text{varname}>_\text{IN}$ - number of internal lines in the amputated topology;
- $<\text{varname}>_\text{N}$ - name of the found topology.

The following arrays $\text{amputated(}\text{original})$ are indices of lines of the amputated topology which corresponds to the original:

- $<\text{varname}>_\text{E}$ - external lines of original <-> external lines of amputated;
- $<\text{varname}>_\text{IE}$ internal lines of original <-> internal lines of amputated;
- $<\text{varname}>_\text{I}$ internal lines of original <-> external lines of amputated.

The absolute value of elements of these arrays are indices of the lines and their signs correspond to their direction.

External lines to be removed by the operator $\amputateTopology$ are marked by another TM operator,

\begin{verbatim}
\rmExtLeg(n)
\end{verbatim}

where $n$ is the index of the external line. There can be more than only one external line which the user wants to be removed.

\(^{2}\text{TM language is used by DIANA, see [1]}\)
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