Neurocomputing *in Geography?*

Why bother???

Contents

- ★ Hype
- ★ History
- ★ Possible attractions
- ★ Possible problems
- ★ Its very EASY!

Why Bother?

- *Many Human Geographers have given up computers, numbers, and **retreated** to the **land of their dreams!***
- *Many physical geographers are still firmly attached to their **old ways** full of mathematical rigour, bits of physics chemistry etc, and like their theories to be SIMPLE-ish*

Others just use neural nets because...

- they exist
- they work
- they are easy to use
- they are not complex
- they are very useful in modelling complex systems
- **whats the fuss??**

If you are NOT yet CONVINCED then what will convince you?

Lets look at some background events

- We are in an IT era
- Are world is full of computer systems
- Most routine management tasks have been computerised
- Computer systems are reaching in all aspects of our lives
- Its true of home, work, and play
- It affects HOW WE DO all subjects including geography

Geographers have got more to worry about than most!

- *We now live in a world that is increasingly spatial data rich*
- *The subjects of geographical study are very complex in both physical and human forms*
- *There are new tools out there which can help us do whatever forms of geography we are interested in*

AND

Neural Nets are one of them!

Three major interrelated developments

- **Spatial Data Explosion** due to developments in GIS, automated data capture and galloping computerization
- **Major revolution in the economics and speed of High Performance Computing** due to Massively Parallel Processing
- **Availability of Artificial Intelligence tools** that work on real problems

Spatial Data Explosion

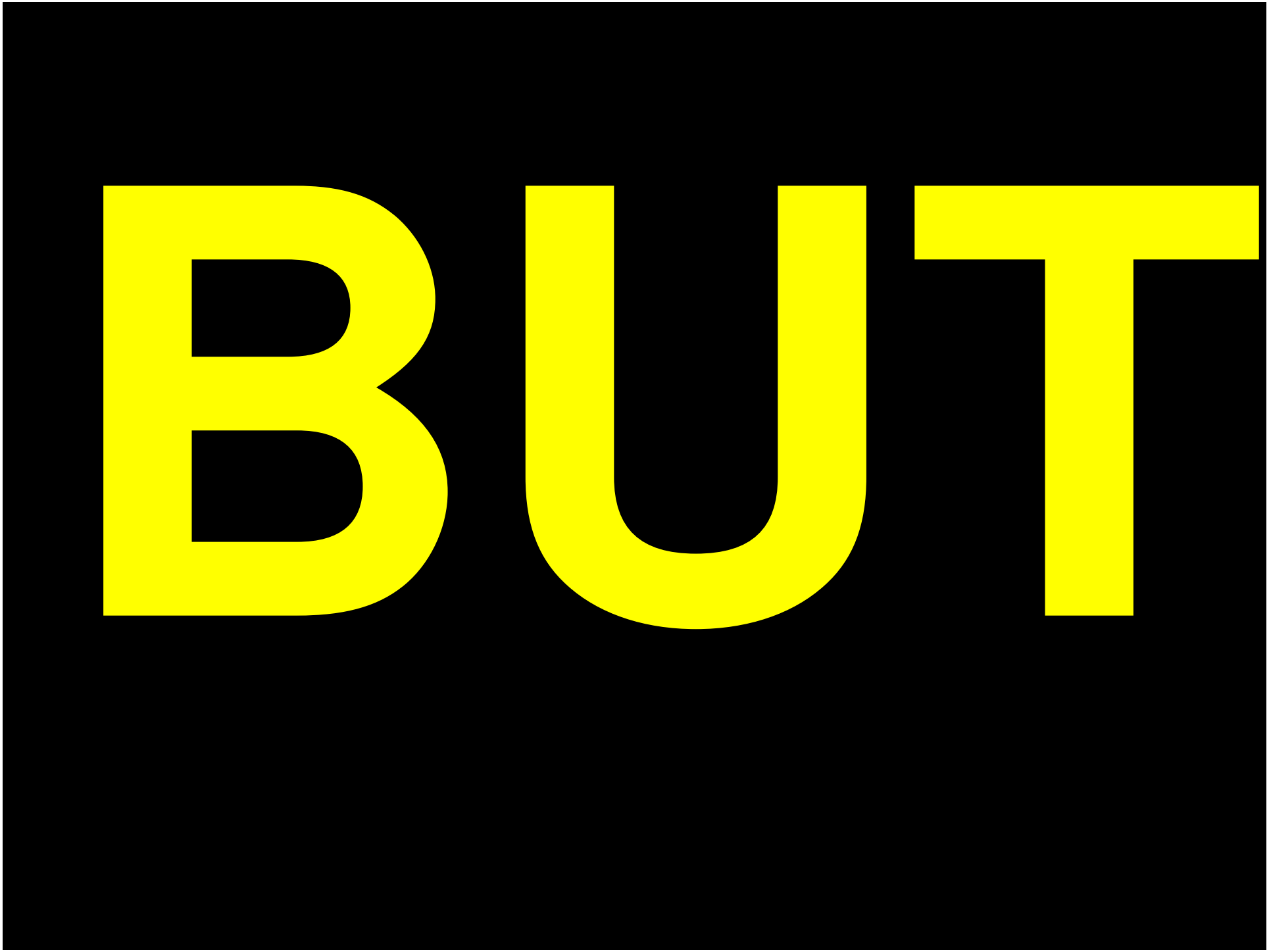
- The world is in the throes of an information explosion due to
  - *developments in IT*
  - *the computerization of everything*
  - *automated data capture and sensing devices*
  - *falling costs of storage*
  - *computing power that doubles every 2 years*

Much of the Information is now Spatially Referenced

Geographic Information Systems

- GIS provides excellent tools for storing, managing, manipulating, mapping, and querying spatial information
- GIS is now a mature global technology
- GIS has added geographical coordinates to many data bases opening them up to analysis and modelling

But


BUT

Where are the tools for Analysis and Modelling that can cope?

- **GIS is very poor at handling time**
- **GIS is very poor at handling people data**
- **GIS lacks modern spatial analysis and modelling tools**
- **GIS Revolution essentially driven by cartographers and AM/FM interests**

A new era that is Spatial Data Rich needs a New Set of Modelling and Analysis Tools

Data Warehouses, Data Marts, Operational Data Stores

- *being used to STORE terabytes of data*
- *Data Mining is a vibrant NEW area of modelling and analysis*
- *GEOGRAPHY is a relevant discipline in these developments*
- **BUT.. we need to get going..**

The new needs are for:

Data Driven Modelling

Data Driven Analysis

by

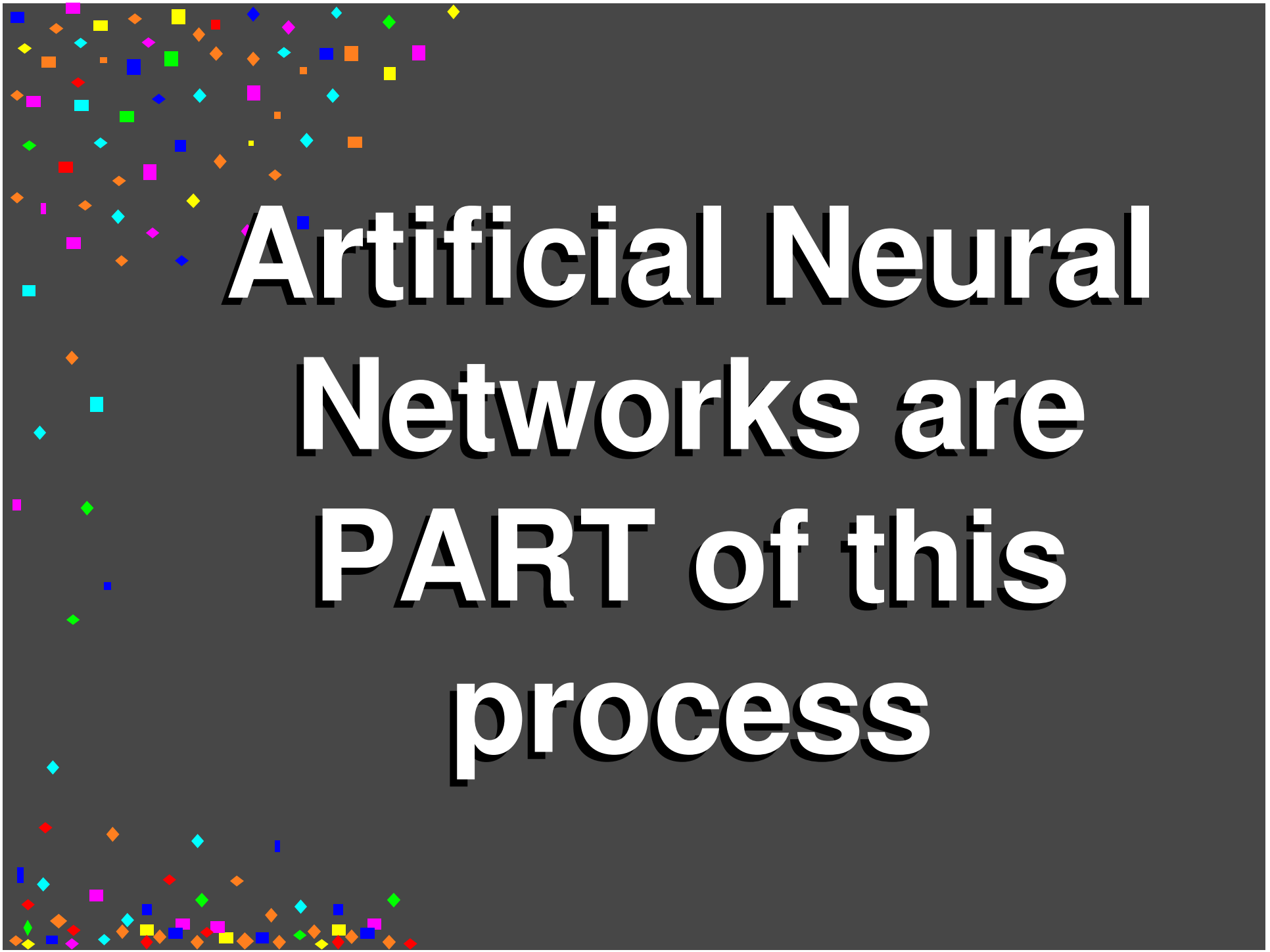
Inductive Mechanisms

and

Neurocomputing is one way of computing our way out of some of the problems!

Why?

- Maybe we can COMPUTE our way to
  - better solutions to old problems
  - solutions to previous impossible problems
  - develop entirely new approaches to going Geography and many other Social Sciences
- Computationally Intelligent Tools such as neural networks are clearly part of this tool kit


Artificial Neural Networks are PART of this process

What is Neurocomputing?

- loosely based on how the brain is thought to work
- it is an emulation of primitive neural processes in software (or hardware)
- it attempts to mimic (it cannot yet copy) the workings of a real brain
- best neural net is currently equivalent to a brain damaged worm but astonishingly this is good enough for many problems

So ...

- ★ *go EASY on the artificial BRAIN stuff*
- ★ **best to regard neurocomputing as being BIOLOGICALLY inspired**
- ★ *you do not have to build a REAL brain to emulate some of the principal properties*
- ★ **it is this EMULATION or SIMULATION that is neurocomputing**

BEWARE
of the neurobabble
or JARGON put
there by different
disciplines

History

- Neural Networks are not NEW inventions!!!!!
- They were tried once before and FAILED miserably
- History is not going to repeat itself
- Lets have a quick look at it

Brief History

- First neural Nets, 1943-49
- Years of Gloom and Dormancy, 1969-82
- The new neural nets, 1982-86
- Take off, 1987-
- 1994 First Geography Text!

First Neural Nets, 1943-69

- Speculations about artificial brains date from 1930s and before
- McCullock and Pitts (1943) developed simple model of a neuron as a summation device
- Hebb (1949) demonstrated learning mechanisms
- Wiener (1948), von Neumann (1951) suggested research into brain like computers

The PERCEPTRON was the first SUCCESSFUL neurocomputer

- ★ *Rosenblatt (1958) developed the mark 1 Perceptron*
- ★ *It was a pattern recognition device*
- ★ **It caught people's imagination and stimulated much research**
- ★ *Other neurocomputers developed by Widrow and Hoff (1960)*

There were many problems

- Many researchers were carried away by their enthusiasm
- Little rigour and much experimentation
- Predictions were made that Artificial Brains were only a few years away
- Computers were slow and there was very little software
- No theory

Other problems

- Unrealistic expectations and hype
- Lack of multi-level training methods
- Absence of theoretical mathematical understanding
- Lack of practical benefits and commercial products
- A venomous campaign against neural nets started by AI researchers

Minsky and Papert (1969) critique

- *Minsky and Papert proved mathematically that a Perceptron could not implement the EXCLUSIVE OR logical function*
- *It also couldn't handle many other predicate functions*
- **This bizarre and trivial fact was used to argue that all neural networks were doomed**

Years of gloom and dormancy : 1969 - 82

- *Neurocomputing research became very unpopular and went underground*
- *New researchers continued to work in this area but called it something other than neural computing*
- *Examples are the COGNITRON, WISARD, ART, Associative Computer Memories, self-organising map etc.*

The new neural nets : 1982 - 86

- *US Department of Defense funded some of the work for missile guidance systems*

- **It's evil!** ***(They cry)***

- *Hopfield (1982-84) credited with reviving interest in neural nets as a means of making advanced computer memories*
- *Hopfield is credited with restoring scientific credibility to the area*

Take off : 1987+

- *Rumelhart and Williams (1986) published a solution to the problem of training multi-level Perceptrons*
- ***The EXCLUSIVE OR problem could now be solved!***
- *Rumelhart and McCelland's (1986) book on Parallel Distributed Processing greatly stimulated interest in the area*
- ***As did the NETtalk demo***

Neural computing revolution

- *Tremendous surge of interest in one discipline after another soon followed*
- *Exponential growth in literature*
- *Increasing number of commercial products*
- ***Expert Systems were failing and neural computing offered a practical alternative way towards Intelligent Knowledge Based Systems***

Neural nets are here to stay

- *Computers now much faster*
- *Computers now much bigger*
- *Wide range of applications*
- *Plentiful software*
- *Easy to use*

Neurocomputing is now an accepted and widely diffused technology

- ★ it works
- ★ there are lots of software
- ★ it is widely applicable
- ★ it is a mature technology
- ★ BUT...still

not many geographical applications

Where is the neural net revolution in geography

Geographical applications still restricted

- *Only a few papers deal with traditional geographic applications (cf remote sensing)*
- *Only one book so far but a few more forthcoming*
- *Technology is widely diffused but is not being widely used?*
- ***Some argue there's no need for a revolution in geography because it's already happened***

Benefits

- Non linearity
- Adaptivity
- Noise tolerancy
- Universal approximation capability
- Promise of good levels of performance
- Extends the domain of computing into many soft areas
- Works well on hard problems

Geographical appreciation

- Offers a new paradigm for performing many spatial analysis and modelling tasks in geography
- Supervised neural nets probably have the greatest potential

Geographical applications

- *As replacement technology conventional statistical and mathematical modelling methods*
- *As models of systems that are too complex for good understanding*
- *No need for in-depth prior knowledge of the processes being studied*
- *Freedom from mathematical and statistical complexity*

Geographical applications

- *Flexibility*
- *Can handle soft problems*
- *A means of tackling applications previously thought to be too hard for computer analysis and quantitative geography*
- *A means of helping geographers cope with a spatial data rich world*

A one stop shop

Possible problems (1)

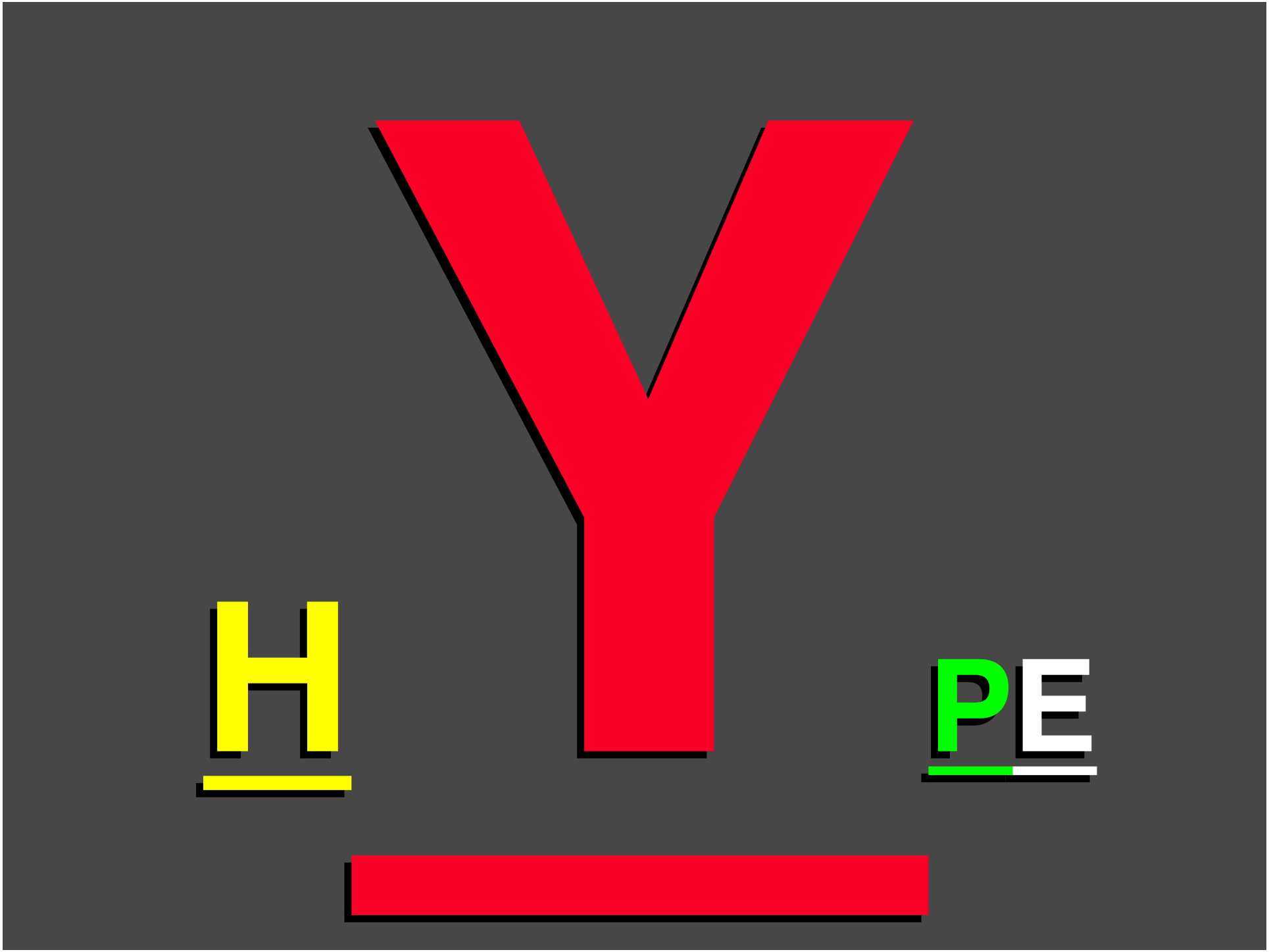
- *It's a black box technology*
- *It's a data driven technology*
- *Impossible to use existing knowledge*
- *Many different types of neural net to choose from*
- *There are often statistical alternatives*
- *Analogy with the brain is misleading*

Possible problems (2)

- *Unresolved technical problems related to training issues*
- *Neural nets have to learn everything from data that may not be correct*
- *The results may not be capable of generalisation*
- *No understanding of process provided*
- *Large amounts of unfamiliar technical jargon*

Possible problems (3)

- Hype
- Hype
- Hype
- Hype
- Hype
- Hype
- In fact...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BEWARE
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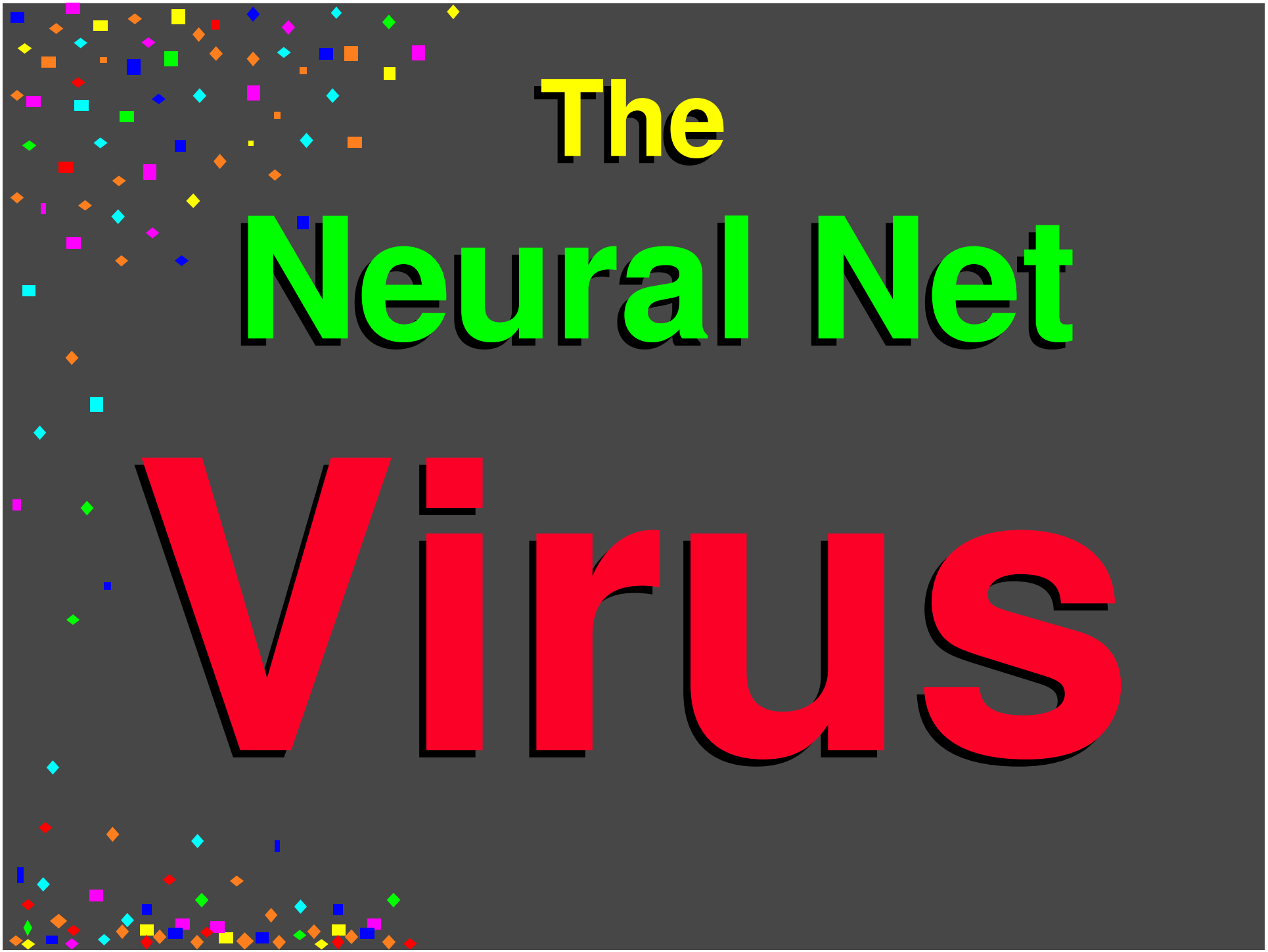
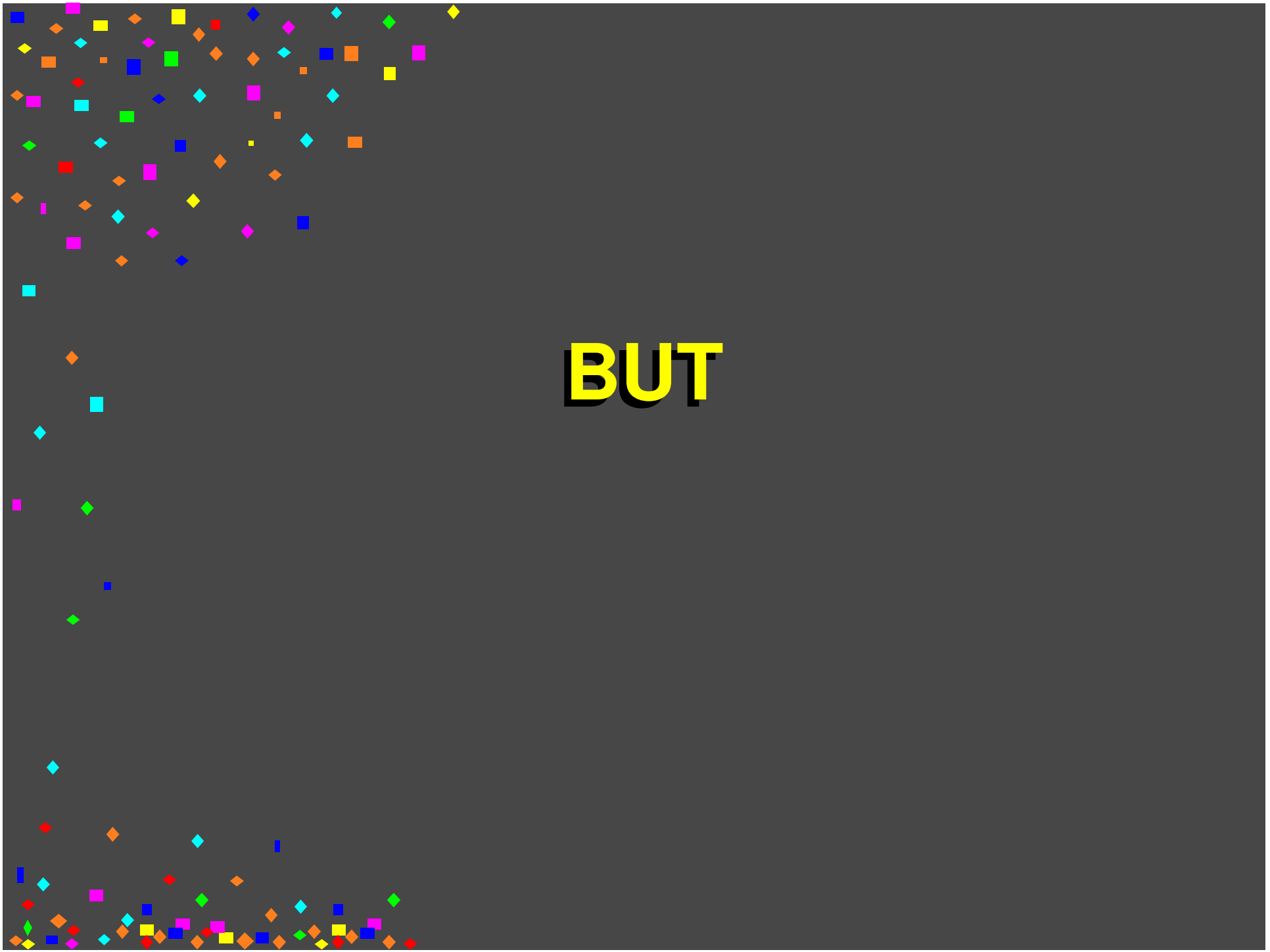

The
Neural Net
Virus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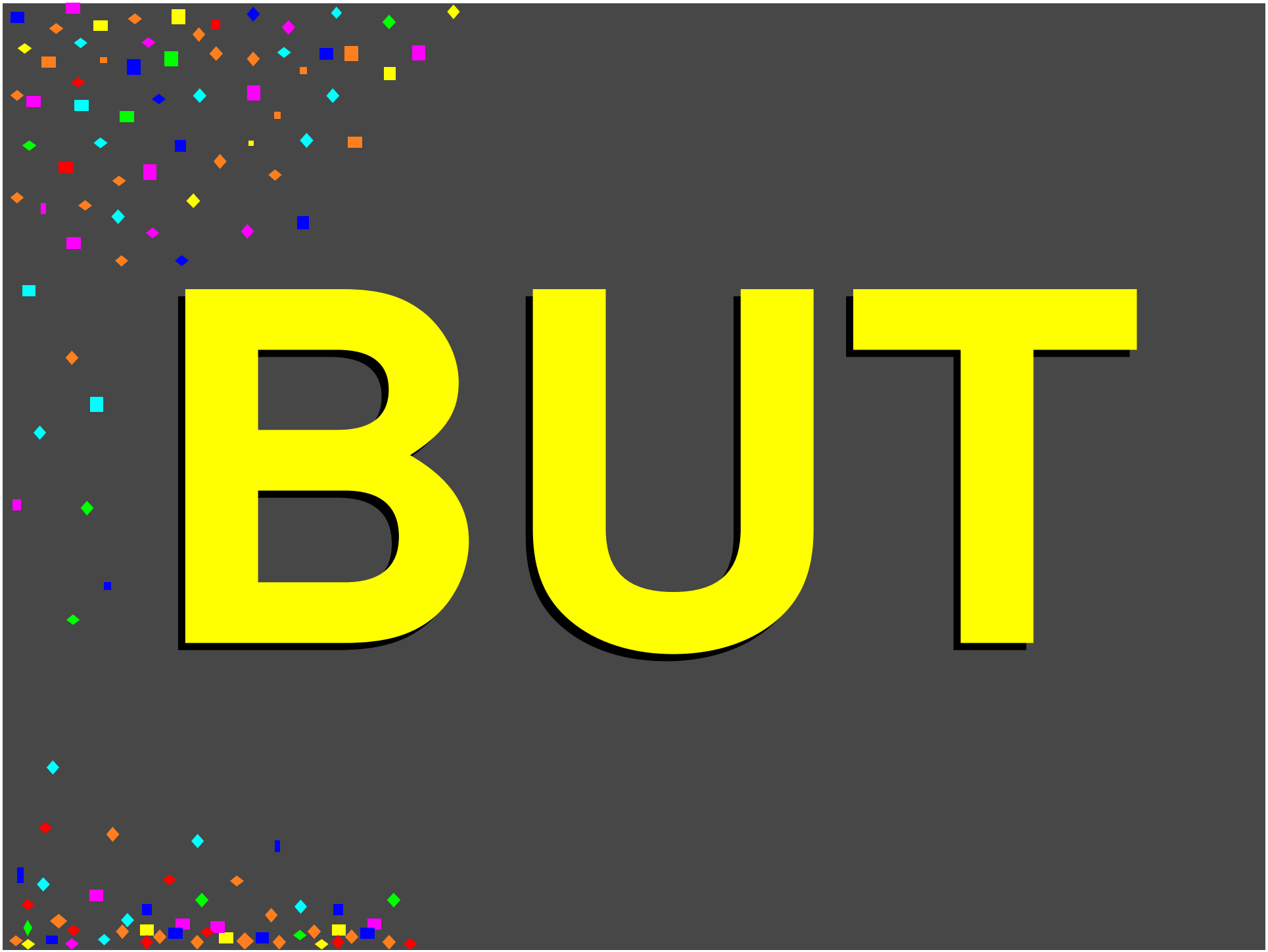
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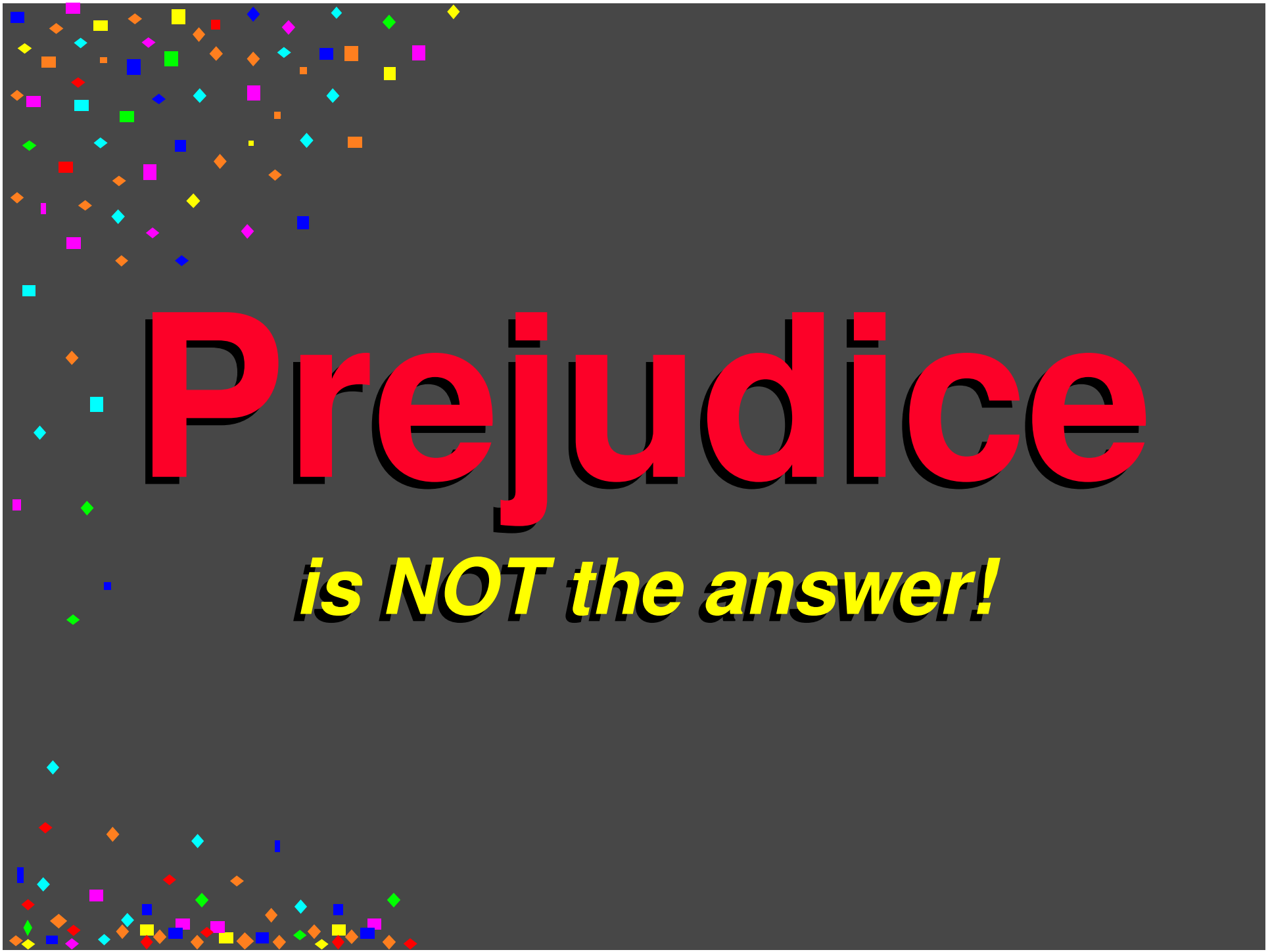

Prejudice
is NOT the answer!

Do not be too negative

- *Neural networks run by an undergraduate can come close to beat a world expert statistician in problems where there are alternatives*
- *Will excel in other problems where there is no conventional alternative*
- *Neural nets can emulate all existing models*
- *They can also be embedded in hybrid systems*

We SHOULD be thinking about teaching undergraduates neurocomputing instead of simple statistical methods that are inappropriate for most geographical problems

Neural computing is a highly empirical technology

- ★ *Onus of proof rests with the user*
- ★ *Can be a brittle technology and you have to prove it's not*
- ★ *Can work extremely well or fail totally*
- ★ *It is not necessarily a universal panacea*
- ★ **It's worth considering**

HYPE (2)?

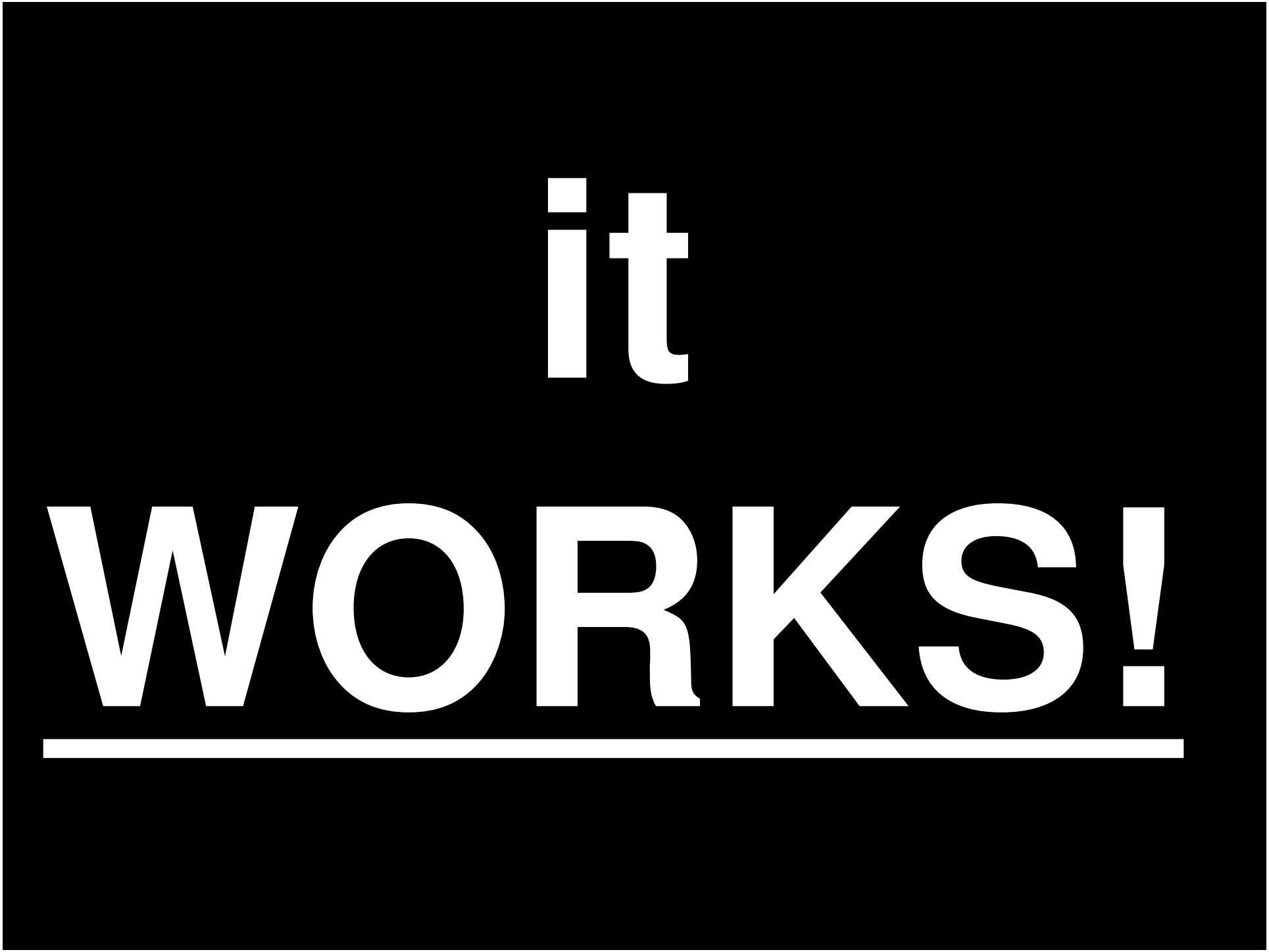
- *A second computer revolution in geography*
- *The ultimate black box modeller*
- *Can be applied to all problems*
- *Much easier to use than many other conventional alternatives*
- **You should take it seriously**

Neurocomputing is very attractive technology because:

- ★ it uses data to learn (or discover) patterns and relationships instead of relying totally on people to specify them
- ★ it offers Equation Free modelling of complex processes that are hard to handle
- ★ it has universal modelling capabilities
- ★ it is a non-linear technology
- ★ it is noisy data resistant
- ★ highly automated modelling

More...

- it can do what conventional models do but with the promise of better empirical performance and sometimes greater speed
- it offers the basis for self-adapting models that change themselves as the data changes
- it is widely applicable being a kind of universal application independent technology of wide applicability


it
WORKS!

BUT

its

not

MAGIC

Neural Headaches

- essentially Black Box models
- many different architectures (50+)
- many subjective decisions to be made and reeks of ‘black art’
- strongly held prejudices bias opinions and perceptions of the benefits
- some technical problems (ie training)
- lengthy computer runs

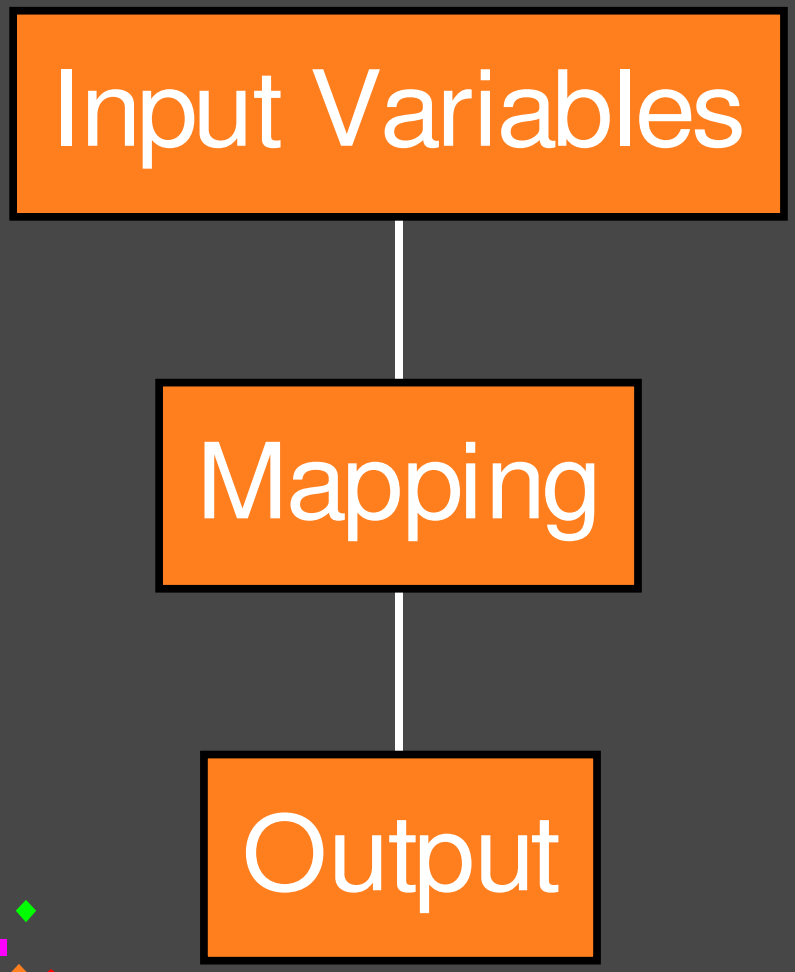
Black Box Modelling of processes is regarded as unhelpful!

- ★ no increase in conceptual knowledge
- ★ no interpretation is possible
- ★ large element of faith needed
- ★ caveat emptor applied!

BUT..

- models that are understood but fail to work very well are definitely unhelpful
- it is possible to adopt the engineers approach
- it is also often possible to look inside neural network based models and gain some understanding

Neural Nets operationalise a Generic Modelling Process



There are also OTHER types of modelling tool that might be useful

- ★ Conventional Maths Models
- ★ Genetic Model Breeding
- ★ Inductive rule generators
- ★ Memory based reasoning
- ★ Fuzzy Logic Modelling

Conclusions

- Neural computing promises much in a geographical context
- It can be very effective
- Its not hard to apply
- However YOU have to prove it works!

Neural Computing ..

- *increasing being used as a component in the construction of Hybrid Intelligence Systems that are smart because they are ADAPTIVE, AUTOMATED, and SELF-IMPROVING*
- **What more can any reasonably minded geographer ask for?**

The HOPE is that..

- it will soon be possible to develop higher performance plug in replacements
- develop the new models that offer more flexible frameworks for micro-macro hybrids
- obtain some real benefits from having models capable of handling the more complex spatial people systems that appear to be evolving in the modern world

However

Lots of Questions LEFT for you..

- Questions of interpretability
- Questions of robustness
- Questions of generalisability
- Questions of sustainability
- Questions of how to do even better

There is much left to be done!