Display Math in Formula

Where is it and where can it go

Or Is $\TeX$ really good at math?

The present

Basics

Equation Numbering

$$\rule{3em}{1em} + \rule{3em}{1em} + \rule{1.6em}{1em} = \rule{1.6em}{1em} \tag{1}$$

```
\placeformula \startformula
  ...
\stopformula
```

Location of equation number

(2) $$\blacksquare + \blacksquare + \blacksquare = \blacksquare$$

```
\setupformulas[location=left]
```

Conversion of equation numbers

[redacted] + [redacted] + [redacted] + [redacted] + [redacted] = [redacted] (C)

```
\setupformulas[conversion=Characters]
```

Formatting of equation numbers

$$\blacksquare + \blacksquare + \blacksquare + \blacksquare = \blacksquare \qquad \textbf{\textit{(4)}}$$

```
\setupformulas[numberstyle=bold]
```

Formatting of equation numbers

[redacted] + [redacted] + [redacted] + [redacted] + [redacted] = [redacted]   [5]

```
\setupformulas[left={[},right={]}]
```

Placement of fomrula

$$\rule{1cm}{0.6cm} + \rule{2.2cm}{0.6cm} + \rule{1.5cm}{0.6cm} = \rule{1.5cm}{0.6cm} \tag{6}$$

```
\setupformulas[align=left]
```

Placement of fomrula

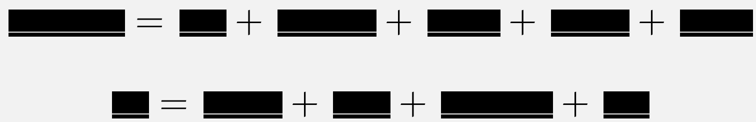
$$\blacksquare + \blacksquare + \blacksquare + \blacksquare = \blacksquare \tag{7}$$

```
\setupformulas[align=right]
```

The present

AMSTeX features

Gather

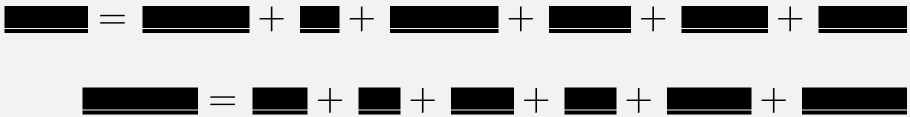


```
\startformula
  \startalign[ n=1 ]
    \NC ... \NR[+]
    \NC ... \NR[+]
  \stopalign
\stopformula
```

Left gather

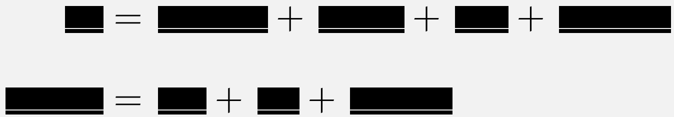
```
\startformula
  \startalign[n=1,  align=left ]
    \NC ... \NR[+]
    \NC ... \NR[+]
  \stopalign
\stopformula
```

Right gather



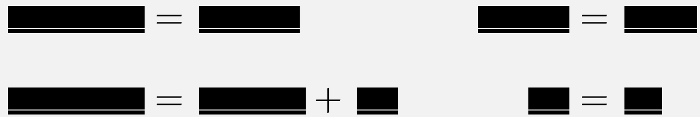
```
\startformula
  \startalign[n=1, align=right ]
    \NC ... \NR[+]
    \NC ... \NR[+]
  \stopalign
\stopformula
```

Align



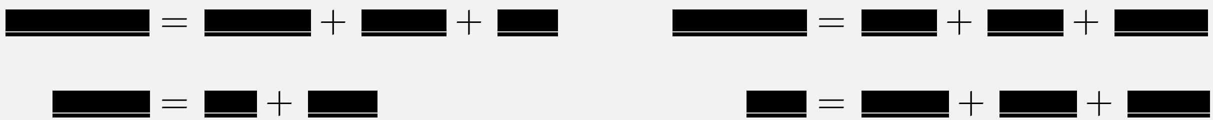
```
\startformula
  \startalign[ n=2 ]
    \NC ... \NC ... \NR[+]
    \NC ... \NC ... \NR[+]
  \stopalign
\stopformula
```

Alignat



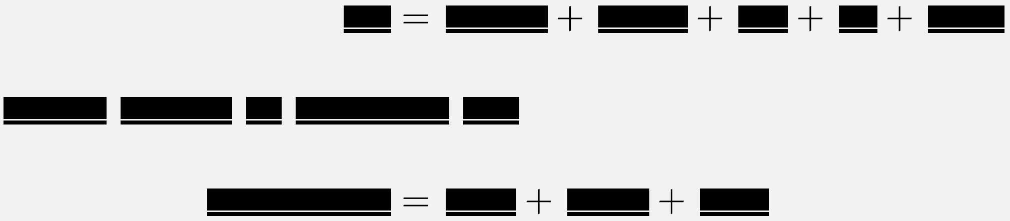
```
\startformula
  \startalign[n=2,  m=2, distance=2em ]
    \NC ... \NC ... \NC ... \NC ... \NR[+]
    \NC ... \NC ... \NC ... \NC ... \NR[+]
  \stopalign
\stopformula
```

Flaign



```
\startformula
  \startalign[n=2, m=2, distance=1em plus 1fill ]
    \NC ... \NC ... \NC ... \NC ... \NR[+]
    \NC ... \NC ... \NC ... \NC ... \NR[+]
  \stopalign
\stopformula
```

Intertext



```
\startformula
  \startalign
    \NC ... \NC ... \NR[+]
  \intertext{...}
    \NC ... \NC ... \NR[+]
  \stopalign
\stopformula
```

Multi-column numbered equations

$$\blacksquare = \blacksquare + \blacksquare \qquad (8) \qquad\qquad \blacksquare = \blacksquare \qquad (10)$$

$$\blacksquare = \blacksquare + \blacksquare \qquad (9) \qquad\qquad \blacksquare = \blacksquare + \blacksquare \qquad (11)$$

```
\placeformula  \startformulas
  \startformula \startalign
   ...
  \stopalign \stopformula
  \startformula \startalign
   ...
  \stopalign \stopformula
 \stopformulas
```

Subformulas

$$\blacksquare = \blacksquare + \blacksquare + \blacksquare \tag{12a}$$

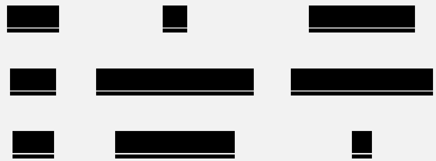
$$\blacksquare = \blacksquare + \blacksquare + \blacksquare + \blacksquare \tag{12b}$$

```
\startsubformulas
\startformula \startalign
    \NC ... \NC ... \NR[+]
    \NC ... \NC ... \NR[+]
\stopalign \stopformula
\stopsubformulas
```

The present

Subexpressions

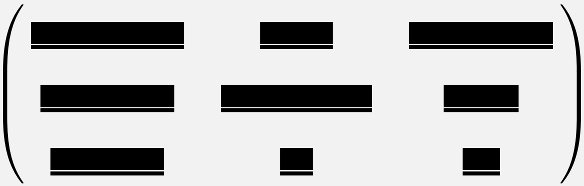
Matrix



(13)

```
\startformula
  \startmathmatrix[n=3]
    \NC ... \NC ... \NC ... \NR
    \NC ... \NC ... \NC ... \NR
    \NC ... \NC ... \NC ... \NR
  \stopmathmatrix
\stopformula
```

Matrix – parenthesis

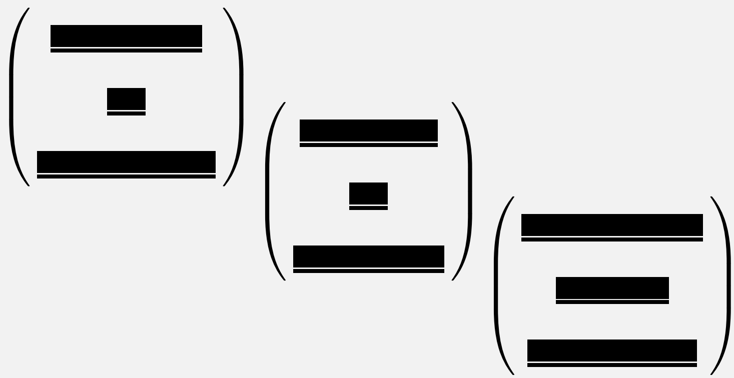


```
\startformula
  \startmathmatrix[n=3, left={\left(\,}, right={\,\right)}]
    \NC ... \NC ... \NC ... \NR
    \NC ... \NC ... \NC ... \NR
    \NC ... \NC ... \NC ... \NR
 \stopmathmatrix
\stopformula
```

Defining matrices

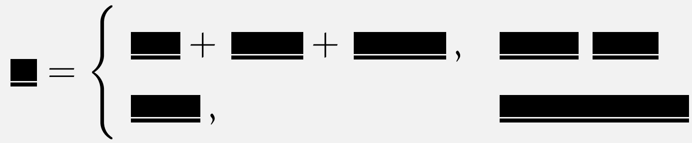
```
\definemathmatrix[pmatrix][left={\left(\,}, right={\,\right)}]
```

Aligning matrices



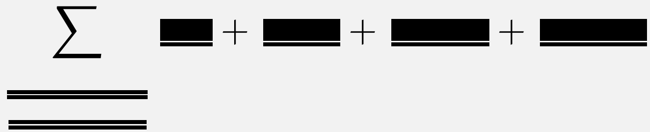
```
\startformula
  \startmathmatrix[ location=low ]    ... \stopmathmatrix
  \startmathmatrix[ location=middle ] ... \stopmathmatrix
  \startmathmatrix[ location=high ]   ... \stopmathmatrix
\stopformula
```

Cases



```
\startformula
  ... =  \startcases
    \NC ... \NC ... \NR
    \NC ... \NC ... \NR
  \stopcases
\stopformula
```

Substacks



```
\startformula
  \sum_{\startsubstack
    \NC ... \NR
    \NC ... \NR
  \stopsubstack ...
\stopformula
```

Missing features

Simple yet have no support

- Arbitrary tag's as equation numbers

$$E = mc^2 \tag{Einstein's Formula}$$

  Need to come up with a consistent user interface

- gathered, aligned, etc.

  Is really simple to code from scratch, hard to reuse parts of mathalign

Not so simple and still have no support

- Complete support of multline

  If you do not care about location of equation numbers, support is easy.

- Proper support for equation numbers in multiline equations

  Need a two pass algorithm, current support is only a one pass algorithm.

- Location of equation numbers — ctags, tbtags

  Currently ConTEXt does not even attempt to do this

- Proper support for `split`

  Easy once location of equation number is done.

- *Correct* support for `align` when there are multiple columns

  Find the size of all columns and split the remaining space equally between them

- Controlling page break between equations

  Something more fine tuned than the current all or none approach

- Using `\shortdisplayskip`

  Can be done, (`breqn` does it), but I don't really understand TeX that well.

Example

$$
\begin{aligned}
&{}^4b_t^1(x_t, y_t^2, u_t^2, s_{t-1}^2) \\
&\quad = \Pr\Big(X_t = x_t, Y_t^2 = y_t^2, U_t^2 = u_t^2, S_{t-1}^2 = s_{t-1}^2 \,\Big|\, Y^{1,t} = y^{1,t}, U^{1,t} = u^{1,t}; {}^4\varphi^{t-1}\Big) \\
&\quad = \Pr\Big(U_t^2 = u_t^2 \,\Big|\, X_t = x_t, Y_t^2 = y_t^2, S_{t-1}^2 = s_{t-1}^2 Y^{1,t} = y^{1,t}, U^{1,t} = u^{1,t}; {}^3\varphi^{t-1}, g_t^2\Big) \\
&\qquad \times \Pr\Big(X_t = x_t, Y_t^2 = y_t^2, S_{t-1}^2 = s_{t-1}^2 \,\Big|\, Y^{1,t} = y^{1,t}, U^{1,t} = u^{1,t}; {}^3\varphi^{t-1}, g_t^2\Big) \\
&\quad \overset{(c)}{=} \mathbb{I}\Big[u_t^2 = g_t^2(y_t^2, s_{t-1}^2)\Big] \\
&\qquad \times \Pr\Big(X_t = x_t, Y_t^2 = y_t^2, S_{t-1}^2 = s_{t-1}^2 \,\Big|\, Y^{1,t} = y^{1,t}, U^{1,t} = u^{1,t}; {}^3\varphi^{t-1}\Big) \\
&\quad = \mathbb{I}\Big[u_t^2 = g_t^2(y_t^2, s_{t-1}^2)\Big]\, {}^3b_t^1(x_t, y_t^2, s_{t-1}^2) \\
&\quad =: {}^3F^1({}^3b_t^1, g_t^2)(x_t, y_t^2, s_{t-1}^2) \qquad (2.59)
\end{aligned}
$$

where (c) follows from the sequential order in which the system variables are generated.

4. Consider ${}^4o_t^1 = (y^{1,t}, u^{1,t}) \in (\mathcal{Y}^{1,t} \times \mathcal{U}^{1,t})$, $y_{t+1}^1 \in \mathcal{Y}^1$, $x_{t+1} \in \mathcal{X}$, $s_t^2 \in \mathcal{S}^2$, and ${}^1\varphi^t = ({}^4\varphi^{t-1}, l_t^2)$. Then a component (x_{t+1}, s_t^2) of a realization ${}^1b_{t+1}^1$ of ${}^1B_{t+1}^1$ is given by

$$
\begin{aligned}
{}^1b_{t+1}^1 &= \Pr\Big(X_{t+1} = x_{t+1}, S_t^2 = s_t^2 \,\Big|\, Y_{t+1}^1 = y_{t+1}^1, {}^4O_t^1 = {}^4o_t^1; {}^1\varphi^t\Big) \\
&= \frac{\Pr\Big(X_{t+1} = x_{t+1}, S_t^2 = s_t^2, Y_{t+1}^1 = y_{t+1}^1 \,\Big|\, {}^4O_t^1 = {}^4o_t^1; {}^1\varphi^t\Big)}{\Pr\Big(Y_{t+1}^1 = y_{t+1}^1 \,\Big|\, {}^4O_t^1 = {}^4o_t^1; {}^1\varphi^t\Big)} \qquad (2.60)
\end{aligned}
$$

Now,

$$
\begin{aligned}
&\Pr\Big(X_{t+1} = x_{t+1}, S_t^2 = s_t^2, Y_{t+1}^1 = y_{t+1}^1 \,\Big|\, {}^4O_t^1 = {}^4o_t^1; {}^1\varphi^t\Big) \\
&\quad = \Pr\Big(Y_{t+1}^1 = y_{t+1}^1 \,\Big|\, X_{t+1} = x_{t+1}, S_t^2 = s_t^2, {}^4O_t^1 = {}^4o_t^1; {}^1\varphi^t\Big) \\
&\qquad \times \Pr\Big(X_{t+1} = x_{t+1}, S_t^2 = s_t^2 \,\Big|\, {}^4O_t^1 = {}^4o_t^1; {}^1\varphi^t\Big) \\
&\quad = P_{N^1}\Big(n_t^1 \in \mathcal{N}^1 : y_{t+1}^1 = h_t^1(x_{t+1}, n_{t+1}^1)\Big) \\
&\qquad \times \Pr\Big(X_{t+1} = x_{t+1}, S_t^2 = s_t^2 \,\Big|\, {}^4O_t^1 = {}^4o_t^1; {}^1\varphi^t\Big) \qquad (2.61)
\end{aligned}
$$

Further,

$$
\begin{aligned}
&\Pr\Big(X_{t+1} = x_{t+1}, S^2_t = s^2_t \,\Big|\, {}^4O^1_t = {}^4o^1_t; {}^1\varphi^t\Big) \\
&\quad = \sum_{\substack{x_t \in \mathcal{X}, y^2_t \in \mathcal{Y}^2 \\ u^2_t \in \mathcal{U}^2, s^2_{t-1} \in \mathcal{S}^2}} \Pr\Big(X_{t+1} = x_{t+1}, X_t = x_t, Y^2_t = y^2_t, U^2_t = u^2_t, \\
&\qquad\qquad\qquad S^2_{t-1} = s^2_{t-1}, S^2_t = s^2_t \mid {}^4O^1_t = {}^4o^1_t; {}^1\varphi^t\Big) \\
&\quad = \sum_{\substack{x_t \in \mathcal{X}, y^2_t \in \mathcal{Y}^2 \\ u^2_t \in \mathcal{U}^2, s^2_{t-1} \in \mathcal{S}^2}} \Pr\Big(X_{t+1} = x_{t+1} \mid X_t = x_t, Y^2_t = y^2_t, U^2_t = u^2_t, \\
&\qquad\qquad\qquad S^2_{t-1} = s^2_{t-1}, S^2_t = s^2_t, {}^4O^1_t = {}^4o^1_t; {}^1\varphi^t\Big) \\
&\qquad\qquad \times \Pr\Big(S^2_t = s^2_t \mid X_t = x_t, Y^2_t = y^2_t, U^2_t = u^2_t, \\
&\qquad\qquad\qquad S^2_{t-1} = s^2_{t-1}, {}^4O^1_t = {}^4o^1_t; {}^4\varphi^{t-1}, l^2_t\Big) \\
&\qquad\qquad \times \Pr\Big(X_t = x_t, Y^2_t = y^2_t, U^2_t = u^2_t, S^2_{t-1} = s^2_{t-1}, {}^4O^1_t = {}^4o^1_t; {}^4\varphi^{t-1}, l^2_t\Big) \\
&\quad \overset{(d)}{=} \sum_{\substack{x_t \in \mathcal{X}, y^2_t \in \mathcal{Y}^2 \\ u^2_t \in \mathcal{U}^2, s^2_{t-1} \in \mathcal{S}^2}} P_W\Big(w_t \in \mathcal{W} : x_{t+1} = f(x_t, u^1_t, u^2_t, w_t)\Big) \mathbb{I}\left[s^2_t = l^2_t(y^2_t, u^2_t, s^1_{t-1})\right] \\
&\qquad\qquad \times \Pr\Big(X_t = x_t, Y^2_t = y^2_t, U^2_t = u^2_t, S^2_{t-1} = s^2_{t-1}, {}^4O^1_t = {}^4o^1_t; {}^4\varphi^{t-1}\Big) \\
&\quad = \sum_{\substack{x_t \in \mathcal{X}, y^2_t \in \mathcal{Y}^2 \\ u^2_t \in \mathcal{U}^2, s^2_{t-1} \in \mathcal{S}^2}} P_W\Big(w_t \in \mathcal{W} : x_{t+1} = f(x_t, u^1_t, u^2_t, w_t)\Big) \mathbb{I}\left[s^2_t = l^2_t(y^2_t, u^2_t, s^1_{t-1})\right] \\
&\qquad\qquad \times {}^4b^1_t(x_t, y^2_t, u^2_t, s^2_{t-1}).
\end{aligned} \tag{2.62}
$$

where (d) follows from the sequential order in which the system variables are generated. Combining (2.60)–(2.62) we get

$$
{}^1b^1_{t+1}(x_{t+1}, s^2_t) =: {}^4F^1({}^4b^1_t, l^2_t, y^1_{t+1}, u^1_t)(x_{t+1}, s^2_t) \tag{2.63}
$$

where ${}^4F^1$ is given by (2.60)–(2.62). □

Structural properties

In this section, we provide structural/qualitative properties of optimal control laws of agent 1 that are true for every arbitrary but fixed control and state-update strategies of agent 2. These properties are subsequently used to convert the model of variation v2 into a model similar to variation v1.

Theorem 2.5 (Structure of optimal control laws of agent 1). *Consider variation v2 of the model of Problem 2.1. For any arbitrary but fixed control and state-update strategies*

The Future?

What is wrong with current math support in TeX?

Separation of content from presentation

Display math is becoming write once format

Automatic
line breaks

Can luaTeX help?

Allow non-TeXperts
to experiment with
line breaking
algorithms

What is needed for automatic line breaks

```
\startdisplay
  .........
\stopdisplay
```

1. Dimensions (height, width, depth) of each “character”
2. Mathcode of each character (relation, operator, delimiter, punctuation, etc)
3. What else ...
4. Can TEX know this (commands like `\over` etc) ...

Easy to convert from display to inline

```
\startinline
  .........
\stopinline
```

- TeX should do *the right thing* for both display and inline modes
- `nath` does that to a large extent.

Thank you