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(54) Title: BLENDING A DIGITAL IMAGE CUT FROM A SOURCE IMAGE INTO A TARGET IMAGE

(57) Abstract: Method for blending a foreground object of a first image into a second image in which the transition boundary region between the foreground object and the background comprises a linear color transition based on the colors of the foreground object and the background, respectively.
BLENDING A DIGITAL IMAGE CUT FROM
A SOURCE IMAGE INTO A TARGET IMAGE

In recent years, vast strides have been made in the field of computer-assisted image processing. The creation and manipulation of images has proved a boon to many engaged in the graphic arts field, industrial monitoring, and surveillance, but there are still problems in the initial stages of rendering an already existing image into processable form. The classic approach to securing a computerised image is to scan a photographic original to form a file in which data are stored representing properties of a large number of portions of the image, so-called pixels. Each pixel is characterised by a number of parameters corresponding to colour and intensity. The file also contains data relating to the location of each pixel so that, when the file is called up by an appropriate program, the image is displayed on screen. More recently, the process of scanning has been supplemented by the development of so-called digital cameras, which produce an image file directly.

The invention is related to the insertion of an image, cut out from a source image A, into a target image B to form a so-called composite image. The source image needs firstly to be broken down into different areas corresponding to the image to be cut out and the remainder. The method of
segmenting an image using the watershed method, as outlined in patent WO
03/052696, enables accurate identification of the edges of an object in the
source image. The pixels which form the object to be cut out are labelled
"foreground", and those forming the boundary or boundaries of the object
are called "edge" pixels. The remaining pixels in the source image are
labelled "background".

Many automated methods of segmentation are based upon the assumption
that, within an image, at the edge of an object the digital values associated
with each of the pixels change substantially from one pixel to the next.
However, the changes that do occur at the edge of an object may extend
over many pixels away from an edge (e.g. unfocussed edges, hair, fur).
Thus, the pixels forming the edge of a foreground object are "mixed" in the
sense that they contain colour information from both the foreground and the
background of the image. By defining a quantitative "opacity" of a mixed
pixel as the proportion of that pixel's colour derived from the foreground of
the original image, this quantity can be used in the context of an image mask
to super-impose an abstracted image onto a new background.

In order to provide satisfactory integration of the cut-out object into a target
image, the contribution from the background of the source image must be
removed from the mixed colour data for the edge pixels, and replaced with
corresponding information from the target image. This may be accomplished
by using local and global colour information to determine the proportion of
foreground colour in a given edge pixel, and hence enabling an opacity value
and a pure (foreground) colour to be assigned to it. Then for each edge
pixel, the foreground colour of the original may be blended with the
background of the target image to create a mixed pixel for eventual use in
the composite image.

It is assumed that each edge pixel has a digital colour value that is a mixture
of the colours of an adjacent or nearest object pixel or set of pixels and an
adjacent or nearest set of background pixels. It is usually possible to find
object and background pixels in the neighbourhood of a given edge pixel, by
searching the neighbouring pixels, starting from those adjacent and
gradually expanding the search until a predetermined termination point is
reached. The mean colours of the object and background pixels found can
then be used to determine the opacity of the edge pixel, by applying vector
algebra in colour space.

In particular, taking the point in colour space on the line drawn between the
background and foreground colours which is closest to the colour of the
mixed pixel, the opacity is proportional to the distance from this point to the
background colour divided by the distance between the foreground and
background colours.

As each edge pixel is processed, the colour values assigned to it are
accordingly reset to be those of the object colour that was used to determine
its opacity fraction. Thus the colour of the mixed pixel in the composite
image to be constructed by compositing the object part of the source image
A onto the new background of the target image B will be a mixture of the
pure object colour with the new background colour, the influence of the
original background colour from the source image A is completely removed.

If there is a failure to find object and/or background pixels within the preset
limits of the search, then the colours of the object and/or background in the
whole source image are scanned to find the pair of colours that gives the
fractional composition approximating most closely to the colour of the edge
pixel, again using vector algebra in colour space. In brief, a set of colour
classes (from the colour watershed based classification and segmentation)
which occur only in the foreground is generated, and is then reduced to
include only classes which occur in regions which are adjacent to regions on
the edge of the foreground area of the image. The modal colour of each
class present in that set of regions is taken as being a candidate foreground
colour, and a set is thus formed of potential foreground colours. A similar process finds a set of candidate background colours. Appropriate foreground and background colours are chosen by minimising the distance in colour space between the candidate mixed pixel and a line drawn between (each of) the foreground colour(s) and (each of) the background colour(s). The colour of the mixed pixel is reset to be that which was chosen as the foreground endpoint of the line in colour space, and the opacity is calculated as before.

Finally, the opacity data is used to construct an image mask, in which object pixels are assigned full opacity and each edge pixel has the opacity corresponding to the contribution to its colour from the foreground. The background pixels are assigned full transparency. The object can then be super-imposed over a target image B according to the mask value. Where the mask is transparent no change to the target image is made. Where the mask is opaque the target image pixel values are replaced with the object pixel values. Where the mask has an intermediate opacity value, that fraction of the object pixel colour is combined with the complementary fraction of the target image pixel colour.

The following examples will serve to illustrate how the invention may be put into practice, these refer to the accompanying drawings in which:

Figure 1 is a sample edge region of an image,

Figure 2 is as Figure 1 but showing a candidate pixel,

Figure 3 is a diagram of the immediate surroundings of the candidate pixel,

Figure 4 is a diagram in colour space illustrating the determination of the opacity value for the candidate pixel,
Figure 5 is a diagram of the immediate surroundings of a more difficult candidate pixel, and

Figure 6 is a diagram as Figure 5 but showing more of the surroundings of the candidate pixel.

Figure 1 shows a small region of an image's status, containing background b, foreground f and mixed m pixels. As the blending process takes place, each m pixel is considered, and local knowledge is used when possible to determine appropriate foreground and background colours to use as blending endpoints.

Figure 2 shows the same region. The first step is to consider the immediate region of the candidate pixel c. Initially, all the pixels immediately adjacent to c are examined.

Figure 3 shows all the pixels which will initially be considered. In fact, in this first example, this is as far as the examination goes: there are four b pixels, so their mean colour will be used as the background endpoint for the blending process. There is one f pixel, whose colour will both be assigned to the c pixel, and used as the foreground endpoint.

Figure 4 shows the line in colour space joining the background pixel b and the foreground pixel f. Let p be the closest point on this line to the candidate pixel c. The opacity value \( \alpha \) to assign to the mask in the location of c is defined as the ratio of the distance d from p to b and the total distance between b and f,

\[
\alpha = \frac{d}{d + d'} = \frac{|\mathbf{bc}| \cos \theta}{|\mathbf{bf}|},
\]

using elementary trigonometry, where \( \theta \) is the angle between bc and bf.
Using the definition of scalar product, (Ref: M.L. Boas, Mathematical
Methods in the Physical Sciences, 2nd ed. Wiley, 1983 or any linear algebra
book)

\[ \mathbf{bc} \cdot \mathbf{bf} = |\mathbf{bc}| |\mathbf{bf}| \cos \theta, \]

the formula for the opacity value becomes

\[ \alpha = \frac{\mathbf{bc} \cdot \mathbf{bf}}{|\mathbf{bf}|^2}. \]

If it turns out that the closest point on the line to c does not lie between b and
f, in other words, if \( 0 \leq \alpha \leq 1 \) is false, then the status of c is changed from m
to f (if \( \alpha > 1 \)), or b (if \( \alpha < 0 \)), and \( \alpha \) is set to 1 or 0 respectively.

The following example concerns a less easily analysed situation, related to a
different candidate pixel selected from the same small area of an image as
before.

Figure 5 shows the immediately adjacent pixels to this new candidate. It is
clear that, though three foreground pixels are present, and so a foreground
endpoint can be determined by taking their mean colour, there are no
adjacent background pixels available. The solution is to look further.

Figure 6 shows the pixels adjacent to c, and those adjacent to them. There
are now pixels of both background and foreground in scope, so the
endpoints can be found. They will be the mean colour of the four background
pixels, and the mean colour of the ten foreground pixels.

If an endpoint were still missing after this, the region could be expanded
again, etc. It is prudent to limit this expansion to a maximum size to allow for realistic processing times. This does introduce the possibility that the process will terminate for a given pixel without having successfully calculated the opacity and colour for that pixel.

There are several ways to escape from this situation. A multi-pass approach is taken, so that if the process fails on the first pass over the image for a pixel, that pixel is left unprocessed for the time being, and awaits the second pass.

During the second and subsequent passes, the system is extended to increase the likelihood of a successful result for each pixel. This is done in two ways:

- The limit upon the size at which the search is terminated is increased with each pass. The hope is that the increased processing time per pixel is offset by the presence of fewer pixels to process, and the increased likelihood of success on this pass if a larger area is used.

- As well as searching for nearby f and b pixels, nearby m pixels which have been successfully processed in a previous pass are used. If the f and b based method fails, either or both of the endpoints which were used to process any nearby successful ms may be used as a substitute, being averaged in the same way as fs and bs to generate an endpoint for this candidate.

This repeated passing over the image should lead eventually to all the pixels having been processed. However, to ensure that the computation will be completed within a reasonable time, after a certain time, or once each pass is having success with only a small proportion of the remaining pixels, a final improvement is made which guarantees the completion of the blending process for every pixel.
Having used up to now only local information to determine the endpoints, global information from the image's classification and segmentation are now introduced. The current method is as follows, though variations or other sensible ways of generating the data from the assignments in an image are possible:

1. From the watershed division of the colour space and the status assignment of every pixel in the image, generate a set of colour classes which occur only in the foreground, and segment the foreground into regions, each region being formed from adjacent pixels having the same colour class.

2. Form a set \( R' \) consisting only of the non-edge regions in \( R \), i.e. discard those regions which have adjacent pixels of different status.

3. Form a set of \( R'' \) consisting only of the non-edge regions in \( R \), i.e. discard those regions which have adjacent pixels of a different status.

4. Intersect \( C \) with \( C'' \). This usually gives a small number of foreground colour classes.

5. If the resulting set of colour classes is empty, use in its place the set of colour classes obtained by undertaking \( C \) and \( C' \), where \( C' \) is the set of colour classes occurring in \( R' \).

6. If the set is still empty, use the set of all foreground-only colour, classes \( C \).

7. Finally, determine the modal colour of each class/region, and thus generate a list of potential colours to use as foreground endpoints.

A similar process generates a set of potential background endpoints. Now
that these extra sets of colours are available, there is a final solution if the
methods based only on nearby pixels fail. Essentially, for each endpoint that
has not been found, each member of the corresponding set of potential
endpoints is tried, and that which minimises the shortest distance between c
and bf is chosen. This distance is given by \[ \frac{|bf \times bc|}{|bf|}. \]
CLAIMS

1. A method of digital image processing in which an object is excised from a first digitised image and pasted on to a second digitised image, the method including the steps of identifying a set of pixels corresponding to the object, and within that set which pixels correspond to the edge(s) of the object and which to the interior, for each pixel corresponding to the edge(s) of the object assigning a contribution factor dependent upon the parameters associated with its immediate neighbours including other edge pixels, pixels corresponding to the interior of the object and peripheral background pixels corresponding to the parts of the first digitised image which lie outside the excised object but adjacent its edge(s), substituting for the parameters associated with each edge pixel of the set parameters based on the contribution factor and on the parameters associated with the peripheral background pixels of the second digitised image, and constructing a new digitised image file from the pixels of the second digitised image not located at positions corresponding to the pixels of the excised object, the pixels of the interior of the object, and the edge pixels with substituted parameters.

2. A method according to Claim 1 wherein the edge pixels of the set are identified by carrying out an image segmentation process as described in WO 03/052696.

3. A method according to Claim 1 or 2 wherein the contribution factor is calculated by a method including locating in colour space
a first point corresponding to the colour of pixels adjacent or near the respective edge pixel and assigned to the set of interior pixels,

a second point corresponding to the colour of pixels adjacent or near the respective edge pixel and being peripheral background pixels,

and calculating the contribution factor dependent upon the position along the line of the point on the line in colour space connecting the first point and the second point closest to the point in colour space corresponding to the edge pixel for which the contribution factor is to be calculated.

4. A method according to Claim 3 where the contribution factors for the edge pixels are first calculated for all edge pixels in respect of which the surrounding eight pixels include both interior pixels and peripheral background pixels, thereafter for those of the remaining edge pixels in respect of which the surrounding 24 pixels include both interior pixels and peripheral background pixels, and, in respect of any still incalculable pixels, taking into account a greater number of pixels surrounding the respective edge pixel.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 GO6T5/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 7 GO6T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
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<td>X</td>
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<td>US 5 708 479 A (GEHRMANN RAINER) 13 January 1998 (1998-01-13) column 2, line 48 - column 4, line 51</td>
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Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents:
  *A* document defining the general state of the art which is not considered to be of particular relevance
  *E* earlier document but published on or after the international filing date
  *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  *O* document referring to an oral disclosure, use, exhibition or other means
  *P* document published prior to the international filing date but later than the priority date claimed
  *I* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
  *S* document member of the same patent family

Date of the actual completion of the international search: 6 October 2004
Date of mailing of the international search report: 11/11/2004

Name and mailing address of the ISA
European Patent Office, P.B. 5618 Patentiban 2
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Authorized officer
Rockinger, O.
Continuation of Box II.2

Claims Nos.: 2

The wording of claim 2 tries to define the subject-matter for which protection is sought by merely by referencing the description of another patent application (WO03/052696). However, this results in a severe clarity issue so that a meaningful search is not possible for this claim (cf. also the PCT Guidelines, 5.10).

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.
### Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.; because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.; because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

   see FURTHER INFORMATION sheet PCT/ISA/210

3. □ Claims Nos.; because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. □ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

□ The additional search fees were accompanied by the applicant's protest.

□ No protest accompanied the payment of additional search fees.
### INTERNATIONAL SEARCH REPORT

**Information on patent family members**

<table>
<thead>
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<th>Patent document cited in search report</th>
<th>Publication date</th>
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Form PCT/SA/010 (patent family annex) (January 2004)