Display Math in ConTExt

ConTExt rehab for amsmath addicts

Abstract
This article explains how to do various kinds of alignments in ConTExt. A visual output is presented, and it is then shown how that effect can be achieved in LaTeX and ConTExt. We hope that article will make the transition from LaTeX with amsmath package to ConTExt easier.

Keywords
ConTExt, LaTeX, math alignment, amsmath

Introduction
Plain TeX provides several macros like \( \texttt{\textbackslash align} \), \( \texttt{\textbackslash alignno} \), \( \texttt{\textbackslash displaylines} \), \( \texttt{\textbackslash matrix} \), \( \texttt{\textbackslash matrix} \), \( \texttt{\textbackslash cases} \), and \( \texttt{\textbackslash align} \), for math alignments. These macros are adequate for most constructions that occur in practice. AMS-TeX and the amsmath package for LaTeX supply math alignment environments that provide a layer of abstraction for the user and makes it (slightly) easier for him/her to type the common math alignments. Most people learning TeX these days start from LaTeX and those writing substantial math use the amsmath package; they know nothing about the plain TeX math alignment macros. In earlier versions of ConTeXt, since the plain TeX macros could be used, no additional macros for math alignments were provided. This made writing math alignments difficult for users who came to ConTeXt with a LaTeX background. They did not know about plain TeX macros and kept looking for something equivalent to the amsmath package. There was an amsel package module by Giuseppe Bilotta, but it was very limited. Moreover, doing alignments with multiple alignment points in plain TeX requires a good understanding of the TeX alignment mechanism; making them obscure for a typical user. This resulted in a general impression that ConTeXt does not handle math very well.

Recently (in January 2006 to be precise), Hans added math alignment macros in ConTeXt. These macros provide a very nice user interface to plain TeX's alignment mechanism; they can be used to achieve the functionality of amsmath package macros; and, like all user macros in ConTeXt, they are easy to customize. These macros, however, neither copy the user interface of amsmath package, nor the implementation. So, translating your existing LaTeX math code into ConTeXt requires some effort and the result is not necessarily, pixel by pixel, identical.

In this article, I describe how to convert the common alignment constructions from LaTeX to ConTeXt, highlighting some of the flexibility offered by ConTeXt. This is a visual document: I first show how the output should look like, then present LaTeX and ConTeXt examples that give that output. This article is not meant as a tutorial for math alignments in LaTeX or ConTeXt, and I do not explain the LaTeX and the ConTeXt syntax. The article is not exhaustive; it provides a small sample of math alignments that can be done using LaTeX and ConTeXt. For an in-depth treatment of LaTeX's math capabilities see Herbert Voß's mathmode. \(^1\) For a introduction to ConTeXt math alignment see My Way on \texttt{\textbackslash startalign} and friends. \(^2\) The objective
of this article is not to compare the features of these two macro packages, rather it is to show that ConTeXt is capable of handling “complicated” math alignments.

Math Alignments

ConTeXt provides mathalignment series of macros (\definemathalignment, \setupmathalignment, \startmathalignment, and \stopmathalignment) to take care of the different math alignments. Below, I describe some common math constructs, and examples of how to achieve them in LaTeX and ConTeXt.

gather
The gather environment of amsmath package allows you to write multi-line formulas with each line center aligned. It is perhaps the simplest form of “alignment”. In ConTeXt the same effect can be achieved using appropriate options to \startmathalignment.

$$v = u + at, \quad d = ut + \frac{1}{2} at^2.$$ (1)

In LaTeX

\begin{gather}
v = u + at, \\
d = ut + \frac{1}{2} at^2.
\end{gather}

(2)

In ConTeXt

\placeformula \startformula
\startmathalignment[n=1]
\NC v = u + at, \\
\NR[+]
\NC d = ut + \frac{1}{2} at^2.
\stopmathalignment
\stopformula

(1)

(2)

left gather
Sometimes one wants multi-line formulas, where each line is left or right aligned, rather than center aligned as in the gather environment. Although, LaTeX does not provide any in-built environment for such constructions, it is easy to exploit the align environment to achieve this output. In ConTeXt passing align=left to \startmathalignment gives the desired output.

$$v = u + at,$$ (1)

$$d = ut + \frac{1}{2} at^2.$$ (2)
In $LaTeX$:

\begin{align}
    & v = u + at, \quad (1) \\
    & d = ut + \frac{1}{2} at^2. \quad (2)
\end{align}

In Con$TeX$t:

\begin{verbatim}
\placeformula
\startformula
\startmathalignment[n=1,align=left] \%align=left does the magic
   \NC v = u + at, \NR[+]
   \NC d = ut + \frac{1}{2} at^2. \NR[+]
\stopmathalignment
\stopformula
\end{verbatim}

$v = u + at, \quad (1)$

$d = ut + \frac{1}{2} at^2. \quad (2)$

**right gather**

For multi-line formulas with each line right aligned, in $LaTeX$ you can exploit the align environment, while in Con$TeX$t you need to pass align=right to \startmathalignment

\begin{verbatim}
\begin{align}
    v &= u + at, \quad (1) \\
    d &= ut + \frac{1}{2} at^2. \quad (2)
\end{align}
\end{verbatim}

align

This is the simplest and the most widely used form of alignment. In the simplest case, there are two columns, one right aligned and the other left aligned. In $LaTeX$ the align environment takes care of such alignments; in Con$TeX$t \startmathalignment
In LaTeX
\begin{align}
v &= u + at, \\
d &= ut + \frac{1}{2} at^2.
\end{align}

In ConTeXt
\placeformula
\startformula
\startmathalignment
\NC v \NC = u + at, \NR ++ \\NR v = u + at, \tag{1}
\NC d \NC = ut + \frac{1}{2} at^2. \NR ++ \\NR d = ut + \frac{1}{2} at^2. \tag{2}
\stopmathalignment
\stopformula

split
The \texttt{split} environment of \texttt{amsmath} package is used for writing a single formula which needs more than one line. The whole formula gets a single number. In ConTeXt you have to manually specify which line to number.

\begin{equation} \begin{split}
(x+1)^8 &= x^8 + 8x^7 + 28x^6 + 56x^5 + 70x^4 \\
&+ 56x^3 + 28x^2 + 8x + 1.
\end{split} \end{equation}

In LaTeX
\begin{equation} \begin{split}
(x+1)^8 &= x^8 + 8x^7 + 28x^6 + 56x^5 + 70x^4 \\
&+ 56x^3 + 28x^2 + 8x + 1.
\end{split} \end{equation}

In ConTeXt
\placeformula
\startformula
\startmathalignment
\NC (x+1)^8 = \NC x^8 + 8x^7 + 28x^6 + 56x^5 + 70x^4 \NR \\NR NC \NC + 56x^3 + 28x^2 + 8x + 1. \tag{1}
\stopmathalignment
\stopformula

\begin{equation} \begin{split}
(x+1)^8 &= x^8 + 8x^7 + 28x^6 + 56x^5 + 70x^4 \\
&+ 56x^3 + 28x^2 + 8x + 1.
\end{split} \end{equation}

\begin{equation} \begin{split}
(x+1)^8 &= x^8 + 8x^7 + 28x^6 + 56x^5 + 70x^4 \\
&+ 56x^3 + 28x^2 + 8x + 1.
\end{split} \end{equation}
Notice that in LaTeX the spacing around = in the first line has to be manually corrected by typing {}. ConTeXt takes care of this automatically. In LaTeX you can control the position of the tag with tbtags or centertags option to the amsmath package. Right now, with the math alignment macros in ConTeXt you can only achieve the result equivalent to tbtags. To get the result equivalent to centertags you have to use the \eqalign macro of plain TeX.

alignat

The alignat environment of amsmath package allows you to align at several places. The alignment order alternates between right and left aligned columns. In ConTeXt the same effect can be achieved by m=... option of \startmathalignment.

\begin{alignat}{2}
\nabla \cdot \mathbf E &= \frac{\rho}{\varepsilon_0}, & \nabla \times \mathbf E &= -\frac{\partial \mathbf B}{\partial t}, \\
\nabla \cdot \mathbf B &= 0, & \nabla \times \mathbf B &= \mu_0 \mathbf j + \varepsilon_0 \mu_0 \frac{\partial \mathbf E}{\partial t}.
\end{alignat}

In LaTeX

\begin{alignat}{2}
\nabla \cdot \mathbf E &= \frac{\rho}{\varepsilon_0}, & \nabla \times \mathbf E &= -\frac{\partial \mathbf B}{\partial t}, \\
\nabla \cdot \mathbf B &= 0, & \nabla \times \mathbf B &= \mu_0 \mathbf j + \varepsilon_0 \mu_0 \frac{\partial \mathbf E}{\partial t}. 
\end{alignat}

In ConTeXt

\begin{alignat}{2}
\nabla \cdot \mathbf E &= \frac{\rho}{\varepsilon_0}, & \nabla \times \mathbf E &= -\frac{\partial \mathbf B}{\partial t}, \\
\nabla \cdot \mathbf B &= 0, & \nabla \times \mathbf B &= \mu_0 \mathbf j + \varepsilon_0 \mu_0 \frac{\partial \mathbf E}{\partial t}. 
\end{alignat}

\begin{alignat}{2}
\nabla \cdot \mathbf E &= \frac{\rho}{\varepsilon_0}, & \nabla \times \mathbf E &= -\frac{\partial \mathbf B}{\partial t}, \\
\nabla \cdot \mathbf B &= 0, & \nabla \times \mathbf B &= \mu_0 \mathbf j + \varepsilon_0 \mu_0 \frac{\partial \mathbf E}{\partial t}. 
\end{alignat}

flalign

The flalign environment is the same as alignat environment but with the equations a little more “out spaced”. In ConTeXt you can control the space between the “blocks” by distance=... option to \startmathalignment.
In LaTeX

\begin{flalign*}
\nabla\cdot \mathbf E &= \frac{\rho}{\varepsilon_0}, & \nabla\times \mathbf E &= -\frac{\partial \mathbf B}{\partial t}. \\
\nabla\cdot \mathbf B &= 0, & \nabla\times \mathbf B &= \mu_0 \mathbf j + \varepsilon_0\mu_0 \frac{\partial \mathbf E}{\partial t}.
\end{flalign*}

In ConTeXt

\startformula
\startmathalignment[m=2,distance=2em plus 1 fil]%
\NC \nabla\cdot \bf E \NC= \frac{\rho}{\varepsilon_0}, \NR
\NC \nabla\times \bf E \NC= -\frac{\partial \bf B}{\partial t}, \NR
\NC \nabla\cdot \bf B \NC= 0, \NR
\NC \nabla\times \bf B \NC= \mu_0 \bf j + \varepsilon_0\mu_0 \frac{\partial \bf E}{\partial t}. \NR
\stopmathalignment
\stopformula

\intertext
The \texttt{intertext} macro from amsmath allows you to break the alignment and write some text, which does not affect the alignment. ConTeXt provides the \texttt{intertext} macro and a \texttt{startintertext}, \texttt{stopintertext} environment for the same.

In LaTeX

\begin{align*}
\cos 2\theta &= \cos^2 \theta + \sin^2 \theta \\
\text{intertext}(replace $\sin^2 \theta$ by $1 - \cos^2 \theta$)
\end{align*}

\k= 2\cos^2 \theta - 1
\[ \cos 2\theta = \cos^2 \theta + \sin^2 \theta \]

replace \( \sin^2 \theta \) by \( 1 - \cos^2 \theta \)

\[ = 2 \cos^2 \theta - 1 \]

In ConTExt

\[ \begin{align*}
\cos 2\theta &= \cos^2 \theta + \sin^2 \theta \\
&= 2 \cos^2 \theta - 1
\end{align*} \]

linear equations

In LaT\TeX\ linear equations can be handled using \texttt{alignat} environment; in ConT\TeX\ appropriate options to \texttt{\startmathalignment} take care of this construction. \footnote{In ConT\TeX\}.

\[ \begin{alignat}{5}
&x_1 &{} + {}& x_2 &{} + {}& 6x_3 &{} = {}& 170, \quad (1) \\
&3x_1 &{} - {}& 110x_2 &{} - {}& x_3 &{} = {}& 4, \quad (2) \\
&14x_1 &{} + {}& 13x_2 &{} + {}& 10x_3 &{} = {}& 25. \quad (3)
\end{alignat} \]
In Con\TeX t

\placeformula \startformula
\startmathalignment
\NC x_1 \NC + \NC x_2 \NC + \NC 6x_3 \NC = \NC 170, \NR[+]
\NC 3x_1 \NC - \NC 110x_2 \NC - \NC x_3 \NC = \NC 4, \NR[+]
\NC 14x_1 \NC + \NC 13x_2 \NC + \NC 10x_3 \NC = \NC 25. \NR[+]
\stopmathalignment
\stopformula

\begin{align}
    x_1 + x_2 + 6x_3 &= 170, \\
    3x_1 - 110x_2 - x_3 &= 4, \\
    14x_1 + 13x_2 + 10x_3 &= 25.
\end{align}

In L\TeX \textit{we are limited to left and right aligned columns. In Con\TeX t it is easy to change the alignment of individual columns. For example}

\placeformula \startformula
\startmathalignment[n=7, align={middle, middle, middle, middle, middle, middle, middle}]
\NC x_1 \NC + \NC x_2 \NC + \NC 6x_3 \NC = \NC 170, \NR[+]
\NC 3x_1 \NC - \NC 110x_2 \NC - \NC x_3 \NC = \NC 4, \NR[+]
\NC 14x_1 \NC + \NC 13x_2 \NC + \NC 10x_3 \NC = \NC 25. \NR[+]
\stopmathalignment
\stopformula

\begin{align}
    x_1 + x_2 + 6x_3 &= 170, \\
    3x_1 - 110x_2 - x_3 &= 4, \\
    14x_1 + 13x_2 + 10x_3 &= 25.
\end{align}

\textbf{multi-column numbered equations}

Sometimes, while writing formulas in blocks, you need to number formulas in all blocks. I do not know of any easy way to do this in L\TeX. Herbert Voß's Mathmode\textsuperscript{1} has an example in Section 73 of using \texttt{tabular} to achieve this effect. Con\TeX t provides \texttt{\startformulas} for multi-column formulas, which allows numbering of formulas in each column.

\begin{align}
    \begin{array}{llll}
    = & + & + & = (1) \\
    = & + & + & = (2)
    \end{array}
\end{align}

\placeformula \startformulas
\startformula \startmathalignment
\NC \nabla \cdot \bf E \NC= \frac{\rho}{\varepsilon_0}, \NR[+]
\NC \nabla \cdot \bf B \NC= 0, \NR[+]
\stopmathalignment \stopformula

\startformula \startmathalignment
\NC \nabla \times \bf E \NC= -\frac{\partial \bf B}{\partial t}, \NR[+]
\NC \nabla \times \bf B \NC= \mu_0\bf j+\varepsilon_0\mu_0 \frac{\partial \bf E}{\partial t}. \NR[+]
\stopmathalignment \stopformula

\stopformulas
\( \nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}, \quad (1) \)
\( \nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}, \quad (3) \)
\( \nabla \cdot \mathbf{B} = 0, \quad (2) \)
\( \nabla \times \mathbf{B} = \mu_0 j + \varepsilon_0 \mu_0 \frac{\partial \mathbf{E}}{\partial t}. \quad (4) \)

**Defining your own alignments**

In the examples given above, I passed the arguments to \texttt{\startmathalignment}. This can be repetitive if you have to use the same alignment many times. \texttt{Con\TeXt} provides \texttt{\definemathalignment} to define a new math alignments. Suppose you have to type a lot of linear equations, you can define your own alignment as follows.

\begin{verbatim}
definemathalignment [linearequations] [n=7,align={middle,middle,middle,middle,middle,middle,middle}]
\placeformula \startformula
\startlinearequations
\NC x_1 \NC + \NC x_2 \NC + \NC 6x_3 \NC = \NC 170, \NR
\NC 3x_1 \NC - \NC 110x_2 \NC - \NC x_3 \NC = \NC 4, \NR
\NC 14x_1 \NC + \NC 13x_2 \NC + \NC 10x_3 \NC = \NC 25. \NR
\stoplinearequations
\stopformula
\end{verbatim}

You can define similar alignments for each special case that you have to use.

**Matrix and Arrays**

\texttt{Con\TeXt} provides \texttt{mathmatrix} series of macros (\texttt{\definemathmatrix}, \texttt{\setupmathmatrix}, \texttt{\startmathmatrix}, and \texttt{\stopmathmatrix}) to take care of matrix alignments. These macros can provide functionality of array environment as well as the matrix series of macros from \texttt{amsmath} package.

**Simple Matrix**

A matrix is a collection of objects that are arranged in rows and columns. In \LaTeX\ this alignment is provided by the array environment. In \texttt{Con\TeXt} \texttt{\startmathmatrix} provides this feature.

\begin{verbatim}
\begin{equation*}
\setlength{\arraycolsep}{1em}
\begin{array}{ccc}
A & k & B \, & C \ \\
AA & k & BB \, & CC \ \\
AAA & k & BBB \, & CCC
\end{array}
\end{equation*}
\end{verbatim}
\begin{array}{ccc}
A & B & C \\
AA & BB & CC \\
AAA & BBB & CCC
\end{array}

In Con\TeX

\startformula
\startmathmatrix[n=3,align={left,middle,right}]
\NC A & \NC B & \NC C \\
\NC AA & \NC BB & \NC CC \\
\NC AAA & \NC BBB & \NC CCC
\stopmathmatrix
\stopformula

In LaTeX the alignment of each column can be changed by the \texttt{r,c,l} options to \texttt{array}. In Con\TeX you need to pass appropriate arguments to \texttt{align=\ldots}.

In Con\TeX

\begin{equation*}
\begin{array}{lcr}
A & B & C \\
AA & BB & CC \\
AAA & BBB & CCC
\end{array}
\end{equation*}

In LaTeX the alignment of each column can be changed by the \texttt{r,c,l} options to \texttt{array}. In Con\TeX you need to pass appropriate arguments to \texttt{align=\ldots}.

In Con\TeX

\begin{equation*}
\begin{array}{lcr}
A & B & C \\
AA & BB & CC \\
AAA & BBB & CCC
\end{array}
\end{equation*}

\textbf{pmatrix, et. al}

The \texttt{amsmath} package provides \texttt{pmatrix}, \texttt{bmatrix}, etc. environments that make it easy to typeset matrix surrounded by delimiters. In Con\TeX it is straightforward to define such matrices uses \texttt{\definemathmatrix}. 

In Con\TeX

\begin{equation*}
A = \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}
\end{equation*}
\[ A = \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} \]

In Con\TeX{}

\begin{verbatim}
\definemathmatrix
\[pmatrix]\[left={\left(},right={\right)}\]
\startformula
A = \startpmatrix[location=low] 1 \NR 2 \NR 3 \stoppmatrix
\startpmatrix[location=middle] 1 \NR 2 \NR 3 \stoppmatrix
\startpmatrix[location=high] 1 \NR 2 \NR 3 \stoppmatrix
\stopformula
\end{verbatim}

\[ A = \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} \]

\textbf{delarray package}

The delarray package in LaTeX allows you to typeset arrays with properly scaled delimiters, even when the array is not middle aligned to the baseline. In Con\TeX{} the \texttt{\definemathmatrix} takes care of proper scaling of delimiters.

\begin{verbatim}
\begin{equation*}
\begin{array}{|c|c|c|}
\hline
1 & 2 & 3 \\
\hline
\end{array}
\end{equation*}
\end{verbatim}

\[ \begin{array}{|c|c|c|}
\hline
1 & 2 & 3 \\
\hline
\end{array} \]

In Con\TeX{}

\begin{verbatim}
\begin{verbatim}
\definemathmatrix
\[pmatrix]\[left={\left(},right={\right)}\]
\startformula
\begin{array}{|c|c|c|}
\hline
1 & 2 & 3 \\
\hline
\end{array}
\end{array}
\stopformula
\end{verbatim}
\end{verbatim}

\[ \begin{array}{|c|c|c|}
\hline
1 & 2 & 3 \\
\hline
\end{array} \]
\[
\begin{pmatrix}
1 \\
2 \\
3
\end{pmatrix}
\begin{pmatrix}
1 \\
2 \\
3
\end{pmatrix}
\begin{pmatrix}
1 \\
2 \\
3
\end{pmatrix}
\]

Cases

Cases is another common math alignment.

\[\text{\textasciitilde} = \left\{ \begin{array}{r}
\text{\textasciitilde} + \text{\textasciitilde}, \\
\text{\textasciitilde} + \text{\textasciitilde} + \text{\textasciitilde}, \\
\text{\textasciitilde} + \text{\textasciitilde} + \text{\textasciitilde} + \text{\textasciitilde}
\end{array} \right.\]

The amsmath package provides a cases environment to build such alignments. ConT\text{\textasciitilde}x provides \texttt{startmathcases}.

\textit{In La\text{T\textasciitilde}X}

\begin{verbatim}
\begin{equation*}
|\mathit{x}| = \begin{cases} 
\mathit{x}, & \text{if } \mathit{x} \ge 0; \\
-\mathit{x}, & \text{otherwise.}
\end{cases}
\end{equation*}
\end{verbatim}

\[|\mathit{x}| = \left\{ \mathit{x}, \text{ if } \mathit{x} \ge 0; \right.\]
\[\left. \mathit{-x}, \text{ otherwise.} \right.\]

\textit{In ConT\text{\textasciitilde}x}

\begin{verbatim}
\begin{startformula}
|\mathit{x}| = \begin{startmathcases} 
\NC \mathit{x}, \NC \text{ if } \mathit{x} \ge 0; \ \NR
\NC -\mathit{x}, \NC \text{ otherwise.} \ \NR
\stopmathcases
\end{startformula}
\end{verbatim}

\[|\mathit{x}| = \left\{ \mathit{x}, \text{ if } \mathit{x} \ge 0; \right.\]
\[\left. \mathit{-x}, \text{ otherwise.} \right.\]

In the cases environment, the rows are set in textstyle. The mathtools package provides a dcases environment to set the rows in displaystyle. In ConT\text{\textasciitilde}x you can set the rows in displaystyle by passing style=\texttt{\textasciitilde}\texttt{displaystyle} to \texttt{startmathcases} (or defining a new cases structure using \texttt{\textasciitilde}\texttt{definemathcases}).

\textit{In La\text{T\textasciitilde}X}

\begin{verbatim}
\begin{equation*}
f(\mathit{x}) = \begin{dcases} 
\int_0^\mathit{x} g(\mathit{y}) \, d\mathit{y}, & \text{if } \mathit{x} \ge 0; \\
\int_{-\mathit{x}}^0 g(\mathit{y}) \, d\mathit{y}, & \text{otherwise.}
\end{dcases}
\end{equation*}
\end{verbatim}

\[f(\mathit{x}) = \left\{ \int_0^{\mathit{x}} g(\mathit{y}) \, d\mathit{y}, \text{ if } \mathit{x} \ge 0; \right.\]
\[\left. \int_{-\mathit{x}}^0 g(\mathit{y}) \, d\mathit{y}, \text{ otherwise.} \right.\]
In Con\TeX t
\begin{align*}
f(x) &= \begin{cases}
\int_0^x g(y) \, dy, & \text{if } x \ge 0; \\
\int_{-x}^0 g(y) \, dy, & \text{otherwise}.
\end{cases}
\end{align*}

Predefined Alignments

Con\TeX t already has\begin{itemize}
\item \texttt{\definemathalignment[align]}
\item \texttt{\definemathmatrix[matrix]}
\item \texttt{\definemantcases[cases]}
\end{itemize}
defined. This means that in all the above examples, you can shorten \texttt{\startmathalignment ... \stopmathalignment} to \texttt{\startalign ... \stopalign}, \texttt{\startmathmatrix ... \stopmathmatrix} to \texttt{\startmatrix ... \stopmatrix}, and \texttt{\startmathcases ... \stopmathcases} to \texttt{\startalign ... \stopalign}.

Conclusion

Con\TeX t now provides macros for math alignments. This makes it easier for the users to write complicated math alignments in Con\TeX t. The syntax is consistent with the rest of Con\TeX t macros, and thereby different from \texttt{amsmath} package syntax. Hopefully, this article will help eliminate the myth that Con\TeX t is not able to handle complicated math. In Con\TeX t features are added on user requests; so if there is something that you need which is not present in Con\TeX t, ask for a feature request on the mailing list.

Notes

3. Compare these solutions from Exercise 22.9 in the \TeX book.

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